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Editorial preface

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Dear Readers,

It is my great pleasure to present to you the latest issue of the Scientific Journals of the Maritime University in Szczecin in a new graphical layout which will be used in the forthcoming 10 issues.

This issue, No. 60 (132), is the last one of this year, so I would like to use my position as Editor-in-Chief to briefly summarise the current year. In 2019, the Scientific Journals of the Maritime University in Szczecin published 69 scientific papers prepared by 129 authors (in total, without republishing). Among them, 19.37% of authors had a foreign affiliation, and the greatest contribution came from Nigerian researchers, with 6 authors. We also received contributions from 5 Ukrainian authors, 4 Croatian authors, and 4 scientists from Iran.

In addition, I would like to inform you that on 9 October 2019, the Scientific Journals Evaluation Team of Index Copernicus International delivered the assessment of our quarterly according to the ICV indicator – the Index Copernicus Value. The Index Copernicus International Team evaluates scientific journals from all over the world. Journals are then included in the ICI Journals Master List database. The scientific journals are reviewed in two categories:

- 1 – the quality of the journal, which includes: editorial standards, publishing frequency and regularity, online availability, and internationalisation;
- 2 – analysis of citation trends of the journal based on the ISI Web of Science and Scopus.

The Scientific Journals of the Maritime University of Szczecin generated a ICV score of 99.59 for 2018, which was slightly lower than the 2017 value of 100 ICV. It should be stated that this is still a strong result because a score above 100 ICV can usually be obtained by journals with current IF and SJR indices.

This issue of the Scientific Journals of the Maritime University in Szczecin presents results of twenty-seven research papers in five sections: Civil Engineering and Transport, Environmental Engineering, Mining and Energy, Management and Quality Studies, Mechanical Engineering, and Miscellaneous.

The Civil Engineering and Transport section, includes eight papers which are mainly devoted to the issues of transport, including maritime, inland, rail, or motor vehicle. The authors discussed the economic, social, safety, and ecological aspects of particular modes of transportation and also presented new solutions with possible future applications.

The Environmental Engineering, Mining, and Energy section, features two articles. Both papers showcase problems with environmental protection. The first article outlines the development of pro-ecological investments in Poland from 2014–2020, including an analysis of investment risks. The authors of the second paper present the results of research on the application of new mathematical models in cheaper devices capable of measuring PM₁₀ concentrations.

The Management and Quality Studies section contains ten articles. The authors discuss issues related to managing methods of transport for better economic results, the impact of e-commerce on transport development and the economy, and recent innovations in e-commerce. There is also research on social issues related to managing the operations of a seaport and individual workers.

The Mechanical Engineering section contains four articles. The authors of the first paper discuss ideas related to the determination of steam injector operating parameters for different drive steam parameters. The next article is devoted to the reliability and availability of fire alarm systems on ships. The third paper presents an analysis of vertical shear forces and bending moments during nodule loading for a standard bulk carrier in the Clarion-Clipperton Zone. The last article in this thematic group describes the results of simulation-based and academic research on child safety seat suspension.

The last section, Miscellaneous, contains three articles on very different topics. The first paper presents research on the properties of *Annona Muricata* and its possible future applications as a medicinal component. The second paper discusses the cooperation between China and Central Asian, Middle Eastern, African, and European countries. The third article discloses research results on the influence of intellectual property on the economic development of a country.

Finally, I would like to take this opportunity to encourage authors from all over the world to publish their articles in our scientific journal – the Scientific Journals of the Maritime University of Szczecin. Readers are welcome to visit our website, <http://scientific-journals.eu/>, where they may access the online version of the current issue as well as archival issues.

JANOWSKI BW

Robert Jasionowski, PhD
Editor-In-Chief
Szczecin, 18.12.2019

Civil Engineering and Transport

Parametric study on the flow field generated by river barge bow steering systems

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Key words: Magnus effect, bow rotor steering system, river barge, flow field, CFD

Abstract

Low controllability under strong winds presents a problem for the operation of inland vessels, which can be improved using passive bow rudders and transverse thrusters. Bow thrusters can sufficiently improve the manoeuvrability at low speeds, but an unsolved problem is course maintaining and yaw checking of a vessel at medium and high speeds. This paper proposes the use of a bow steering system in which the bow rotors generate a Magnus force. The first physical test model of the system showed promising results and that much more research must be performed before this system can be used in industrial applications. The paper presents the results of a numerical study on the flow field generated by bow rotors. The first stage of a ship's turn using the bow rotors was used to determine the dependence of the expected steering force on the inflow velocity and rotational speed of the rotors. The influence of the flow generated by the bow steering system on river banks and quay walls during manoeuvres was also discussed.

Introduction

Inland navigation primarily occurs in restricted waters with navigational limits due to shallow water, under-bridge clearances, and narrow winding waterways with alternating currents. The main factor influencing the safety of inland navigation is the width of the safe manoeuvring area – the width of the lane and good vessel manoeuvrability during the entire voyage over a wide speed range.

Inland fleet ship-owners continuously seek new technologies to improve the manoeuvring characteristics of inland vessels. An unsolved problem is how to control motions of shallow-draft vessels under strong winds at medium or high vessel speeds. The bow steering system described in this paper can reduce the required lane width and bend radius due to improved ship manoeuvrability. Previous investigations using a physical model on a 1:20 scale of a river push barge (Abramowicz-Gerigk, Burciu

& Jachowski, 2017; Abramowicz-Gerigk & Burciu, 2018) gave very promising results related to the increased manoeuvrability of a pushed train and have become the subject of interest of the largest Polish ship-owner.

The main problem related to commercialization of the bow steering system is Magnus lift force control. The available published results which have investigated rotor dynamics have mainly considered aerodynamic phenomena at low Reynolds numbers (Catalano et al., 2003; Champmartin, Ambari & Roussel, 2007; Everts et al., 2014; Rao et al., 2014; Yao, Zhou & Wang, 2016; Pullin, Cheng & Samtaney, 2018). For instance, Karabelas et al. (Karabelas et al., 2012) used the results of a CFD study to propose an empirical method to determine the lift force generated on a rotor in the air at $Re = 10^5$, $Re = 10^6$, and $Re = 5 \cdot 10^6$, which corresponded to the Reynolds numbers of rotors in a river barge steering system.

This paper presents a possible application area of the proposed steering system and a parametric study of the flow field generated by bow rotors in the first stage of vessel turning. The dependence of Magnus force on bow rotor revolutions and push train speed was investigated. This study also includes a discussion on the influence of the bow rotor on a quay wall or river bank compared with a bow thruster.

Manoeuvrability of the units operated in inland waterborne transport

The systems used in inland waterborne freight transport can be categorized depending on the type of propulsion forces they use, e.g. river current, own drive, pushing or towing force (self-floating down a river system, self-propelled motor barge, and towing and pushing units). The most basic system is a pushing unit (pushed train or convoy), which is comprised of pusher and pushed barges (Figure 1).

Due to several advantages, pushed systems nearly made towed systems obsolete (Lantz et al., 2018). Pushed trains have several advantages compared with self-propulsion and towing systems, including a lower resistance related to loading capacity, fewer crew members, the ability to use different pushed barge formations, and lower pushed barge construction costs.

Manoeuvring space of inland waterborne transport units – lane width

The main factors related to the safe lane in river transport are as follows (PIANC, 2019): factors

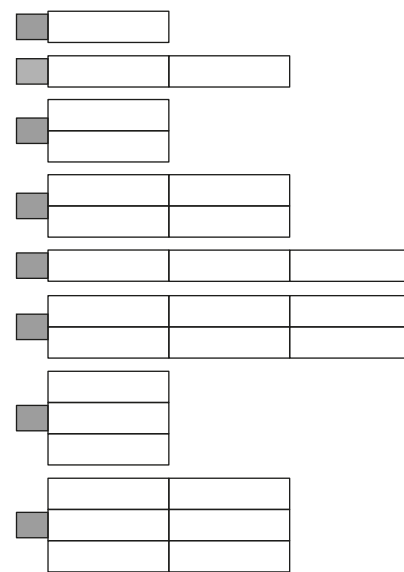


Figure 1. Pushed trains, examples of combinations of barges in pushed systems

related to the ship manoeuvrability, fairway bounding by banks, type of seabed, wind speed, transverse water current, and navigational markings.

The vessel breadth and drift angle resulting from ship motions under hydrometeorological conditions are the main ship manoeuvrability parameters which would necessitate increasing the width of a lane. The drift angle is defined as the angle between the ship centre line and velocity vector, or between the real ship course and its path over the water. The drift angle depends on wind speed, bend radius, propulsion power, loading condition of the pushed train, and the speed and direction of the pushed train down or up the river.

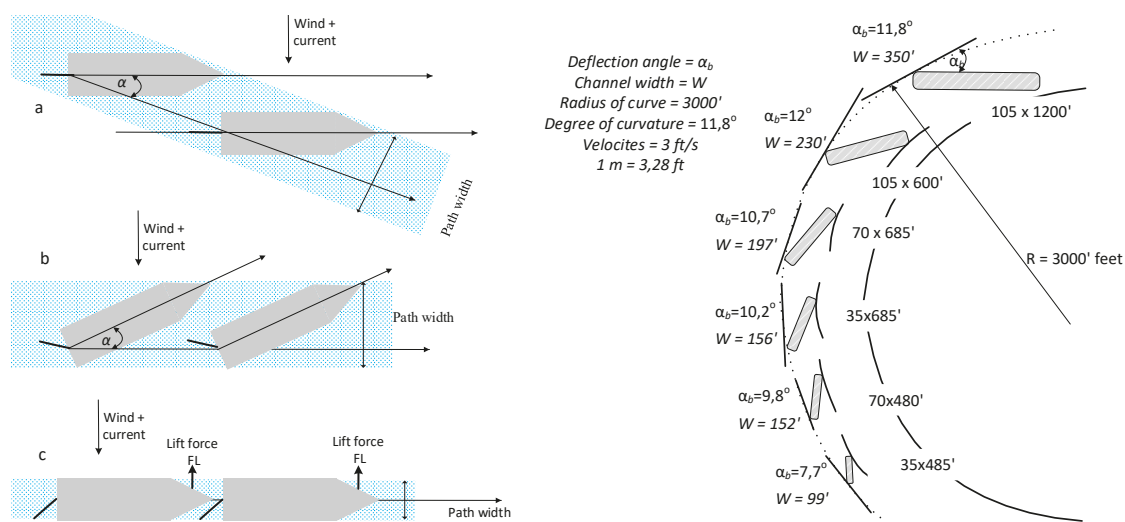


Figure 2. Increase in the manoeuvring path width due to hydrometeorological conditions: (a) no ship reaction to the drift, (b) pitch adopted to the drift, (c) reduction of the path width due to drift angle reduction by the steering force applied at the bow, (d) the drift angle α_b of convoys moving down the river in a bend with a ~900 m radius

Reducing the drift angle and improving turning characteristics of a push train are possible when additional steering forces are generated in forward motion. The most effective solution is the use of a bow steering system. An increase in the safe manoeuvring path width due to hydrometeorological conditions and possibly reducing the path width due to the drift angle reduction by a steering force applied at the bow is presented in Figure 2 a, b, c. The decreased drift angle can significantly enhance the safety of manoeuvres. The drift angles of convoys of various dimensions moving down the river in a bend with a 3000 feet (about 900 m) radius are presented in Figure 2d (Julien, 1997).

Manoeuvrability of a pushed convoy with a bow steering system

Auxiliary steering systems used to enhance push train manoeuvrability include passive bow rudders and tunnel thrusters installed on the first pushed barge in a convoy or on the independent floating modules equipped with bow thrusters that can be connected to the first barge. The limits of the passive and active systems are the small steering force of a bow rudder and a small range of velocities at which the steering force can be generated. The high power of the active units is also negatively affected by the river environment, construction, and other vessels. An illustration comparing the performance of a bow thruster and hydrodynamic rotor is presented in Figure 3. The thrust ratio is defined as the thrust at a given ship speed divided by the maximum possible thrust.

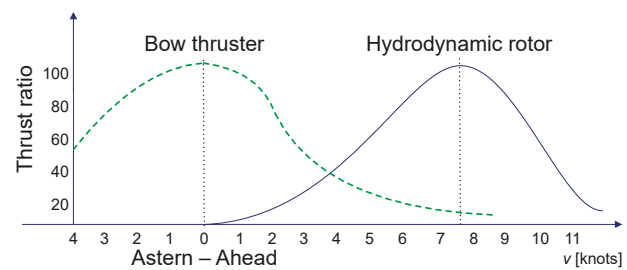


Figure 3. Thrust ratio as a function of the speed of a 150 m length vessel (Dymarski, Wieliczko & Nalewajski, 2003), compared with the efficiency of bow rotors as a function of speed of the 100 m length pushed train (Abramowicz-Gerigk, Burciu & Jachowski, 2017)

Bow steering system based on Magnus Effect

The steering force direction generated by rotors is related to the direction of the inflow velocity and depends on the pushed train velocity direction and rotor positions. The model tests presented in (Abramowicz-Gerigk, Burciu & Jachowski, 2017; Abramowicz-Gerigk & Burciu, 2018) confirmed that the steering force generated by rotors strongly influences the pivot point position during manoeuvres. The results of turning tests carried out for a 100 m long pushed train model in a 1:20 scale – performed using various combinations of stern rudders, bow rotors, and a dynamic coupling system – are presented in Figure 4.

Figure 5 presents the influence of a decreased drift angle due to bow rotor operation on manoeuvring path width during navigation on a straight course as a function of Δd and during an evasive manoeuvre (lateral displacement).

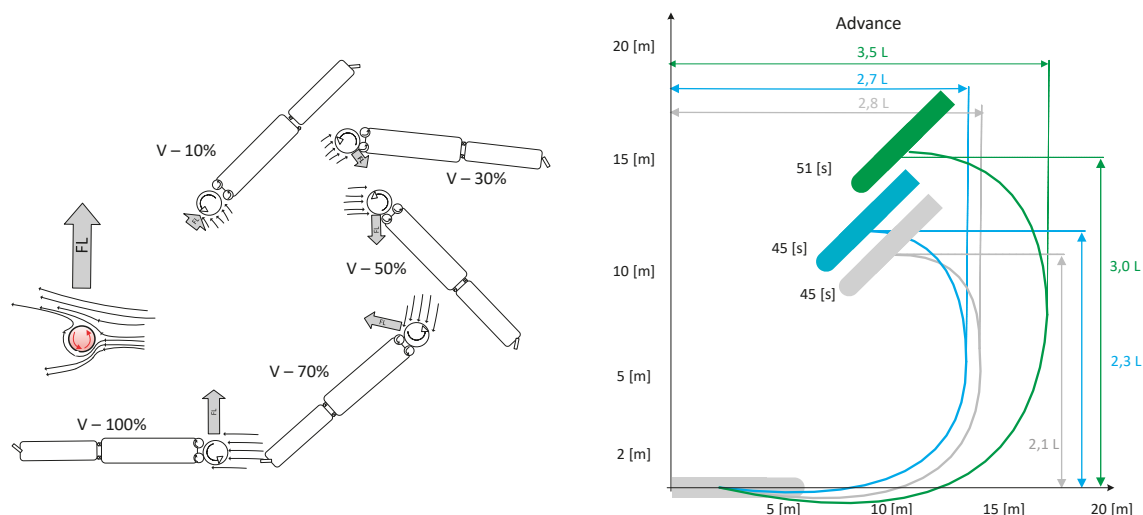


Figure 4. Turning using hydrodynamic bow rotors and main rudders – changes in the lift force related to changes in the inflow speed and direction. Turning manoeuvre of the pushed train using bow rotors (green); stern rudders and bow rotors (blue); stern rudders, bow rotors, and dynamical coupling system (grey)

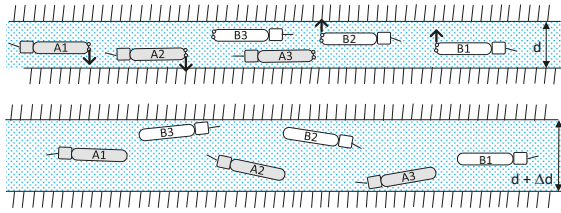


Figure 5. Required waterway width for navigation in a fixed course – evasive manoeuvre of pushed trains navigating with and without the use of hydrodynamic bow rotors

Parametric study on the lift force generated by a bow steering system

The Magnus effect is a phenomenon in which a lift force is generated perpendicular to the flow direction or to the motion direction of a fluid acting on a rotating cylinder or other rotational body. The theoretical value of the force in an incompressible fluid is determined by the Kutta-Joukowski law, which states that if an incompressible fluid flows around an infinitely long cylinder whose axis is perpendicular to the direction of the undisturbed flow, the lift force calculated per cylinder length unit can be defined by Equation (1):

$$F_L = \rho \cdot (v \times \Gamma) \quad (1)$$

where F_L is the lift force (N), ρ is the fluid density (kg/m^3), v is the relative speed of the fluid (m/s), and Γ is the rotation speed along a closed contour around the cylinder (m/s^2) (2):

$$\Gamma = 2\pi a^2 r \quad (2)$$

where a is the rotor radius [m], and r is the rotational speed of the cylinder [rad/s].

The lift force calculated for steady inviscid flow using Formula (1) is greater than the expected real mean force which varies with respect to the flow separation, edge losses, interaction effects, changes in the inflow velocity, and direction.

Based on a CFD study, Karabelas et al. (Karabelas et al., 2012) used Equation (3) to predict the lift force generated on a rotor in the air at high Reynolds numbers (10^5 , 10^6 , $5 \cdot 10^6$). This formula can be used to calculate the lift force of a fully-submerged rotor in the absence of a free surface effect:

$$F_L = C_L \cdot \rho \cdot v^2 \cdot a \quad (3)$$

where $C_L(\text{Re}, \alpha)$ is the lift force coefficient (Karabelas et al., 2012), the Reynolds number Re is defined as $\text{Re} = v \cdot 2a / \nu$, where ν is the kinematic viscosity of the fluid, and α is defined as:

$$\alpha = r \cdot a / v \quad (4)$$

Real conditions can be modelled using CFD simulations which allows the flow field pattern around the rotating cylinder to be observed and determines the lift force on a rotor under real conditions, including the influence of rotor geometry, motion parameters, and free surface effect. The tested geometry and motion parameters were assumed based on previous model tests (Abramowicz-Gerigk, Burciu & Jachowski, 2017; Abramowicz-Gerigk & Burciu, 2018).

Lift force generated on a rotor in open water conditions

The lift forces F_L calculated from Equation (3) for an assumed water density $\rho = 1000 \text{ kg/m}^3$, kinematic viscosity $1.1 \cdot 10^{-6} \text{ Pa}\cdot\text{s}$, $v = 2.8 \text{ m/s}$, $r = 40 \text{ rad/s}$, $a = 0.25 \text{ m}$, and $a = 0.5 \text{ m}$, $H/D = 1$ and $H/D = 2$ ($D = 2 \cdot a$) were compared with the mean/maximum lift forces $F_{L\text{mean}}/F_{L\text{max}}$ calculated using CFD simulations (FlowVision 2.5). The results are presented in Table 1.

Table 1. Lift forces calculated from Equation (3) and CFD simulations for $a = 0.25$ and $a = 0.5 \text{ m}$

a	v	Re	r	H	α	H/D	$ F_L $ (3)	$ F_{L\text{mean}} $ (CFD)	$ F_{L\text{max}} $ (CFD)
m	m/s	–	rad/s	m	–	–	kN	kN	kN
0.25	2.8	1.11	40	1	3.57	2	5.9	3.25	3.3
0.5	2.8	2.23	40	1	7.14	1	16.7	4.5	7.0

Doubling the rotor radius resulted in a 2.8 times greater lift force F_L , 1.4 times greater $F_{L\text{mean}}$, and 2.12 times greater $F_{L\text{max}}$. The rotor aspect ratio also significantly influences the lift force. $F_{L\text{max}}$ calculated for the rotors with aspect ratios $H/D = 2$ and $H/D = 1.0$ using CFD are almost twice as small as the values obtained from Equation (3) for the rotor of infinite length, due to both edge losses and the free surface effect, as illustrated in Figure 6.

The free surface effect for a rotor of $a = 0.5$, $H/D = 1$, $r = 40 \text{ rad/s}$, positioned $0.2H$ below the free surface and for two inflow velocities of 2.8 m/s and 5.6 m/s is presented in Figure 7.

The time series of rotational speed and generated lift forces are presented in Figure 8.

The lift forces calculated from Equation (3) for $\text{Re} = 2.21 \cdot 10^6$ and $\text{Re} = 4.43 \cdot 10^6$, $\alpha = 7.2$ and $\alpha = 3.6$ were equal to 19.3 kN and 51.0 kN . The effect of a free surface is greater at higher flow velocities, and the maximum forces calculated using CFD simulations were 2.8 kN and 4.9 kN , respectively. The lift

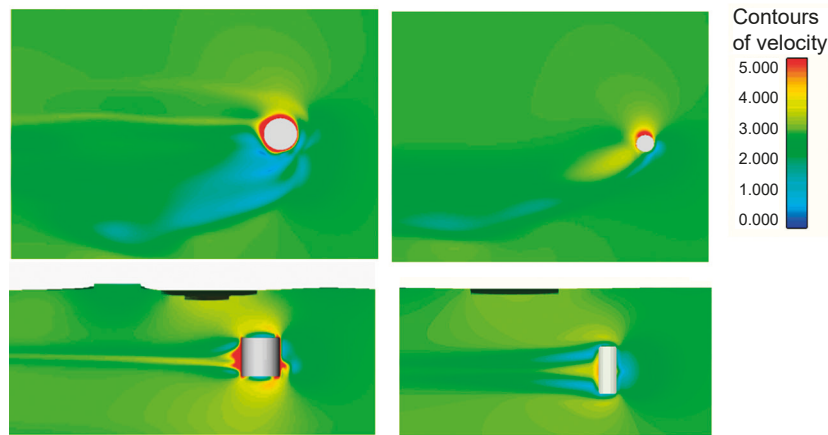


Figure 6. Flow velocity field generated by rotor, $r = 40$ rad/s, inflow velocities: $v = 2.8$ m/s, $a = 0.5$ m (left) and $a = 0.25$ m (right), $Re = 1.11 \cdot 10^6$ and $Re = 2.23 \cdot 10^6$, $\alpha = 3.57$ and $\alpha = 7.14$, respectively

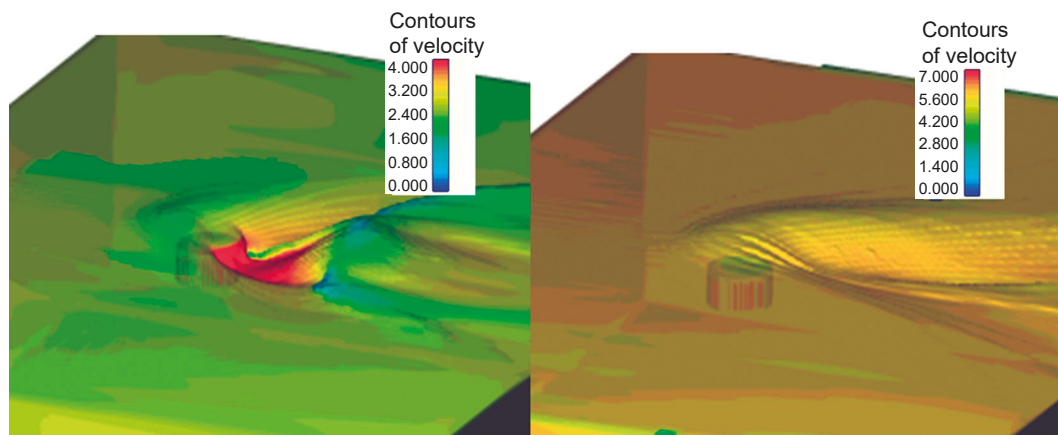


Figure 7. Flow velocity field generated by a rotor positioned $0.2H$ below the free surface: $a = 0.5$, $H/D = 1$, $r = 40$ rad/s, inflow velocities: $v = 2.8$ m/s (left) and $v = 5.6$ m/s (right)

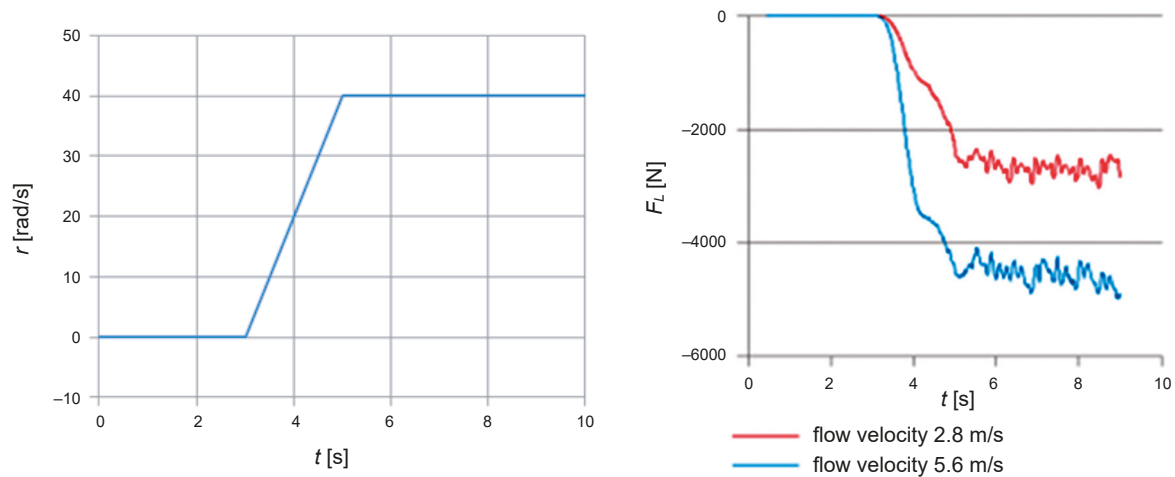


Figure 8. Time series of a rotor rotational speed r [rad/s], hydrodynamic lift forces generated by the rotor positioned $0.2H$ below the free surface: $a = 0.5$, $H/D = 1$, $r = 40$ rad/s, inflow velocities 2.8 m/s (red line) and 5.6 m/s (blue line)

forces began to increase at $\alpha = 3.6$ ($r = 20$ rad/s) for both velocities and reached constant values at $r = 40$ rad/s, $\alpha = 7.2$ for $v = 2.8$ m/s and $\alpha = 3.6$ for $v = 5.6$. The lift forces calculated by taking into account the free surface effect at $\alpha = 7.2$ and 3.6 are presented in Table 2.

Doubling the inflow velocity also causes the lift force to double in open water conditions. When the lift force was dominated by the free surface effect, this ratio was about 1.5. In both cases, $v = 2.8$ m/s and $v = 5.6$ m/s, $F_{L,mean}$ is about ten times smaller than for a rotor of infinite length in open water conditions.

Table 2. Lift forces calculated using Equation (3) and CFD simulation taking into account the free surface effect at $\alpha = 7.2$ and 3.6

a	v	Re	r	α	$ F_L $ (3)	$ F_{Lmean} $ (CFD)	$ F_{Lmax} $ (CFD)
m	m/s	—	rad/s	—	kN	kN	kN
0.5	2.8	2.21	40	7.20	19.3	2.7	2.8
0.5	5.6	4.43	40	3.60	51.0	4.5	4.9

Lift forces generated by rotors of a bow steering system

CFD simulations were carried out for a push train of 86 m length, 11 m breadth, 2 m depth, and 0.75 m draft, using an assumed water depth of 2 m and a water depth-to-draft ratio of 2.7 (Figure 9). The rotors in the bow were positioned on PS and STB sides within the hull form contour.

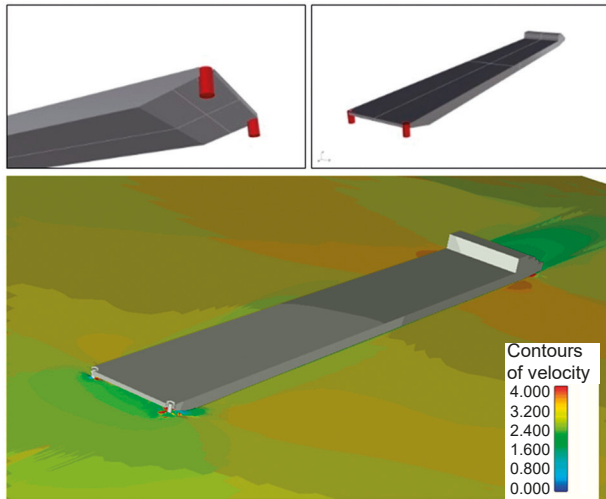


Figure 9. The bow rotors installed on port and starboard sides of the barge

The height of the rotor was 1 m, which was submerged up to 0.77 in calm water. The parametric study included three push train velocities (2 m/s, 3 m/s, and 4 m/s), two rotor radii of 0.465 m and 0.25 m, and rotational speeds related to the inflow velocities of $\alpha = 4.44$, 5.67, and 7.50. The influence of the rotational speed of bow rotors and barge velocity on the lift force is presented in Figures 10, 11, and 12.

The mean lift forces acting on PS and STB rotors calculated using CFD simulation were 200 N and 250 N, respectively.

The different lift force directions on the port and starboard rotor at $r = 0$ rad/s were determined using different flow distributions with respect to the

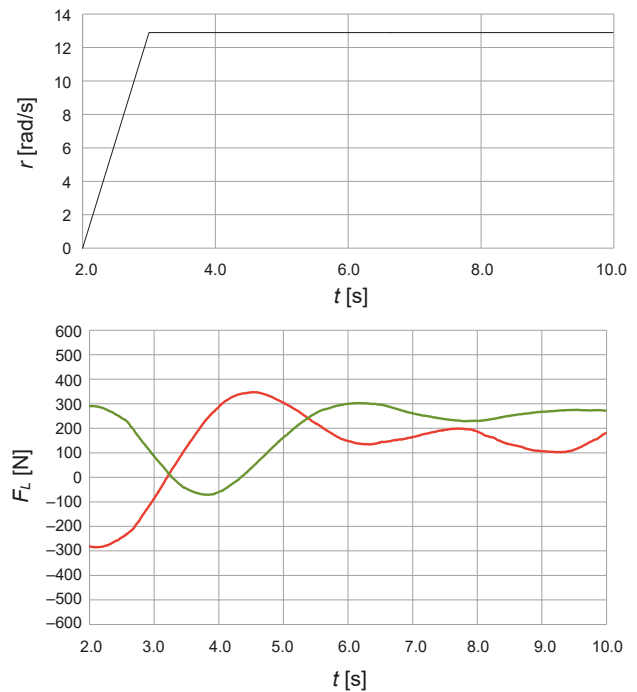


Figure 10. Time series of the rotational speed of rotors and hydrodynamic lift forces generated by the PS (red line) and STB (green line) rotors: $\alpha = 0.465$, barge velocity $v_{\text{barge}} = 2$ m/s, $\alpha = 4.44$

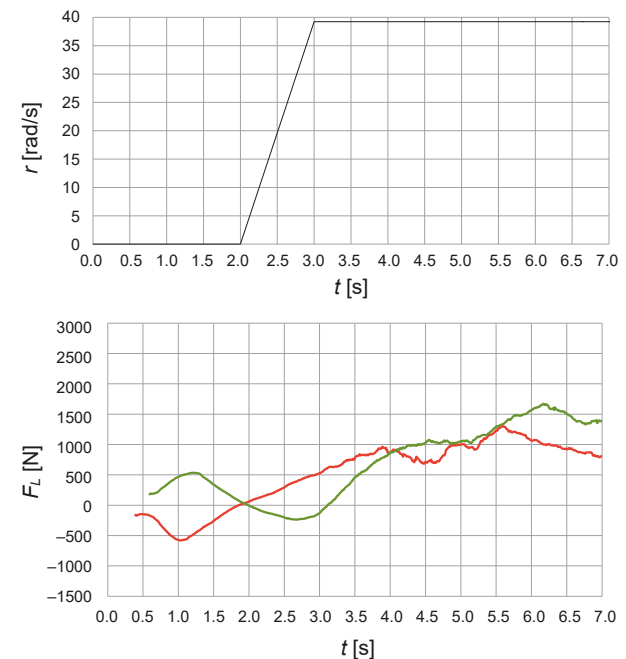


Figure 11. Time series of the rotational speed of rotors and hydrodynamic lift forces generated by the PS (red line) and STB (green line) rotors, inflow velocity $v_{\text{barge}} = 3$ m/s, $\alpha = 7.50$

influence of the hull and bow wave. The mean lift forces calculated using CFD simulations on PS and STB rotors were 1.0 kN and 1.5 kN, respectively.

The mean lift forces calculated using CFD simulations on PS and STB rotors were 4.0 kN and

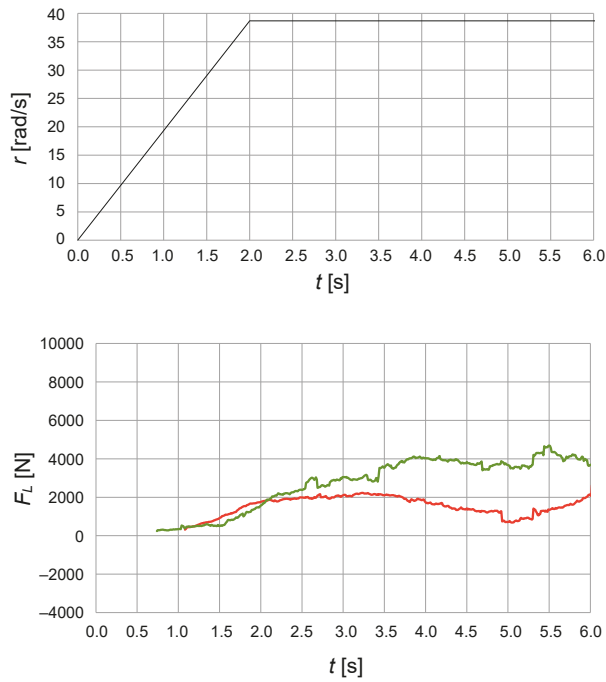


Figure 12. Time series of the rotational speed of rotors and hydrodynamic lift forces generated by the PS (red line) and STB (green line) rotors, barge velocity $v_{\text{barge}} = 4 \text{ m/s}$, $\alpha = 5.67$

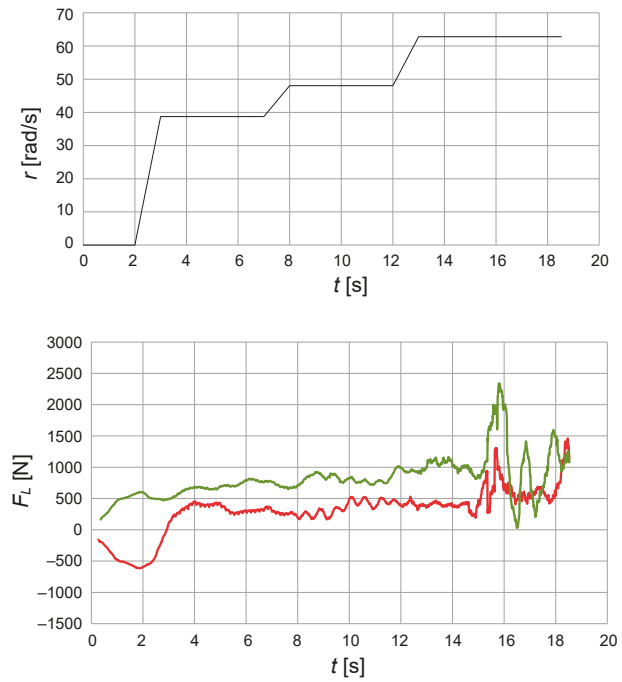


Figure 14. Time series of the rotational speed of rotors and hydrodynamic lift forces generated on the PS (red line) and STB (green line) rotors, $a = 0.25 \text{ m}$, $v_{\text{barge}} = 3 \text{ m/s}$, α values constant over time: $\alpha = 4.06$, $\alpha = 5.21$, $\alpha = 6.54$

2.0 kN, respectively, which are much smaller than those calculated for the open water conditions due to bow wave formation and interaction effects. The velocity fields generated at $v_{\text{barge}} = 3 \text{ m/s}$ for the rotor radii equal 0.25 m and 0.465 m (Figure 13).

The influence of variations in the rotor rotational speed on the lift force is presented in Figure 14.

The increase of the maximum lift forces can be observed for α greater than 5.21.

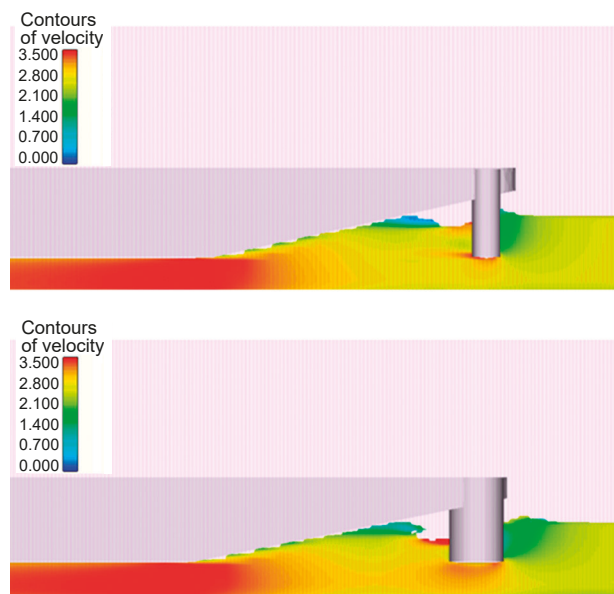


Figure 13. Flow field around rotors $v_{\text{barge}} = 3 \text{ m/s}$, $r = 39 \text{ rad/s}$; $a = 0.25 \text{ m}$, $\alpha = 4.06$ (top); $a = 0.465 \text{ m}$, $\alpha = 7.5$ (bottom)

Comparison of the parameters influencing the lift force

The lift forces calculated for different inflow velocities and rotational velocities of two rotor diameters are presented in Table 3. ΣF_L is the steering force calculated as a sum of maximum PS and STB rotor lift forces.

Table 3. Lift forces calculated for different combinations of α , v , and r

H	a	H/D	v_{barge}	$\text{Re} \cdot 10^6$	r	α	$ F_{L\text{mean}} $ (CFD)	$ F_{L\text{max}} $ (CFD)	ΣF_L (CFD)
m	m	–	m/s	–	rad/s	–	kN	kN	kN
0.77	0.465	1.67	2	1.48	15	4.44	0.3	0.55	0.4
			3	2.22	39	7.5	1.5	3.0	3.7
			4	2.96	39	5.67	4.0	10.0	20.0
	0.25	3.08	3	1.19	39	4.06	0.8	1.0	1.5
					48	5.21	1.0	1.5	3.5
					63	6.54	1.5	3.0	5.0

The maximum steering force was generated at barge velocities of 3 m/s and 4 m/s which corresponded to operational velocities of pushed trains of 10–15 km/h.

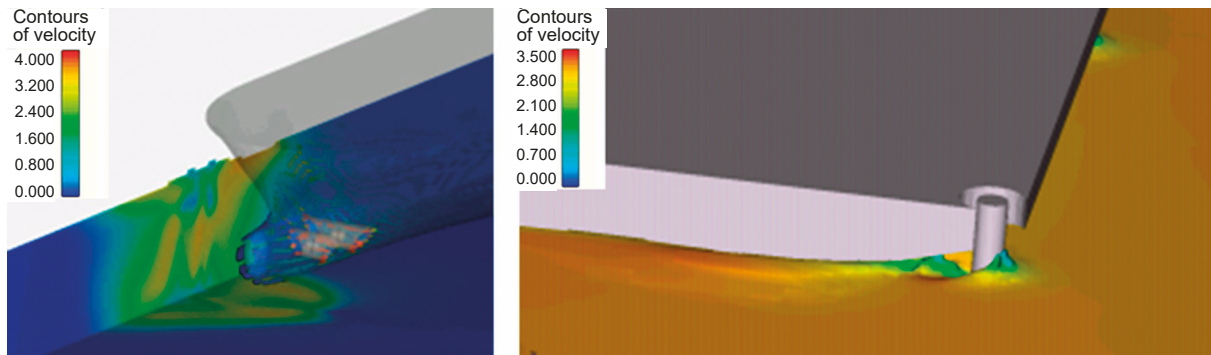


Figure 15. Velocity fields generated by bow thrusters and rotors

Velocity field generated by the bow steering system

The flow fields generated by bow thrusters and rotors are presented in Figure 15.

The bow thruster produced a thrust stream with a constant flow velocity over a distance larger than half of the ship's breadth. In the case of barges, due to the rectangular shape of the bow frames, the outlet opening of the transverse thruster was much closer to the quay wall or riverbank, and the produced thrust stream directly impacted the wall and bottom. The impact of the flow field generated by rotors on the quay walls or banks was different since the high-velocity area was located only near the cylinder surface and depended on the rotor position (Figure 6).

Conclusions

The use of hydrodynamic bow rotors improved the manoeuvrability of pushed trains while navigating inland waterways. The increased turning ability was confirmed by model tests. The manoeuvring space can be reduced due to the reduction of drift angle when turning on a bend and when overtaking and passing other vessels. The ability of a pushed train to maintain its course under a transverse wind can be improved by eliminating leeway and drift.

The presented study was limited to selected parameter ranges due to time-consuming CFD modelling and lack of comparable literature results. However, it allowed the presentation of the influence of rotor diameter, rotor aspect ratio, rotational speed, and inflow velocity on the steering force and provided a direction for future research. The strong influence of the free surface and bow wave on the rotor performance was also observed. The position of a rotor installed in the bow part of a barge determines the inflow velocity and flow restriction, and the inflow velocity to the rotor can be twice less than

the speed of the barge. The simulations also showed that the lift force is directly proportional to the rotor radius. The parametric study using CFD simulations confirmed that the steering force generated by rotors at barge velocities of to 3 m/s and 4 m/s, which corresponded to operational velocities of pushed trains of 10–15 km/h, were generated at higher Reynolds numbers of approximately $2.9 \cdot 10^6$.

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Installation of GNSS receivers on a mobile railway platform – methodology and measurement aspects

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Abstract

Determining the course of a railway track axis using satellite methods relies on ensuring the precise assembly of GNSS receivers in dedicated measuring devices. Depending on the number of receivers, solutions that are based on placing the apparatus directly above the railway track axis (as well as in eccentric positions) are used to indirectly obtain data to form the basis of the desired results. This publication describes the installation of five GNSS receivers on a mobile measuring platform as part of the InnoSatTrack project. The methodology and the procedure of the geodetic measurements required to obtain the geometrical configuration of the measuring apparatus, specified in the technical project, are presented. The publication presents the principles of total station measurement methods as well as the steps taken to achieve precise results from staking out. The process of acquiring the same configuration of the GNSS receivers, based on the geometry of the squares on the two measuring platforms that were used in the research, has been shown. The final determination of the position of the receivers did not exceed an error of 0.010 m with an average error of 0.003 m, despite the occurrence of mounting difficulties. The results have demonstrated the high credibility and effectiveness of the presented solution.

Introduction

Examining a railway track shape with a satellite device requires the right geometry of the measurement system; apart from satellite receivers, this can include accelerometers and inclinometers (Kreye, Eissfeller & Ameres, 2004; Akpınar & Gulal, 2011). The most frequent aim of such measurements is to precisely determine the position of a railway track

axis and to determine the extent of any track deformation (Chen et al., 2015). With the development of mobile laser scanning, interest is growing in automatic detection for rails and ancillary infrastructure objects in point clouds (Arastounia & Oude Elberink, 2016). The output of algorithms that create object models is not presented in a linear form, but as a percentage which indicates the accuracy of the fit-in procedure (Arastounia & Oude Elberink, 2016;

Lou et al., 2018). The first study in Poland concerning railway track shape through precision positioning with the global navigation satellite system (GNSS) was conducted in Kashubia in 2009 (Koc et al., 2009; Specht et al., 2011). The authors proved that it is justified to apply the method based on the accuracy parameters expressed by a mean error of 5 cm at a level of confidence of 2σ . Moreover, studies have stressed the limitations in employing satellite measurements in railway engineering, which are caused by the presence of objects that obscure the sky in urban areas and forests (Koc & Specht, 2009). Subsequent upgrades to the space segment of existing GNSS systems with a full satellite constellation and the creation of new GNSS systems (Specht et al., 2015) favored the development of state-run and commercial active geodetic networks (Baran et al., 2008; Specht, Specht & Dąbrowski, 2017). Since the first study in 2009, the research team has conducted several studies focusing on GNSS positioning accuracy and availability (Specht et al., 2014; Specht & Koc, 2016; Specht et al., 2019) and supporting it with software solutions (Specht, Chrostowski & Koc, 2016). In another area of interest, the team focused on the application of determining coordinates in the design and use of railway tracks (Koc, 2012; Koc & Chrostowski, 2014; Koc, 2016; Koc et al., 2019). The research involved further work aimed at developing railway mobile measurement platforms (MMP).

The issue of satellite positioning for railways, as discussed in the literature, covers the application of additional measurement and numerical methods. Gikas and Daskalakis (Gikas & Daskalakis, 2008) proposed a solution combining conventional tachymetric geodetic measurements with GNSS observations. Multi-sensor solutions are important for the availability and reliability of satellite measurements (Li et al., 2017; Gao et al., 2018; Kurhan et al., 2018) and inert INS (Chen et al., 2015; Chen et al., 2018). Several by studies by Jiang et al. (Jiang et al., 2017a; 2017b) have presented a novel approach to the issue by applying external supporting measurement systems whose application requires the use of innovative methods of design and computation (Yoshimura & Naganuma, 2013; Sánchez, Bravo & González, 2016; Wang et al., 2018). One of the objectives of this research project is to analyze the application of multiple GNSS receivers for one MMP platform. This approach, which is in line with modern research methods, involves the use of a set of devices deployed with strict geometry. The main objective of the project was to precisely determine

the geometric layout of a railway track. This paper describes the preparatory phase of the measurement process, which involves a presentation of the method of the precision deployment of five GNSS receivers in a specific geometric configuration on a measurement platform. Locating the measurement instruments according to the assumed spatial relationships is a key condition of the study conducted as part of the BRIK project.

Methodology

Measurement platform

It was decided to verify the modified concept of conducting measurements on a railway track during a measurement campaign conducted at the end of 2018 on a railway track in Gdańsk. The track shape study employed a measurement set that consisted of three measurement platforms coupled with a tramway, a motor vehicle. The measurement platforms were made from trolleys from a pre-war DWF 300 tramway, with the dimensions: 2.73 m × 1.78 m × 0.75 m. The central GNSS receivers were mounted on the trolley's kingpin, which is situated above the track axis. Over the years, the original trolleys were covered with steel sheets, whose flat upper surfaces enabled additional construction elements to be installed for the measurement instruments. The study uses three platforms, two of which were used to mount two sets of five GNSS receivers and one to mount a satellite compass (Figure 1).

In order to make it possible to set the receivers in the spatial configuration that was predefined in the project, two transverse steel frames with dimensions of 1.80 m, 0.25 m, 0.22 m and a central support on the kingpin were installed on the measurement platforms. The frames consisted of two 6 cm wide parallel steel profiles, with a 13 cm space between them. Two transverse profiles, 8 cm wide, with a 3 cm space between them, were welded in place above the rail at the place where the tribrachs and receivers were installed. The steel profile gauge provided the necessary tolerances for the process of precisely positioning the receiver. A round hole with a diameter of 5 cm was cut out in the central support with the horizontal dimensions of 0.25 m and 0.25 m in order to make it possible to move the tripod's head. The height of the central support could be modified within the range of 0–30 cm owing to a system of screws. The frames and the supports were fixed to the measurement platform with screws in a manner that prevented

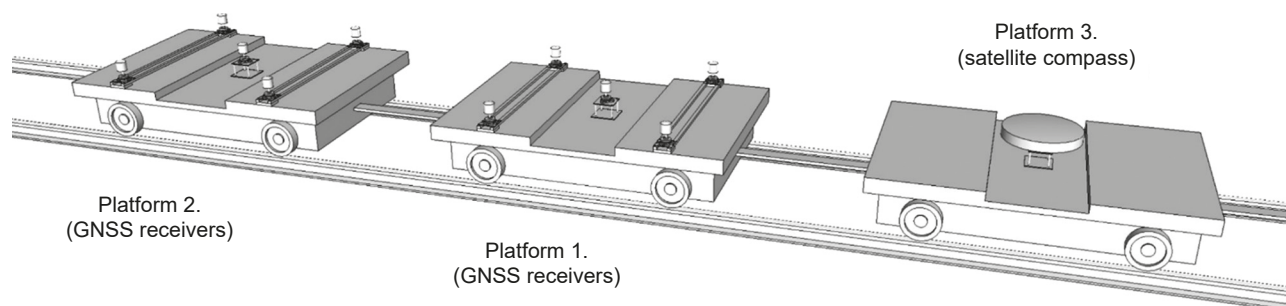


Figure 1. Railway measurement trolleys with the instruments mounted on them

their position from being changed. The GNSS receivers were later placed in a predefined configuration on the structure.

Tachymetric measurement

The setup of the predefined geometric configuration of the measurement instruments was based on conventional tachymetric geodetic measurements. The essence of tachymetric measurements lies in simultaneous measurement of the angle distance: both horizontal and vertical in the local coordinate system of an electronic total station. As with laser scanners, the coordinate system at the measurement stand was the result of setting the device on a tripod. Thus, the horizontal wheel of the device receives a specific spatial configuration with the surroundings defined by the starting direction orientation (the zero value of the horizontal angle) (Figure 2). Currently, the practice of performing geodetic procedures in Poland usually involves conducting flat measurements in the state flat coordinate system PL-2000, which is based on the Gauss-Kruger projection (Hooijberg, 2008) and it is used in cartographic work and maps with scales of more than 1:10,000 (Regulation, 2012a). The horizontal control network is used to determine the georeference corresponding to

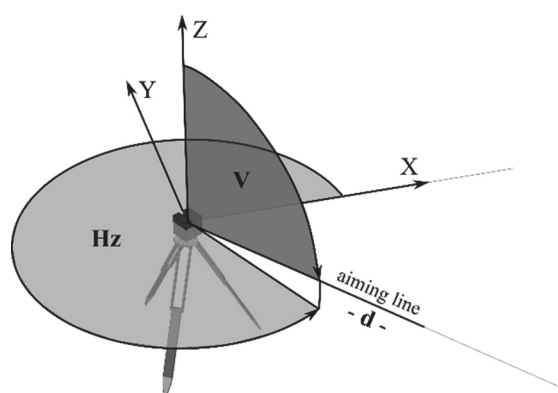


Figure 2. A local coordinate system for a total station and the observations registered during the measurement

the PL-2000 system (Regulation, 2012b). Based on known coordinates of the control network points, the total station computer then determines the rotation matrix coefficients and the translation vector coordinates (Korn & Korn, 2000), which enable coordinate transformation for points measured in the field to the PL-2000 system.

The distance is measured by the electromagnetic method which employs the relationship between the known electromagnetic waves (light) propagation velocity, time between the emission and reception of the beam and the distance covered (Heritage & Large, 2009). It is noteworthy that the beginning of the local coordinate system is situated at the emission and reception center of the measurement device. The horizontal and vertical angles are read from the code markers that are located on the horizontal and vertical wheels, which are integrated with the alidade and the instrument telescope (Wanic, 2007). With the rotation of the instrument around its vertical axis, the horizontal wheel rotates, the wheel's code marker is changed and the new horizontal angle value is read-out. Similarly, when the telescope rotates, a new vertical angle of the instrument's target axis is acquired. The integration of three measurement results (two angles and one distance) enables the determination of the three-dimensional ortho-Cartesian coordinates of the point being measured. Assuming a vertical angle measured downwards from the vertical direction, the coordinates in the right-hand local system of coordinates can be determined from the following formulas:

$$\begin{cases} x = d \sin(V) \cos(Hz) \\ y = d \sin(V) \sin(Hz) \\ z = d \cos(V) \end{cases} \quad (1)$$

where:

- x, y, z – ortho-Cartesian coordinates of the point,
- d – distance between the point and the measurement instrument,
- V, Hz – vertical and horizontal angle of the instrumented target axis aimed at the point.

The transformation of the local system coordinates to another system of coordinates (e.g. state system PL-2000) in matrix notation has the following form:

$$\mathbf{P}' = \mathbf{R} \cdot \mathbf{P} + \mathbf{T} = \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} \quad (2)$$

where:

$\mathbf{P}, \mathbf{P}'$ – vectors of the point coordinates in the primary (x, y, z) and secondary system (x', y', z') ,

$\mathbf{R}$ – rotation matrix around the vertical axis OZ by the angle θ ,

$\mathbf{T}$ – translation vector with coordinates T_x, T_y, T_z .

The observation and the point coordinates are then saved in the device's memory. Moreover, in the same way as with a total station, the recorded point coordinates can be used to carry out further computations or to perform separate measurement procedures, such as staking out.

As part of the tachymetric measurements, the orthogonal measurement method was applied to position the GNSS receiver positioning in the local total station coordinate system. The horizontal coordinates were used to mark out the measurement line which was used to calculate the distance along the baseline (l) and the offset (h). The procedure of staking out the position of the receiver is presented in Figure 3.

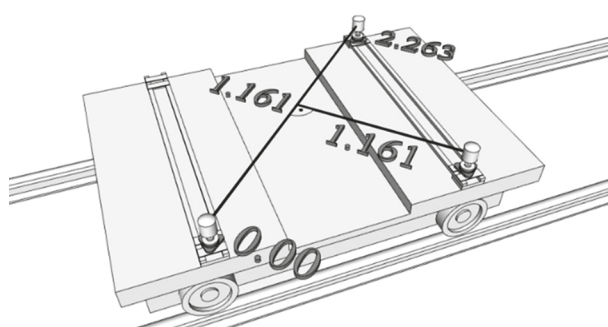


Figure 3. Staking out the position of the GNSS receiver on the platform using the orthogonal method

In a conventional geodetic approach, projecting the staked-out point onto the measurement line is followed by the calculation of the distance along the baseline and that of the offset. It is noteworthy that rectangular left-hand offsets for the measurement line have a negative sign. The flat coordinates of the point are calculated based on the known coordinates

of the points which mark out the measurement line from the following formula:

$$\mathbf{P} = \mathbf{P}_0 + \mathbf{R} \cdot \mathbf{O} = \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix} + \begin{bmatrix} \cos(A) & -\sin(A) \\ \sin(A) & \cos(A) \end{bmatrix} \begin{bmatrix} l \\ h \end{bmatrix} \quad (3)$$

where:

$\mathbf{P}, \mathbf{P}_0$ – vectors of the coordinates for the point being measured (x, y) and the starting point of the measurement line (x_0, y_0) ,

$\mathbf{R}$ – rotation matrix for the azimuth A ,

$\mathbf{O}$ – linear observation matrix for the distance along the baseline l and the offset h .

In the context of the measurement assignment that is presented here, the opposite assignment was carried out. The measurement line was then created based on the position of two GNSS receivers that were facing each other. The point being staked out (the next GNSS receiver) was projected onto the measurement line, which made it possible to calculate the distance along the baseline as well as the rectangular offset. This task requires the canonical equations to be determined: a straight line co-linear with the measurement line and a line which is perpendicular to it and runs through the projected point P (Figure 4).

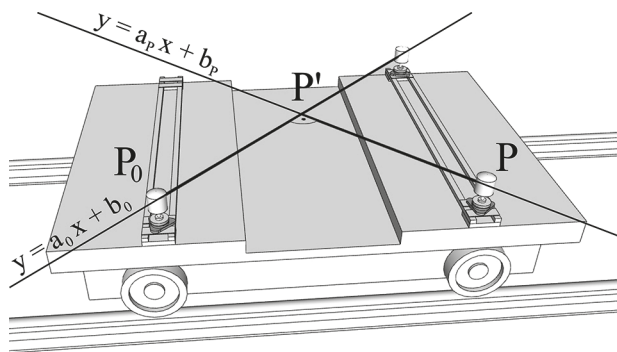


Figure 4. Staking out the position of the GNSS receiver on the platform using the orthogonal method

The slope a and the intercept b for the lines can be determined from the following formulas:

$$a_0 = \tan(90^\circ - A) \quad (4)$$

$$b_0 = y_0 - x_0 \tan(90^\circ - A) \quad (5)$$

$$a_p = -\cot(90^\circ - A) \quad (6)$$

$$b_p = y_p + x_p \cot(90^\circ - A) \quad (7)$$

The solution of a system of two equations of straight lines is the vector of the flat coordinates of

point P projected onto the measurement line (P'). As a matrix, the vector is calculated from the following relationship:

$$\mathbf{X} = -(\mathbf{A}^T \mathbf{A})^{-1} (\mathbf{A}^T \mathbf{L}) \quad (8)$$

where:

$\mathbf{X}$ – vector of the coordinates of point P 's projection (P') onto the measurement line $[x_{P'}, y_{P'}]^T$,

$\mathbf{A}, \mathbf{L}$ – matrix of the slopes as $\begin{bmatrix} a_0 & -1 \\ a_P & -1 \end{bmatrix}$, and the

matrix of the intercepts as $[b_0, b_P]^T$.

The distance along the baseline and the offset can be calculated with the formulas:

$$l = \sqrt{(x_{P'} - x_0)^2 + (y_{P'} - y_0)^2} \quad (9)$$

$$h = \text{sign} \sqrt{(x_{P'} - x_P)^2 + (y_{P'} - y_P)^2} \quad (10)$$

where:

$$\text{sign} = \begin{cases} 1 & \text{for } (A_P - A) \geq 0 \\ -1 & \text{for } (A_P - A) < 0 \end{cases},$$

A, A_P – azimuths of the measurement line and the section: starting point of the measurement line – projected point P .

The linear values determine the point's position relative to the assumed measurement line. This procedure is often used during geodetic work which involves the staking out of points to determine the point's positions in accordance with the design assumptions.

Measurement and results

Preparations for the satellite measurements of the railway track as part of the research project involved

setting the correct geometric configuration of the ten receivers used on the two measurement platforms (Figure 5). The instrument settings presented here enabled the position of the track axis to be independently determined several times. The first determination was conducted by the central receiver of the measurement platform. Subsequent determinations came from the extreme receivers as the middle point of both diagonals. The last determination was obtained by calculating the coordinates of the point at which the lines (diagonals of the square) intersected. The solution applied here has an additional advantage: mutual control of successive determinations of the track position; this significantly improves their reliability.

All of the five GNSS receivers were placed on tripod heads; these were fixed to steel frames that were attached to the tramway measurement trolley. Ensuring the central position of the receiver, both with respect to the track axis and on the diagonals of the square formed by the other four GNSS receivers, was the key condition for the planned experiment. Therefore, it was then justified to start the geodetic work with the central receiver and, based on its position, to determine the position of the other GNSS receivers at the square's vertices. The measurements were conducted with a Leica TPS 1103 electronic total station. As the measurement trolley was rigidly positioned on the track, not every point situated on the longitudinal trolley axis was positioned above the track axis. Considering the receiver configuration, a compromise was adopted where the main receiver was situated on the kingpin. Only one point indicates the position of the track axis in curvilinear track sections. In this experiment, it was marked with a notch on the trolley's surface. In order to verify the reliability of the point, an independent staking out of the track axis was conducted based on the

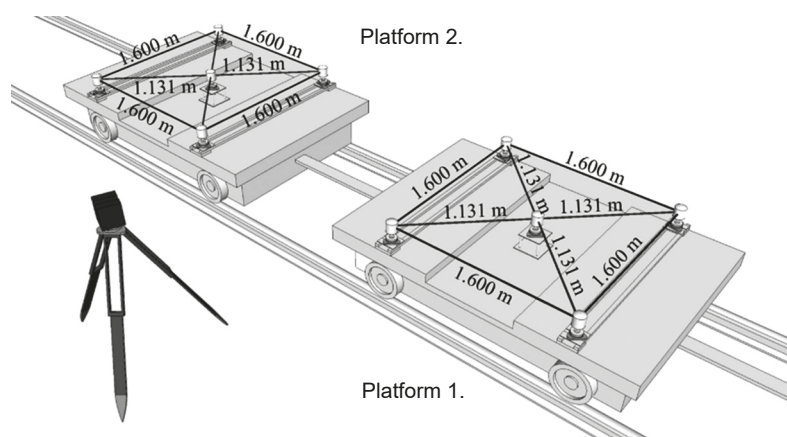


Figure 5. Mutual spatial relationships of the GNSS receivers on the measurement platforms

railway track's cross-sections in front of and behind the measurement trolley. The verification involved measuring points on the rails, calculating the central points of two sections of the cross-sections (points on the track axis) and subsequently, based on the calculated points, staking out a rectilinear section of the track axis. The measurements confirmed that the point on the trolley platform was marked correctly. A steel base with a 5 cm hole was then screwed to the welded bolts above the indicated central point. Owing to the construction of the tripod head, it was then possible to install various devices and measurement devices in its tang, such as the GNSS receivers or conventional measurement prisms. The others are applied in tachymetric measurements and allow millimeter accuracy of the distance between the instrument and the prism to be maintained. Taking advantage of the high accuracy of the method, the position of the central tripod head was staked out; after the measurement was completed, the prism was removed and replaced with a GNSS receiver. Therefore, one of the two conditions of the satellite measurement conditions was fulfilled.

The second stage of the geodetic work involved constructing a square, with the other four GNSS receivers at its vertices. An additional difficulty that was faced during staking out was the need to make sure that the diagonals intersected at the point at which the first receiver was situated. The external receivers were fixed to two metal frames which were situated transversely with respect to the track's direction. There were systems of two steel elements on the frame's edges, with a gap that enabled the installation of the tripod heads. The 3 cm distance between the longitudinal steel profiles ensured a limited range of movement of the tripod head. Staking out of the GNSS receiver's position was initiated by placing the tripod head with the prism onto one of the transverse frames on one of the track rails; therefore, one of the square diagonals was materialized. The position of both tripod heads was measured tachymetrically, which yielded three-dimensional coordinates x, y, z of the points in the local coordinate system of the electronic total station. In the next step, the position of the opposite square's vertex was then determined. The orthogonal staking out mode in the total station was applied for this purpose; the coordinates (1) obtained in the tachymetric measurement were relative to the measurement line determined by the two tripod heads installed on the mobile platform. Each time this procedure was carried out it resulted in presenting the distance along the baseline (9) and the offset (10) for the point being measured; three of

the points considered are co-linear if the offset value is zero. If the offset is not zero, it is necessary to move the tripod head within the tolerance range, which is provided by a gap between the steel elements crowning the frame. When the expected result was achieved, a tachymetric measurement was performed and the coordinates of the third point on the first square's diagonal were recorded.

The next part of the measurements involved positioning two vertical GNSS receivers on the other diagonal of the square. This was done using the geometric properties of the two diagonals of a square, which intersect at a right angle. Thus, in the case of the second diagonal of the square, a condition that has to be fulfilled is that the distance along the baseline (10) must be equal to the distance between the start of the measurement line (the external GNSS receiver) and its end (the middle GNSS receiver). Therefore, the position of the last two vertical receivers on the second diagonal will have an offset with the same absolute value, but with opposite signs. Staking out was based on the measurement line used earlier. The accuracy of the GNSS receiver's position was verified in a similar way as done previously, i.e., by placing the prism on consecutive tripod heads and adjusting any incorrect settings. When the assumed position was achieved, the last two tripod head's positions were measured tachymetrically and their three-dimensional positions were then recorded. There is one more noteworthy measurement aspect: when the prisms were removed from the tripod heads and replaced by the GNSS receivers, the phase centers of the antennas were not positioned at the same height as the prism's center; the vertical offsets of the receivers and the prisms were determined relative to the horizontal plane of the tripod's head in order to precisely determine the phase center position. They were then used as the basis for calculating the height coordinate, which was to be added to the height coordinate of the prism. The prism center coordinates for both measurement platforms are presented in Table 1.

Table 1. Three-dimensional coordinates of the prism centers on the mobile measurement platform

GNSS receiver	Platform 1			Platform 2		
	x [m]	y [m]	z [m]	x [m]	y [m]	z [m]
Front right	95.647	93.057	0.828	98.117	96.077	0.885
Back right	96.654	94.304	0.839	99.128	97.315	0.882
Back left	97.899	93.292	0.835	100.364	96.309	0.880
Front left	96.883	92.043	0.840	99.360	95.065	0.880
Middle	96.776	93.177	0.738	99.239	96.191	0.881

Table 2. Deviations of the linear measures between the project data and the data measured on the platform

Linear element	Platform 1			Platform 2		
	Design	Measurement	Difference	Design	Measurement	Difference
Top	1.600	1.599	−0.001	1.600	1.603	0.003
Right	1.600	1.603	0.003	1.600	1.598	−0.002
Bottom	1.600	1.604	0.004	1.600	1.594	−0.006
Left	1.600	1.610	0.010	1.600	1.599	−0.001
Semi-diagonal 1	1.131	1.135	0.004	1.131	1.128	−0.004
Semi-diagonal 2	1.131	1.134	0.002	1.131	1.129	−0.002
Semi-diagonal 3	1.131	1.129	−0.002	1.131	1.131	0.000
Semi-diagonal 4	1.131	1.139	0.008	1.131	1.132	0.001

This spatial configuration was subsequently compared to the designed configuration. The differences in the linear measures between the assumed design data and the data obtained in the field for both measurement platforms are presented in Table 2.

The columns representing the differences between the design data and those staked out on the platform indicate that the receivers were accurately positioned with an error that did not exceed 0.010 m. It is noteworthy that only three sections out of the sixteen had an error that exceeded 0.004 m. Additionally, the prism coordinates on the central tripod heads differed from the coordinates of the point that was determined as the intersection of the two pairs of diagonals with the value of $\Delta x = -0.008$ m and $\Delta y = 0.000$ m on the first platform and $\Delta x = 0.005$ m and $\Delta y = 0.002$ m on the second. Thus, the second of the planned goals was achieved, i.e., another independent determination of the track axis, which coincides with the position of the central receiver with an error that did not exceed 1 cm. It is noteworthy that

some difficulty occurred as a result of it being impossible to place the transverse frames on the platform in the required position relative to the middle receiver. This was a result of the presence of fixed construction elements in the measurement trolleys. The stages of the staking out procedure for the receivers on the measurement platform are shown in Figure 6.

Conclusions

The track axis at a certain point can be determined twice independently on the same run by applying several GNSS receivers deployed in a specific manner on a mobile measurement platform. The geometry of the five-receiver measurement equipment presented in this paper is based on the shape of a square. Four GNSS receivers are situated at the square's vertices and the fifth at its center of gravity, i.e. at the intersection of the diagonals. Satellite measurements (conducted both in real-time and by recording raw observation data) yielded synchronous positions of

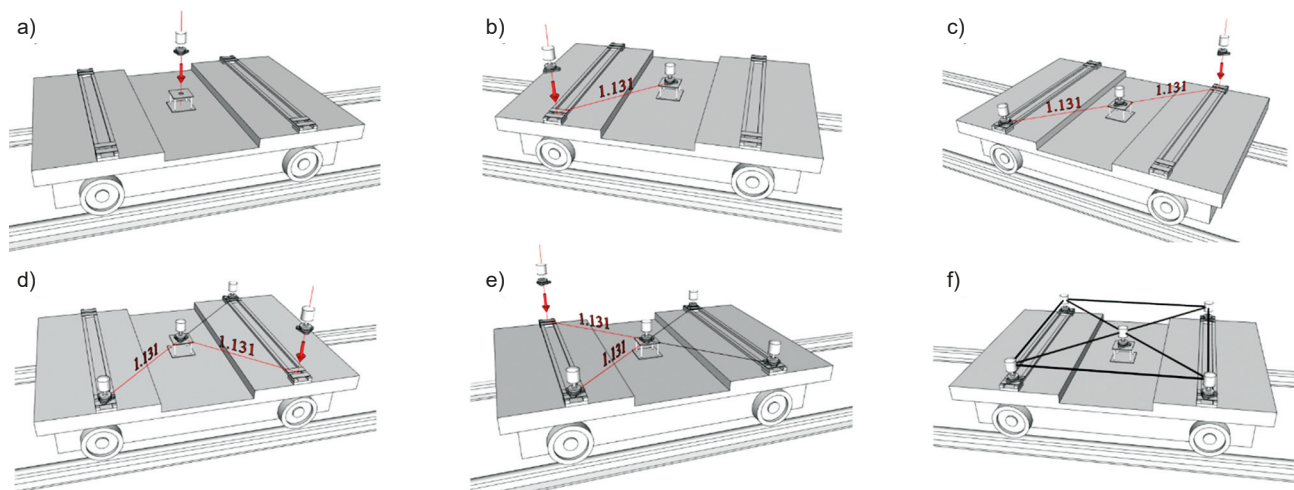


Figure 6. The procedure of staking out the five receivers in the predefined geometric configuration: the central receiver above the trolley kingpin (a), staking out the two receivers on the diagonal of the square (b, c), staking out the other two receivers at the vertices (d, e), the final spatial configuration of the receivers (f)

the GNSS receivers. In the data processing stage, the coordinates were used to analyze the position that was measured by the central receiver and compare it with the position calculated from the diagonal intersection point in the square defined by the other four external receivers. Acquiring reliable results requires the use of precision geodetic techniques to properly deploy the equipment on the measurement platform. The compactness of the measurement infrastructure (the frame and the support) is a different aspect, as it is not made for one type of means of transport in particular. The compactness of the solution is a significant advantage as it allows the apparatus to be installed on both tramway trolleys and railway cars. On the other hand, despite their geometric stability, rigid systems are less versatile and are usually intended for use on one specific vehicle.

The methodology adopted in this study required that the satellite measurement preparation stage should include conducting staking out for the spatial configuration of the GNSS receivers. The tachymetric measurement method allowed for the determination of the position of the satellite receiver on the two platforms with an error not exceeding 0.010 m. This applied to both the linear measures in the square that was made from the frames and the position of the point that indicates the track axis. An important role in the staking out procedure was played by the orthogonal method, which determines the position of the points being analyzed with respect to the assumed measurement line. Despite the obstacles that resulted from the trolley's construction and occasional problems with mounting the frames for the receivers as planned, sub-centimeter accuracy was achieved. This is proof of the usability of the method at the principal satellite measurement stage, the main aim of which is to precisely determine the track axis. The measurement task can be performed within a relatively short time by a geodesist with an electronic total station. Staking out ten receivers and performing the control measurements took approximately 60 minutes in this measurement for the BRIK project. It is necessary to perform the staking out procedure for the GNSS receiver position with the utmost diligence and precision, given its huge impact on the accuracy of lengthy satellite measurements.

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Computational Fluid Dynamic study on the wind characteristics of a multifunctional building system model in developed coastal cities

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Key words: architectural design, Computational Fluid Dynamic (CFD), multifunctional building, system model, optimization, sustainable environment

Abstract

This paper presents an approach for providing innovative technology by applying fluid mechanics to the field of architectural design. The aim is to make a building's shape profitable and strengthen environmental protection by using the wind force to create an integrated wind absorption definition for a multifunctional building system model. Furthermore, taking control of the wind flow over an object can have an impact on not only the designed object itself but also on its surroundings. In modern coastal cities there are issues associated with the wind and ventilation that need to be solved. The presented system model and the calculations conducted are part of the new definition of a multifunctional object and the wind force as a significant subsystem. Systematizing this scope can be useful in design practice.

Introduction

The new trend of architectural design is becoming very similar to ocean engineering. Advanced calculation procedures are becoming a standard part of the building design process. There are many examples of the practical use of Computational Fluid Dynamics (CFD) calculations in the design process (Aydin & Mirzaei, 2017; Naboni, Lee & Fabbri, 2017; Wu & Hsieh, 2017; Zhong, Zhang & Tamura, 2019). The trend of using CFD seems to be increasing (Jo, Jones, & Grant, 2018) which is beneficial in predicting the optimal structural solutions. Harnessing the potential of natural wind power at the design stage tends to create a more environmentally friendly structure that fits into a dense urban environment (Allard, Ghiaus & Szucs, 2009).

By analyzing global wind power installations (Archer & Jacobson, 2005) it can be seen that water-side land is the most profitable land for the application of power generating installations. Furthermore, coastal urban areas are currently characterized by the most dynamic development (Barragán & de Andrés, 2015). Along with the intensification of spatial development there is a concentration of urban tissue, where the control of air flow shows a large scope for the development of knowledge in the field of architectural structural design. Currently cities are characterized by intensive land use: as has been observed in the literature (Gerigk, 2017), multifunctional structures are one of the predominant types of buildings in today's urban agglomeration.

The topic of optimizing wind characteristics is suitable for the surroundings of a building (Shi,

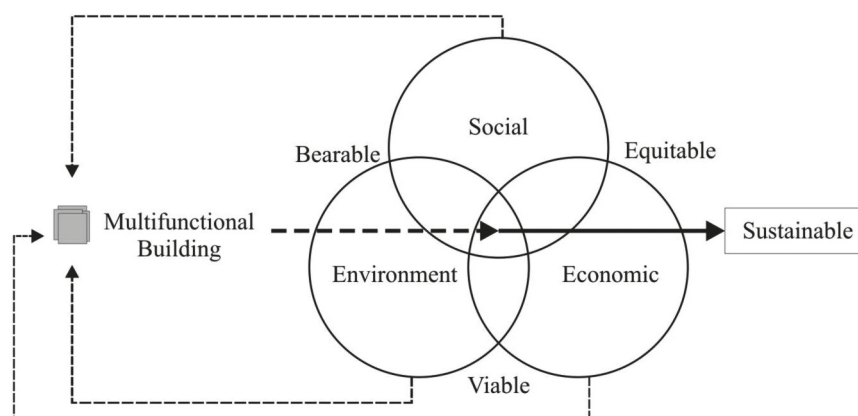


Figure 1. Scheme of the influence of a multifunctional building on sustainable development, presented in a Venn diagram (Gerigk, 2017). Venn diagram based on the literature (Lozano, 2008)

Lu & Li, 2015), where the building's impact on the environment is most significant. However, optimization of wind characteristics is also dependent on how the designed structure makes use of the wind force (Kim, Jeon & Kim, 2016). Wind force can be used to induce wind flow for ventilation, both inside and outside the building, as well as to generate electricity using wind turbines. Wind power is one of the most important environmental factors that are required to be included in architectural design in order to create modern multifunctional buildings.

Creating a sustainable environment is a priority for modern cities. Some projects contain pro-ecological elements, but their presence depends on the expectations of the investors. Not every design office has adequate knowledge regarding the implementation of advanced calculations in the use of wind energy. Within design optimization, it can provide a multifunctional building system model that can bring benefits for the developed environment.

Multifunctional buildings are one of the predominant types of buildings in today's urban agglomeration. However, it is difficult to introduce any systematic change in developments that already exist. It can be said that the integration of functions in one building is currently associated with the expectations of an investor who defines his demands for the project. From a theoretical and practical point of view, it would be beneficial to combine functions with respect to the wider environment; such an approach is beneficial not only for functional reasons. Multifunctional systems also have a social, economic and environmental dimension (Gerigk, 2017), where the CFD approach is necessary to develop the project in the most efficient way. Creating a multifunctional building system model is a systematic way to define the design process in order to achieve the basic values of sustainable development (United Nations

World Commission on Environment and Development, 1987) (Figure 1).

Multifunctional building system model

The holistic representation of a multifunctional building system is a model that contains all the characteristics of a building's design. This is a combined theoretical model dedicated for a building's complex system. By gathering the total amount of information about a multifunctional building project, it can be described as a Multi-Criteria Model (MCM). Embracing all of the model's components in a logical structure is crucial for the model's structure. The Multi-Criteria Model is developed by defining the multifunctional building system, the basic criteria set and the stakeholder group and engaging them with the building's life cycle phases.

The Multifunctional Building System (MBS) is defined by three main subsystems. The first two subsystems are the Internal Functional System (IFS) and the External Functional System (EFS). The third one is the External Environment System (EES); this system is presented in Figure 2. The MBS is the representation of all the physical elements that are included in the building project.

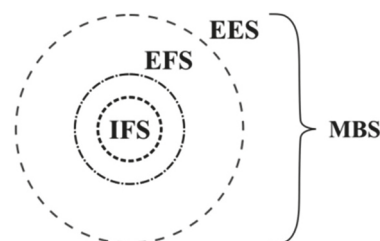


Figure 2. The Multifunctional Building System scheme

The Internal Functional System (IFS) is represented by the subsystems of the Functional System

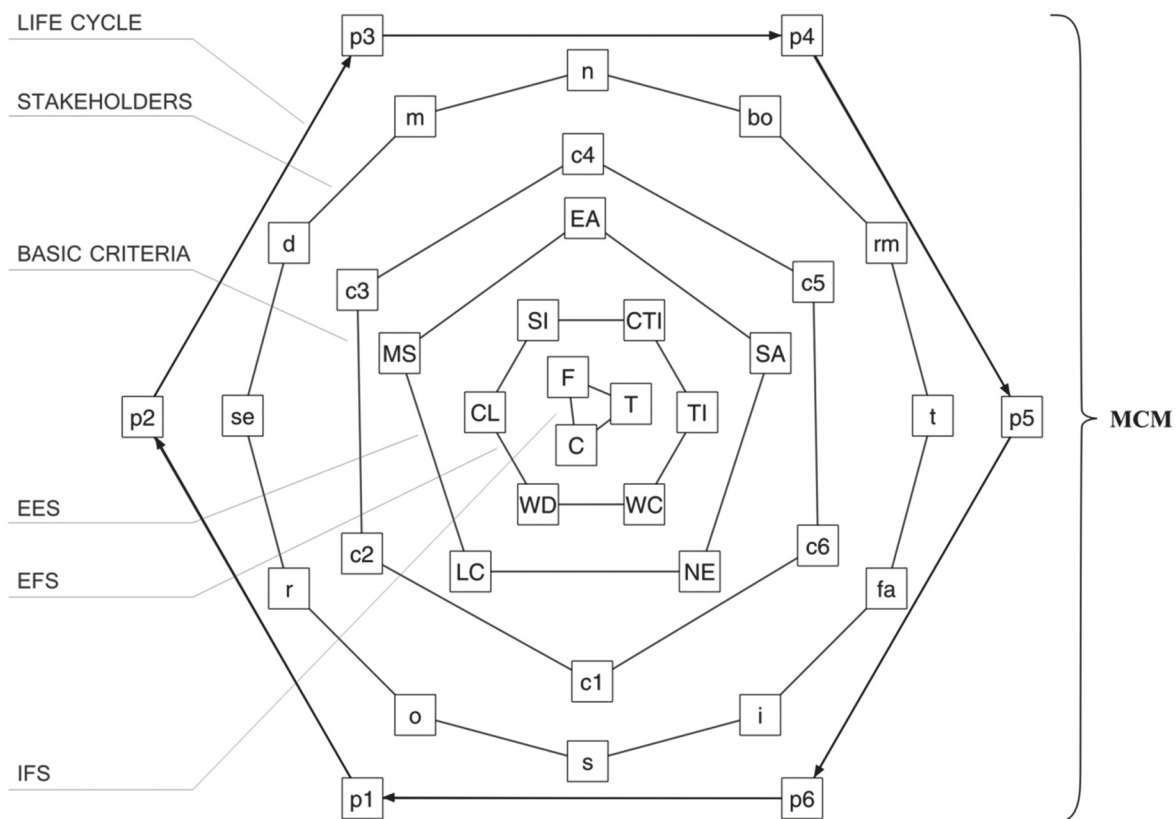


Figure 3. The Multi-Criteria Model scheme

(F), the Construction System (C) and the Technology System (T). This subsystem refers to the determined utilities that the building's design tends to satisfy.

The External Functional System (EFS) includes Social Infrastructure (SI), Transportation Infrastructure (TI), City Logistics (CL), City Technical Infrastructure (CTI), Waste Disposal (WD), and Weather Conditions (WC). The external parts of the subsystem are the location elements that connect the building to the surrounding agglomeration.

The External Environment System (EES) is defined by Social Aspect (SA), Legal Conditions (LC), Management System (MS), Economic Aspect (EA) and Natural Environment (NE). The external environmental elements impose all the basic requirements for the building project.

The designed multifunctional building's output depends on the defined Basic Criteria set which are: aesthetics (c1), functionality (c2), natural environment protection (c3), system safety (c4), system effectiveness (c5), and functional flexibility (c6). This set represents the basic requirements the designed structure must provide to the built environment, and all the stakeholders are obligated to implement them.

The Stakeholder Group in the multifunctional building project are: the building owner (bo), the

tenants (t), the staff (s), the occupants (o), the neighbors (n), the municipality (m), the regulators (r), the designer (d), specialist engineers (se), the risk manager (rm), the insurer (i), and the fire appraiser (fa).

In order to define each stage of the project, it is necessary to construct the building's project life cycle. It contains the following phases: the initial work (p1), the concept (p2), the project (p3), construction (p4), exploitation (p5) and finally the waste phase (p6).

Figure 3 presents the abovementioned components combined into one system, where they form the Multi-Criteria Model (MCM).

The presented model has circular layers composed of the presented sets of variables. The multifunctional building's design process depends on the formation of relationships between the individual multilayer elements resulting in the next steps required to complete the project. This is the basis for the system's development.

The multifunctional building's wind absorption subsystem

In order to carry out the CFD optimization of the designed multifunctional structure, the Wind Absorption System (WAS) must be defined. This

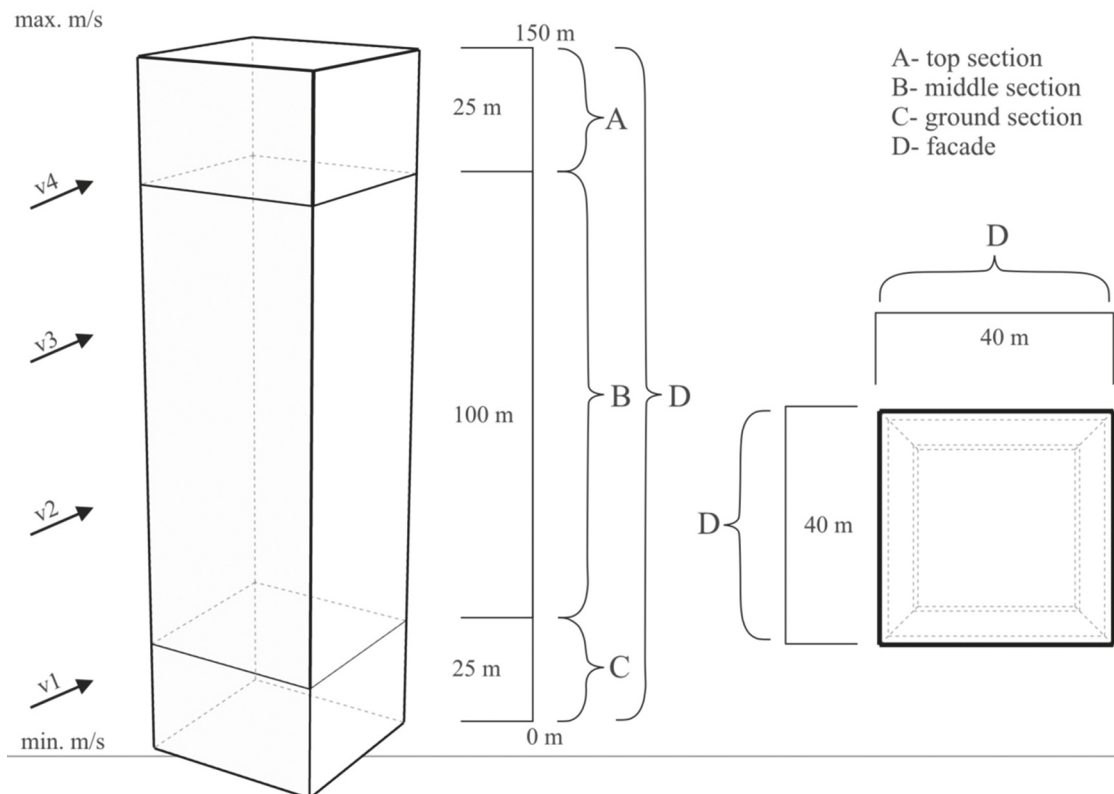


Figure 4. Wind analysis for the multifunctional building's structure scheme. Perspective on the left, top view on the right

concept is a set of measures that are used to shape the building's design, that make possible to use wind power to generate electricity and ventilation support.

The first parameter is the building's dimensions – Physical Volume (pv). In a simplified form the multifunctional structure is a high rise building about 150 meters high with a 40 by 40-meter base. In the Physical Volume, four sections can be distinguished, they are: (A) – the top section, (B) – the middle section, (C) – the ground section and (D) – the facade.

The second parameter is the Wind Speed (ws). For the purpose of this theoretical example the wind speed is not precisely defined but its strength in meters per second is defined for the minimum (v1) near the ground, the maximum (v4) in the top part, and (v2, v3) in the middle part of the building. The wind velocity is simplified, depending on the wind profile's interaction with the parts of the building. The wind analysis for a multifunctional building's structure scheme with the parameters presented above is as shown in Figure 4.

The Wind Absorption System (WAS) is defined using a compilation of characteristics presented above, as shown in Figure 5. This subsystem's main aim is to make the best use of the wind conditions, so the building's section nodes are connected to the correct wind flow.

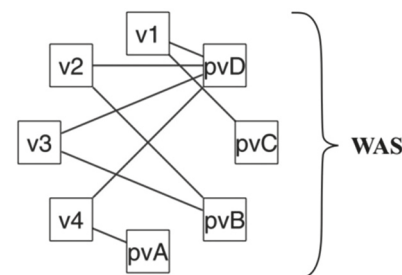


Figure 5. Wind Absorption System (WAS) scheme

Connections between the subsystem's nodes are defined by the strength of the wind and its location. In Figure 6, the Wind Absorption System is joined to the Multi-Criteria Model as part of the complex system. The implementation of the wind absorption system is a process that determines how the wind power can be used and what influence it will have on the project.

CFD optimization of the wind characteristics

The CFD optimization of the wind characteristics can be carried out by modifying the building's shape. Depending on its purpose, the wind power can be useful in four ways: The first is to generate electrical energy, the second is to improve the

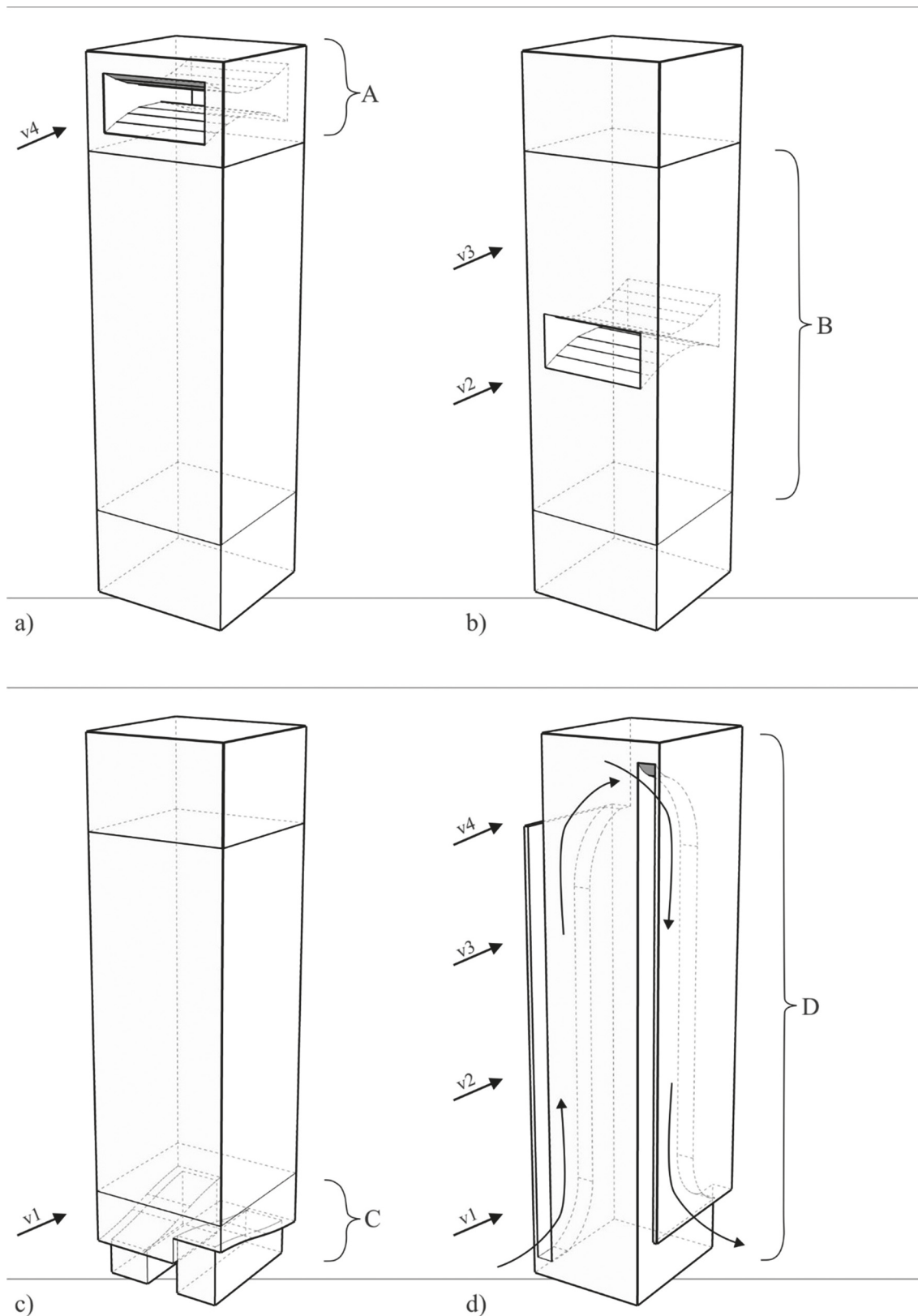


Figure 7. A multifunctional building's CFD shape optimization scheme; a) Optimization of the top section (A); b) Optimization of the middle section (B); c) Optimization of the ground section (C); d) Optimization of the facade (D)

the possibilities of the pro-ecological development of a building and its surroundings. Following the Multi-Criteria Model process, the Wind Absorption

System depends on a specialist engineer to calculate the optimal shape of the building. As the theoretical model has been presented in this work, the next step

will be to define the design procedure and the computational data.

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The influence of temperature on the damping value of shock absorbers determined by the Eusama method

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Key words: diagnostics, suspension, shock absorbers, Eusama method, wheel adhesion, measurement error

Abstract

The article presents the legal requirements for shock absorbers in suspension, for a vehicle in which they are mounted to be allowed on Polish roads. A short description of the working methodology of the device used to determine the effectiveness of a shock absorber's damping (sometimes referred to as relative wheel adhesion) is given on the basis of the Eusama method. The method of carrying out the tests on a sample of five passenger cars are described, along with the tests carried out at different temperatures for shock absorbers installed in a suspension system. The results of the diagnostic tests of the shock absorbers carried out on a diagnostic stand, in accordance with the Eusama method, are presented. The results confirm that the ambient conditions – the temperature of the chassis components (including the shock absorbers) – only slightly influence the values of their damping efficiency.

Introduction

The suspension is one of the fundamental systems in a vehicle; its main task is to ensure proper driving comfort and safety. Older cars (from the last century) were designed to provide maximum comfort while driving; this has changed with improvements in their design and speed, and safety aspects have also become more important.

It comes as no surprise to anyone that in today's vehicles there is quite a significant interaction between the way the suspension system works and the operation of many other systems. In motor vehicles, two of the most important systems in terms of active safety are the braking and steering systems. Currently, there are many mechatronic systems in modern cars that assist the driver, such as ABS, ASR, ESP, emergency braking systems BAS, and obstacle avoidance systems, etc. However, it should be noted that whether or not these systems will work properly depends not only on the functioning of

complex electronics, but also on proper contact with the ground. In order for the forces between the wheel and the road surface to be able to transmit both longitudinal and transverse forces, it must be ensured that, in addition to the highest possible coefficient of friction, there is sufficient pressure. When a vehicle is moving on a flat road, the dynamic loads on the individual wheels vary only slightly. When moving at higher speeds, let alone on uneven roads or when cornering, the pressure changes to a much greater extent.

Reducing wheel pressure reduces the longitudinal and transverse forces between the wheels of the car and the road surface, and can cause the wheel to slip; this undeniably affects the stability of the vehicle.

One of the factors determining wheel adhesion may be the inadequate damping performance of the shock absorbers. In this way, not only does the driving comfort deteriorate, but above all, the effectiveness of the braking and steering systems deteriorates (Juzek et al., 2016).

Analysing the data from the Polish Police Headquarters (Police Headquarters Report, 2018) about the accident statistics in Poland (Jaśkiewicz & Jurecki, 2013; Jurecki & Poliak, 2018) it is easy to see that the defectiveness of a vehicle has a relatively small impact on the occurrence of accidents. There were “only” 40 accidents in 2017 and 38 in 2018 which could be attributed to the defectiveness of vehicles, wherein about 30% were caused by damage to the steering system or the braking system (Police Headquarters Report, 2017; 2018). This damage is often revealed during on-site inspections of vehicles, even though they did not experience a direct impact during the incident. The cause of 23% of accidents is “not adjusting the speed of the vehicle to the prevailing road conditions”. In such situations, in addition to the undeniable influence of the driver, the road and its surroundings are also important. The influence of the technical condition of vehicles in the occurrence of road accidents can be considered to have not been fully estimated. It is certain, however, that the possible poor condition of shock absorbers may significantly affect braking efficiency and, consequently, contribute to the occurrence of a road accident.

In vehicles manufactured today, in which modern mechatronic systems that support the driver are commonly used, there is a need for comprehensive control of their technical condition and their diagnosis.

In the case of shock absorbers, it is very important to periodically check the effectiveness of their damping during technical inspections. In vehicle inspection stations, the technical condition of shock absorbers is commonly checked in Europe with the use of devices based on the Eusama method (European Shock Absorber Manufacturers Association) (Gardulski, 2009). This method allows for very quick testing of the technical condition of a vehicle's shock absorbers. However, more importantly, this method allows analyses to be carried out without any technical data for the tested vehicle, e.g. its sprung mass. An additional advantage is that the devices used do not require any complicated activities to be performed by the diagnostician.

These devices, as shown in many publications, have certain disadvantages in addition to their advantages (Kupiec & Ślaski, 2004; Stańczyk & Jurecki, 2014). Unfortunately, a major flaw of this method is the strong impact of various factors on the obtained values of the effectiveness of the damping of shock absorbers (Zdanowicz, 2010), as documented in many publications (Jurecki, Jaśkiewicz & Wdowski, 2014). These factors include e.g. a change in the tyre pressure or a different sprung weight of

the examined vehicle (Bocheński, Lozia & Mikołajczuk, 1999; Jurecki, Jaśkiewicz & Wdowski, 2014). A change in tyre pressure may cause a significant change in the shock absorber's damping efficiency index for a tested quarter of a vehicle (Kemzūraitė, Žuraulis & Więckowski, 2014; Stańczyk & Jurecki, 2014). In the case of changes in the vehicle's load, this is surprising as the devices measure the mass for each wheel (static pressure) before the measurement is carried out.

It was indicated in the literature (Bocheński, Lozia & Mikołajczuk, 1999) that the results obtained from this method very strongly depend also on the amplitude of the control plates. Changing the value of the plate's amplitude “peak-to-peak” (from 1 to 7 mm) caused a change in the damping efficiency determined on the device from 90% to 0%. The same shock absorber could then be considered as either being very good or extremely bad. This is an important conclusion, because devices with a plate amplitude range of 4–8 mm are available on the market.

Diagnostic tests should give a preliminary answer as to whether the shock absorbers installed in a vehicle are working or not (Lozia, 2000; Jaśkiewicz & Jurecki, 2017). Despite some simplifications in the methods used (Stańczyk & Jurecki, 2014), a positive or negative answer gives a general view on the technical condition of the shock absorbers. However, unlike typical scientific tests of shock absorbers carried out under strictly defined conditions, such diagnostic tests may be carried out under different environmental conditions and, depending on the validity period of the technical test, at a significantly different external temperature.

The aim of this paper is to analyse whether the date of the realization of this type of tests and weather conditions, especially temperature, can affect the obtained results. The answer to the question of whether identical shock absorbers subjected to tests in the winter (at low ambient temperatures) will show the same “efficiency” during a check in summer temperatures, as well as allowing any possible error to be determined and exclude the possibility of any manipulation aimed at the successful completion of the check-up.

Measurement methodology

Cars in Poland are subjected to periodic diagnostic testing, the scope of which is specified in numerous regulations. The main requirements are set out in the Regulation of the Minister of Infrastructure and

Development of 31 July 2015 item 776 on announcing the consolidated text of the Regulation of the Minister of Transport, Construction and Maritime Economy “on the scope and manner of conducting technical inspections of vehicles and drafts of documents used for such inspections” as amended in the years 2016, 2017 and 2018 (Announcement, 2015).

Appendix 1, section 5.3.2 of the Regulation, sets out the actions that must be taken by the diagnostician during the check-up of a vehicle's shock absorbers. In appendix 2, regarding the scope of additional technical inspection that are to be carried out, in point 1.2.1 the method of measuring the damping efficiency of suspension is determined.

Test results obtained by the EUSAMA method are inconsistent with the requirements when:

- 1) the degree of adhesion of the wheel to the plates, referred to as the Eusama Indicator Value (EV) is less than:
 - 15% for cars whose kerb weight does not exceed 900 kg,
 - 20% for cars whose kerb weight ranges from 900 to 1500 kg,
 - 25% for cars whose kerb weight is greater than 1500 kg;
- 2) the relative difference of the EV on the same car axle exceeds 30%, higher values on the axle is used how 100%;
- 3) the absolute value of the difference in the degree of wheel adhesion, EV, on the same axle is greater than 15%.

Conditions 2 and 3 apply when the degree of adhesion on the same axle exceeds 35%.

In this paper, the efficiency tests of shock absorbers were conducted on an SA640 Bosch Beissbarth Device presented in Figure 1.

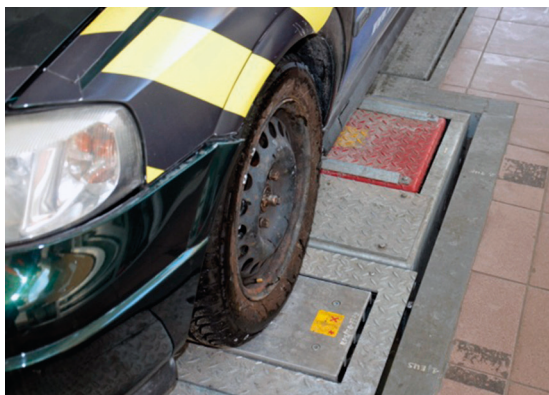


Figure 1. Control plates of the Beissbarth Bosch SA 640 test stand

The SA640 device uses a kinematic system which generates vibrations in the plates up to frequencies

of 25 Hz with a constant amplitude of 6 mm (Bosch, 2014). The starting process and visualization of the obtained results is possible through a computer control system shown in Figure 2.



Figure 2. Control system of the Bosch Beissbarth SA 640 test stand

When the wheels of the vehicle roll onto the measuring plates, the first step is to measure the static pressure of both wheels of the tested axle. Then, after the automatic start of the vibration excitation system, the tested system receives the appropriate frequency of vibration excitation (about 25 Hz). Then the kinematic force of the stand plates is switched off, the vibration is stopped and the pressure of each of the tested wheels and the frequency of the excitation as a function of time are continuously recorded until the wheels are stationary.

The measurement results are displayed on the display in real-time in the form of wheel pressure characteristics as a function of time. After completion of the test, a test report, presented in Figure 3, is generated for both axles.

The report contains the determined values of the minimum Eusama value (EV), also referred to as relative wheel adhesion for all the analysed wheels (yellow fields). The report also includes the resonant frequencies, in which they were determined (blue fields). They are a measure of the “stiffness” of the chassis and their value mainly depends on the characteristics of the elastic elements used in the suspension. Serially produced vehicles show resonant frequency values usually in the range of about 13 to 18 Hz (Bosch, 2014). Lower values indicate soft

BEISSBARTH PROTOKÓŁ URZĘDOWY KONTROLI POJAZDU L00000603

Dane urządzenia Numer homologacji Numer seryjny		Beissbarth GmbH SA600 935603346_01_E_0006860_		Wersja programu Następna kalibracja		TL V2.82/SL V3.30	
ciepły Transit				Dane pojazdu			
				Producent			
				Typ			
				Data rejestracji			
				Przebieg			
Numer klienta		L00000306		Numer podwozia		[REDACTED]	
Numer zamówienia		L00000603		Numer licencji		[REDACTED]	
Wyniki testu zawieszenia							
		po lewej	Przednia oś różnica	po prawej	po lewej	Tylna oś różnica	po prawej
Częstotliwość drgań		17 Hz	0 Hz	17 Hz	16 Hz	1 Hz	15 Hz
Przyczepność		77 %	12 %	68 %	34 %	18 %	28 %
Masa koła		712 kg		663 kg	517 kg		451 kg
Masa osi			1375 kg			968 kg	
Początek pomiaru	25.01.2019 12:19:49		Koniec pomiaru		25.01.2019 12:20:55		
Podsumowanie							
Test zawieszenia			Jest	Granica	Status		
Różnica przyczepności oś przednia			12 %	30 <= %	OK		
Różnica przyczepności oś tylna			18 %	30 <= %	OK *		
* Ocena zawieszenia							

Figure 3. View of the original generated basic report

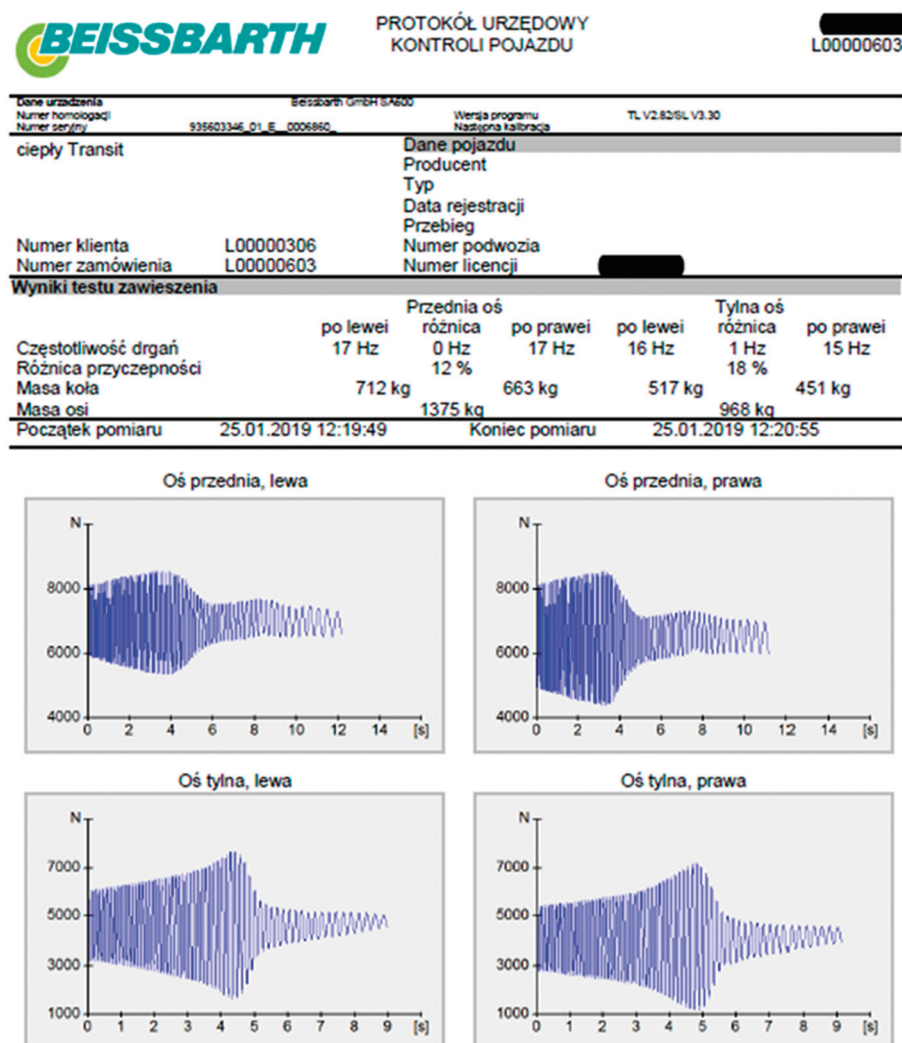


Figure 4. Progress of wheel pressure values on the measuring plates as a function of time on the original report

Wyniki testu zawieszenia

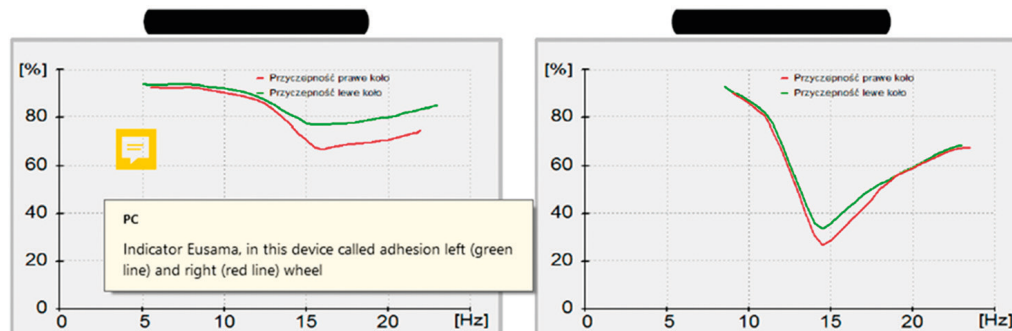


Figure 5. View of the expanded report

suspension – and higher values are usually found in sports vehicles. However, the difference in resonant frequency between the two sides should not exceed 3 Hz. The report also shows the values of the static load on each wheel of the tested axle (red fields).

The additional report (Figure 4) presents graphs of the changes in the wheel pressure force and the Eusama value (EV), also referred to as relative wheel adhesion as a function of the excitation frequency (Figure 5). Such additional presentation of the results provides the possibility of verifying the symmetry of the suspension and detecting any possible damage.

The Eusama value (EV), also known as the relative coefficient of wheel-surface contact, is calculated as the quotient of the minimum dynamic wheel pressure on the test plate and the static pressure measured before the measurement.

The tests were conducted on five vehicles with different kerb weights; the data for these vehicles is shown in Table 1.

Table 1. Data of the tested vehicles

Vehicle Number	Make	Model	Year of production	Weight kg
1	Opel	Astra G Kombi	1999	1220
2	Skoda	SuperB	2002	1520
3	Audi	A4 B7	2007	1630
4	Opel	Astra G	1999	1380
5	Ford	Transit	2013	2250

The damping efficiency tests of the shock absorbers were conducted for all the vehicles in two variants:

- 1) the vehicle was tested after 12 hours of being parked outdoors at an ambient temperature of

–5°C (Figure 5), so that all parts of the vehicle, including the shock absorbers, had a sufficiently low temperature;

- 2) the vehicle was tested after a 12-hour stay inside the laboratory hall, where the temperature was 20°C.

In the first case, a situation was simulated in which a test of the shock absorbers of the vehicle was realized e.g. in winter, when the outside temperature is considerably below zero. In the second case, a situation was simulated when the same vehicle was tested in summer, when ambient temperatures exceed 20°C.

The outdoor temperature was measured using the weather station shown in Figure 6, while the temperature control of the shock absorbers (suspension) was measured just before the test using a FLIR E53 thermal imaging camera using FLIR™ Tools software, shown in Figure 7.



Figure 6. Weather measuring station



Figure 7. View of a FLIR™ camera image

Test results

The efficiency tests of the shock absorbers were conducted for five different vehicles. The results of the tests conducted at temperatures of -5°C and 20°C are presented in Tables 2 and 3, respectively. The tables contain percentage values of the damping efficiency of the shock absorbers, EV, (determined by the Eusama method) in different conditions.

Table 2. Results of the effectiveness of the shock absorbers (EV) in the test conducted at a temperature of -5°C [%]

Vehicle number	Effectiveness of the shock absorbers (EV), %			
	Front axle wheels		Rear axle wheels	
	Left	Right	Left	Right
1	72	66	76	69
2	65	71	65	62
3	79	77	73	72
4	82	72	62	57
5	78	71	44	38

Table 3. Results of the effectiveness of the shock absorbers (EV) in the test conducted at a temperature of 20°C [%]

Vehicle number	Effectiveness of the shock absorbers (EV), %			
	Front axle wheels		Rear axle wheels	
	Left	Right	Left	Right
1	65	59	62	57
2	63	61	59	58
3	75	74	70	68
4	82	69	60	54
5	77	68	34	28

The changes in the value of the damping effectiveness of the shock absorbers, EV, for different conditions are presented in Table 4 and in Figure 3.

Figure 8 shows the value of the relative change in the coefficient determining the effectiveness of the shock absorbers (EV), where a value of 100% is the value obtained at 20°C .

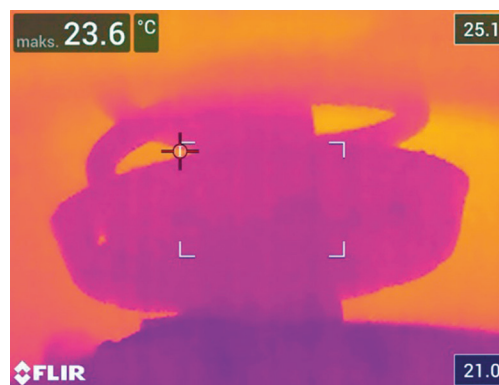


Table 4. Changing results of the damping effectiveness, EV, of the shock absorbers in tests conducted at temperatures of -5°C and 20°C [%]

Vehicle number	Difference of the effectiveness of the shock absorbers (EV), %			
	Front axle wheels		Rear axle wheels	
	Left	Right	Left	Right
1	7	7	14	12
2	2	10	6	4
3	4	3	3	4
4	0	3	2	3
5	1	3	10	10

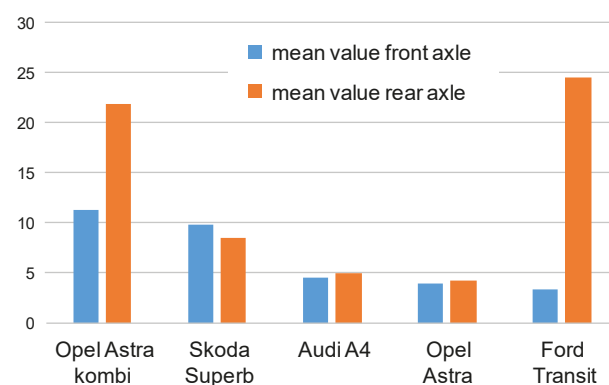


Figure 8. Relative change of EV

In the presented values of temperature it is easy to observe that the lower the temperature, the higher the value of the damping indicator of the shock absorbers, EV. In two of the tested vehicles, the relative change in the values of the effectiveness of the shock absorbers, EV, was very similar and almost unnoticeable, at a value of about 5%. In one case these differences were not much bigger – up to about 10%. In two vehicles, especially for the rear axles, the relative change of the effectiveness of the shock absorbers, EV, exceeded 20%.

Conclusions

From the results in the literature, it can be seen that the value of the damping effectiveness indicator of shock absorbers measured with the Eusama method (EV – Eusama Value) depends on several factors.

Hydraulic or hydraulic-gas shock absorbers used in a vehicle contain oil inside the casing, the physical properties of which, e.g. viscosity, can change significantly at lower temperatures.

As the test shows, the outside temperature can have a small influence on the values of the effectiveness of a vehicle's shock absorbers, as measured by a device using the Eusama Method. When the same car is tested using this device in higher temperatures, the values of the EV damping indicator of its shock absorbers do not decrease significantly. In some cases the relative increase of the damping effectiveness of the shock absorbers EV might even reach a value of 20.

On the basis of the tests conducted in this paper, a relatively small, but noticeable influence of the external temperature on the possible outcome of a diagnostic test has been indicated. In Poland's climatic zone, external temperatures below -5°C are not unusual. Thus, in the case of the inspected vehicles (after a long period of downtime), there may be a slight distortion of the results during low-temperature periods. It should be noted that even lower temperatures are common, usually from December to February, even reaching below -20°C . In such low temperatures, these differences can be even greater. In such cases, the display values of the device may over read slightly.

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Assessing the external costs of urban transport investments: a socioeconomic analysis

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Key words: urban management, investment management, urban transport, external costs of transport, sustainable transport, SCBA

Abstract

Transport is a considerable source of pollution in cities. The social impacts of transport activities result from emissions of pollutants, greenhouse gases, and noise, as well as traffic accidents. Not every urban investment that reduces such 'external' effects of transport will be found acceptable by the public. In order to assess and communicate the social impacts of investments, it is necessary to calculate external costs appropriately. This article discusses issues with estimating the social costs and benefits of transport-related investments in cities. The article also provides a classification of social benefits from urban transport investments and proposes a general methodology for estimating such benefits. Due to the versatility of urban investments, there can be no single, universal method. The article proposes methods for analysing social costs and benefits on the basis of two sample urban investments.

Introduction

Along with the residential sector, transport is a major source of pollution in cities. For example, in Warsaw transport is responsible for 60% of total emissions of PM₁₀ and 50% of nitrogen oxide emissions (Badyda and Kraszewski, 2010). For many people, the quality of transport (type of transport, level of congestion, and public availability) is a decisive factor in choosing a place to live. The management of urban (freight, individual, or public) transport is the responsibility of city authorities. In strategic terms, management requires appropriate planning and then implementation (often very costly) of investments in transport infrastructure and means. City authorities may obtain European funds for such projects. However, first they have to prove that the investment, which may even be unprofitable in financial terms, will benefit inhabitants. Such benefits, referred to as social benefits, must be quantified in monetary units. To that end, it

is necessary to carry out a Social Cost Benefit Analysis (SCBA). This is a particularly challenging task as, in the case of urban investments, it is difficult to estimate or forecast actual numbers of passenger- or tonne-kilometres. This article will discuss issues connected with estimating social costs and benefits of transport-related investments in cities. The article also provides a classification of social benefits from urban transport investments and proposes a general methodology for estimating such benefits. Due to the versatility of implemented urban investments, there is no single, universal method. The article proposes methods for analysing the social costs and benefits of two urban investments specifically: replacement of an urban public transport fleet and construction of a consolidation centre.

The literature review

Each kind of transport activity generates both benefits and costs. While the benefits are provided

mainly to the people who pay for the transport, some costs are incurred by others or by the society as a whole. Therefore, transport costs may be categorised as ‘internal’ or ‘private’ – those incurred by persons engaged in the transport activity – or so-called ‘external costs’ (COM, 1995) (Table 1).

Internal costs incurred by transport participants include the costs of vehicle maintenance and depreciation, costs to the driver’s time and safety, and internalised portions of external costs, i.e. the costs of environmental pollution or greenhouse gases emissions, which are covered by the public tax system. Internal costs also include the very important cost of accessing infrastructure, which may account for as much as 60% of internal costs (Lima and Venables, 2000a). Internal costs are the most fundamental factor in transport competition, which affects demand for transport and selection of transport routes. Lima and Venables note that an increase in transport costs by 10% leads to a decrease in transport volume by 20% (2000b).

Another group of costs is comprised of external costs arising from transport activities but not transferred to the user via the market (Bağ, 2009). These result from greenhouse gases and pollutants emissions, noise, road accidents, and congestion

(Janic, 2007). These also include the costs of planning, construction, maintenance, administration, and operation of the transport infrastructure, which are not accounted for in charges and taxes (Saighani and Sommer, 2019). The effect of external costs on the society is presented in Table 2.

Greenhouse gas emissions have important global impacts, regardless of their place-of-origin (Althor, Watson, and Fuller, 2016). As opposed to greenhouse gases, pollutant emissions depend on the kind of transport as well as the time and place of their production. The social costs of emissions originating in peak hours in city centres are different from the social costs of emissions produced on motorways in rural areas. The costs of noise, similarly to the costs of pollution, depend on their place of origin, and additionally on the time of day when they are produced (Jochem, Doll, and Fichtner, 2016). The same level of noise made by a vehicle passing at night has a different effect on humans than it would during the day. Congestion is the external cost most difficult to measure as it is connected with many factors, i.e. longer travel times, greater costs in vehicle maintenance, the costs of delays, and ensuing decreases in transport operations reliability (COM, 1995). Congestion levels depend on types of infrastructure,

Table 1. Cost categories (COM, 1995)

Cost categories	Costs	
	internal	external
Transport Expenditures	fuel and vehicle costs; tickets/fares	costs paid by others (e.g. provision of free parking)
Infrastructure Costs	user charges, vehicle taxes and fuel excises	uncovered infrastructure costs
Accident Costs	costs covered by insurance, personal accident costs	uncovered accident costs (e.g. pain and suffering imposed on others)
Environmental Costs	personal drawbacks	uncovered environmental costs (e.g. noise disturbance to others)
Congestion Costs	personal time costs	delays/time costs imposed on others

Table 2. Effects of social costs (Bağ, 2009)

s/n	Categories of social costs	Social effects
1	Greenhouse gases	global warming, glacial ice melting, floods, hurricanes, droughts, sea level rising, changes in sea current circulation
2	Pollutants, i.e. NO _x , SO _x , Nm-Voc	acid rains, pulmonary and circulatory diseases, cancer, decreased crops
3	Solid pollutants, i.e. particulate matter (PM ₁₀ , PM _{2.5})	irritation of eyes, skin and airways, pneumoconiosis, allergies and poisonings
4	Noise	loss of hearing, raised stress levels, raised blood pressure, hormonal changes, reduced satisfaction with leisure activities, discomfort during rest, sleep disorders, headaches
5	Traffic accidents	deaths and disabilities of persons involved in accidents, costs of rescuing and rehabilitating the injured, costs of emergency services, production losses, losses of expenditures invested e.g. in education
6	Congestion	extended travel times, increased costs of vehicle operation and maintenance, costs connected with vehicle depreciation and employment, deterioration of service reliability as a result of delays

their capacities, and traffic levels. Some costs of traffic accidents are partially internalised in the costs of motor insurance while others still constitute external costs. In addition to the typically social impact of traffic accident casualties, which is difficult to express in monetary terms, traffic accidents also generate costs related to rescuing and rehabilitating people injured in accidents, and maintaining emergency services, such as police, ambulance, and fire services.

Internalisation of external costs of transport is one aspect of the sustainable development of transport (Kotowska, Pyza & Sivets, 2014). It is also one of the major priorities of the EU's transport policy. Internalisation of external costs aims at making transport users pay the costs of all effects of transport, in other words, it is aimed at transforming all external costs into internal costs (COM, 1995). However, the question of how to estimate all such costs is problematic.

Since the onset of the 21st century, many publications have attempted to estimate the external costs of transport, i.e. (RECORDIT, 2003; UNITE, 2003; Schreyer et al., 2004; Holland et al., 2005; HEATCO, 2006; TREMOVE, 2006; Maibach et al., 2007; EX-TERMIS, 2008; Korzhenevych et al., 2014). In 2016, the Centre for EU Transport Projects published precisely estimated external costs of road transport, for the needs of transport investment projects implemented with the support of EU funds, in *Vademecum Beneficjenta* (Archutowska et al., 2016), which refers to the aforementioned publications to a large extent, in particular to Korzhenevych et al. As opposed to the estimates of other publications, this document's calculations take into account the kind of vehicle, its Euro standard, and the cost centre, and therefore seems suitable for estimating the external costs of urban investments. Thus the aforementioned document is the basis of the method provided in this paper for estimating external costs of transport.

Social benefits of urban transport investments

Organisation of urban transport is a complex process. Urban transport includes urban freight transport, public transport systems, and individual transport. Investment projects implemented within cities may be divided into three groups:

- investments in the generally accessible linear and point infrastructure, i.e. traffic arteries in cities, facilities for EV charging, Park&Ride and

Bike&Ride systems, vehicle monitoring systems (e.g. in limited traffic zones), and intelligent transports systems (ITS);

- investments in infrastructure dedicated to specific forms of transport in cities, e.g. dedicated priority lanes for public transport, shared bus and tram stops, cycling paths, and unloading bays;
- investments in means of transport – e.g. low-emission vehicles and electric vehicles.

Such investments do not bring direct benefits to the investors (their Financial Net Present Value is negative). However, they generate social benefits by decreasing the external costs of transport. Therefore, they may be subsidised with European Union funds. The prerequisite for obtaining a grant is an economic analysis which additionally accounts for estimated social benefits (the Economic Net Present Value is positive) (Figure 1).

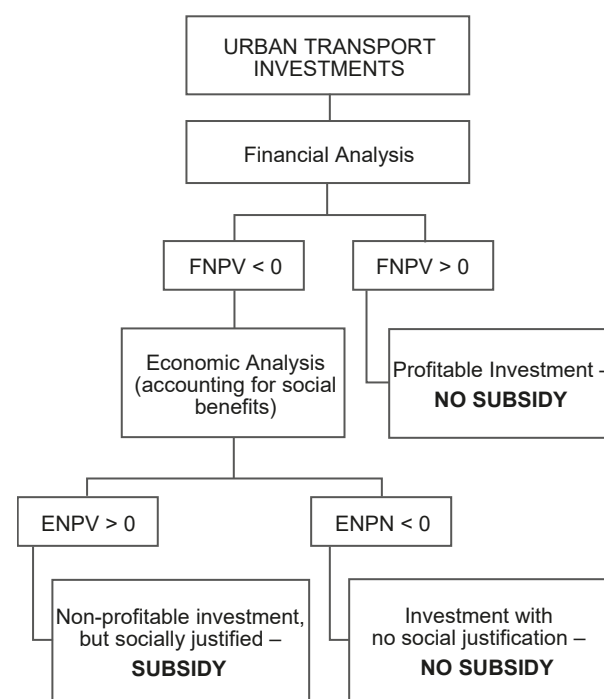


Figure 1. Diagram of the procedure of obtaining EU grants (based on (Jaspers, 2015))

General assumptions of the analysis

The social benefits of introducing particular solutions in urban transport result from a reduction in external costs upon completion of the given investment. Thus, measurable social benefits (B) can be seen as the difference between external costs generated before C_b and after C_a introduction of a given solution.

$$B = C_b - C_a \quad (1)$$

The most important external costs of urban transport include environmental pollution, climate changes, traffic accidents, congestion, and noise. In most cases, social benefits come from two things:

- reduced unit costs;
This happens in with solutions such as purchasing low-emission vehicles, introducing low emissions zones, and establishing bus-only lanes.
- reduced numbers of passenger- or tonne-kilometres;
This happens in the case of solutions applying to, e.g., the traveling salesman problem. They are exemplified by solutions such as establishing urban consolidation centres and using public transport to make deliveries within an urban area.

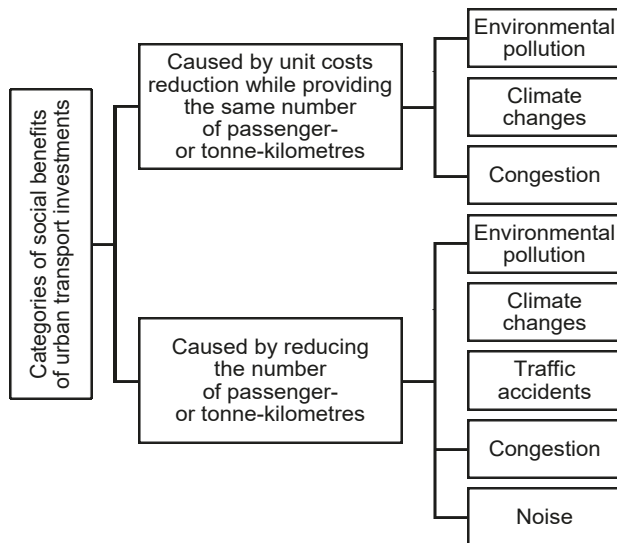


Figure 2. Categories of social benefits of urban transport investments

Assigning the analysed investment to one of the two major categories is the first step to be completed, before assessing social benefits and costs (Figure 2).

Selected examples of estimated social benefits from urban transport investments

Purchase of low-emission buses

It is relatively easy to specify the social benefits of purchasing low-emission buses. The greatest benefit is a reduction in pollutant emissions B_{pe} , which may be estimated in the following way:

$$B_{pe} = \sum_{i=1}^n CPE_i \cdot (N_i - N'_i) \cdot MD \quad (2)$$

where:

CPE_i – unit costs of pollutant emissions by a vehicle with Euro standard i [EUR/vehicle-kilometre],

n – number of analysed Euro standards, $n = 7$ for Euro 0 – Euro 6,

N_i – number of analysed Euro i standards vehicles before implementing the investment,

N'_i – number of analysed Euro i standards vehicles after implementing the investment,

MD – mean distance covered by the vehicle.

The climate change costs are directly proportional to the level of fuel consumption of the vehicle. Newer vehicles, with improved emission standards, consume less fuel. Similarly to the case of environmental pollution, the benefits of reducing the external costs of climate change B_{cc} by replacing the vehicle fleet may be formulated as follows:

$$B_{cc} = \sum_{i=1}^n CCC_i \cdot (N_i - N'_i) \cdot MD \quad (3)$$

where:

CCC_i – unit costs of climate change generated by a vehicle with Euro standard i [EUR/vehicle-kilometre],

N_i, N'_i, MD – as above.

In this case, the costs of noise, traffic accidents, and congestion do not change.

Construction of a consolidation centre

A consolidation centre is a warehouse where smaller consignments are combined into larger cargoes. This makes it possible to deliver them using fewer vehicles, which leads to reducing the number of tonne-kilometres (Pfohl 2001). The key external effect of constructing a consolidation centre will be reductions in pollution and greenhouse gas emissions as a result of decreasing numbers of tonne-kilometres. Moreover, other external costs will also go down: traffic accidents, congestion, and noise.

The benefits of reducing pollutant emissions, in terms of decreased numbers of vehicle-kilometres, may be computed with the formulas:

$$B_{pe} = CPE_{mu} \cdot (VKM - VKM') \quad (4)$$

$$CPE_{mu} = \frac{\sum_{i=1}^n CPE_i \cdot N_i}{N} \quad (5)$$

$$VKM = N \cdot MD \quad (6)$$

$$VKM' = N' \cdot MD' \quad (7)$$

where:

CPE_{mu} – mean unit cost of pollutant emissions generated by vehicles serving the warehouse [EUR/vehicle-kilometre],

- VKM – number of vehicle-kilometres before implementing the investment,
 VKM' – estimated number of vehicle-kilometres after implementing the investment,
 MD' – mean distance covered by a vehicle after implementing the investment,
 MD, N_i – as above,
 N – number of vehicles serving the warehouse before implementing the investment,
 N' – number of vehicles serving the warehouse after implementing the investment.

The benefits of decreasing greenhouse gases emissions may be formulated as follows:

$$B_{CC} = CCC_{mu} \cdot (VKM - VKM') \quad (8)$$

$$CCC_{mu} = \frac{\sum_{i=1}^n CCC_i \cdot N_i}{N} \quad (9)$$

where:

CCC_{mu} – mean unit cost of greenhouse gas emissions by vehicles serving the warehouse [EUR/vehicle-kilometre],

VKM, VKM', N_i , N , CCC_i – as above.

Reducing the number of tonne-kilometres will also lead to fewer traffic accidents B_{ac} , congestion B_{con} , and noise B_n . These can be formulated as follows:

$$B_{ac} = C_{ac,j} \cdot (VKM - VKM') \quad (10)$$

$$B_{con} = C_{con} \cdot (VKM - VKM') \quad (11)$$

$$B_n = C_n \cdot (VKM - VKM') \quad (12)$$

where:

C_{con} – unit costs of congestion [EUR/vehicle-kilometre],

$C_{ac,j}$ – unit marginal costs of traffic accidents [EUR/vehicle-kilometre] in country j ,

C_n – unit costs of noise [EUR/vehicle-kilometre].

The calculation of external costs requires detailed identification of the numbers and structures of vehicles entering a given area, specifying their kinds, carrying capacities, and Euro standards. The data may be gathered via primary research (e.g. counting the numbers of vehicles entering and leaving any given area, taking into account their kinds, carrying capacities, and Euro standards, or surveys). Should there be no possibility of conducting precise primary research, it is possible to use secondary data gathered by motor vehicle departments or statistical services with regard to, e.g., the kinds and structures of vehicles registered in a given region.

Another factor necessary for specifying the external costs of transport is the mean carriage distance. Due to lacks of data, this is one of the most challenging estimates to make. It is possible to do so by identifying representative routes as bases for the mean carriage distance in a particular area. In the cases of activities aimed at restricting vehicle access in a given area, the mean carriage distance may be estimated using the following formula:

$$MD = 2 \cdot \sqrt{\frac{S}{\pi}} \quad (13)$$

where:

S – the area covered by the restriction [m^2].

As external costs differ from country to country, they must be estimated on a country by country basis, taking into account purchasing power parity. The last stage in the estimate is adjusting the cost by a nation's GDP increase for the year of the analysis.

Conclusions

Urban transport investments benefit city inhabitants. Whether they are addressed to passengers of public or private transport or to transport companies that make deliveries in cities, they aim at reducing the harmful effects of transport on city inhabitants, and on our planet. The measures may be divided into two groups. The first is comprised of measures taken to reduce urban traffic (reduce the number of passenger- or tonne-kilometres); the other includes measures taken to streamline traffic in a city, thus reducing its negative impacts on quality of life for city inhabitants. Estimating the social benefits of implementing urban transport investments is a relatively demanding task. The difficulties stem mainly from lack of knowledge about both current and future traffic flows. The proposed methodology, applying the latest tools, such as the Ricardo-AEA study recommended by the European Commission, may be adapted for any analysis of the social benefits and costs of urban investment projects.

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The current state of inland navigation in Poland and its future development under European Union transport policy

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Key words: inland waterways, inland shipping, rivers, inland transport, European Union, development

Abstract

This article presents the activities of the European Union (EU) and Poland to develop inland waterways as an environmentally-friendly transport method. The paper presents positive aspects of transferring part of the load from other methods of transport, such as railways or cars, to inland vessels. It shows the level of development of inland navigation in the EU and indicates favorable natural conditions for doing so. The article addresses the issues of the insufficient state of waterway infrastructure in Poland and presents measures to improve it. It also identifies the main EU and government programs seeking to standardize a common transport space of the EU by developing inland navigation.

Introduction

Inland waterway shipping is used to transport cargo with vessels such as riverboats, barges, and pushing sets within small inland water reservoirs, such as rivers, canals, and lakes. These vessels are propelled by both water currents and their own propulsion systems. The inland waterway transport fleet is characterized by a high loading capacity, which means that a single trip can deliver a large amount of goods. The largest permissible units moving on rivers can take on board more than 500 TEU, which corresponds to the capacity of the same number of

trucks, assuming that one vehicle carries one 20 ft container (VBW, 2011). Inland waterway transport is one of the most environmentally friendly types of transportation because one liter of fuel can be used to ship 127 tons of goods over a distance of 1 km; when it comes to rail transport, 97 tons can be transported, and road vehicles can transport merely 50 t (White Paper, 2001). Figure 1 shows the effectiveness of various means of transport.

In the era of reducing emissions of harmful compounds into the atmosphere, its low energy consumption gives inland waterway transport a unique advantage. Figure 2 compares the amount of CO₂ emitted by individual transport methods. European Union (EU) transport policy strives for optimal and sustainable use of various transport modes in order to minimize negative environmental impacts. The effect of this is to promote inland waterway shipping as an environmentally friendly transport method due to its relatively low energy consumption, and thus low emission of harmful substances into the atmosphere. Additionally, it enables the elimination of traffic congestion as a result of transferring transport from motor vehicles to river methods of transportation.

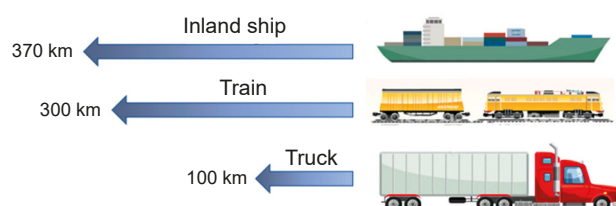


Figure 1. The distance for shipping one ton of cargo by various means of transport with the same energy input (Umweltbundesamt, 2012)

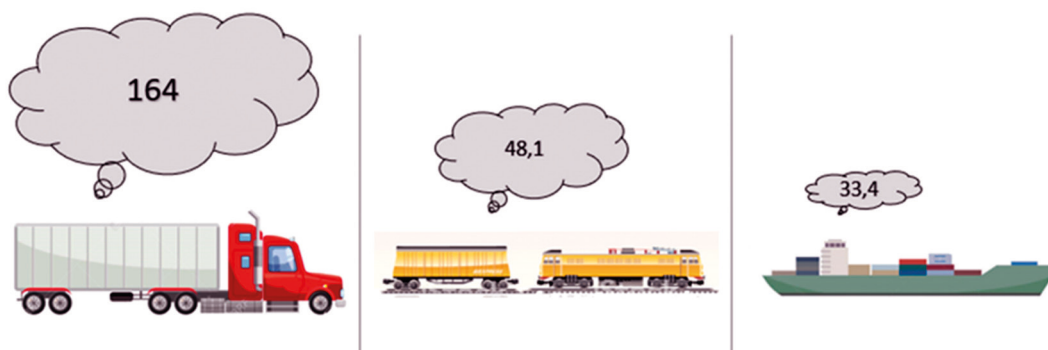


Figure 2. Carbon dioxide emissions released by the different means of transport in gr/tkm (Umweltbundesamt, 2012)

All these factors reduce external transport-related costs borne by society (White Paper, 2011).

Due to their natural occurrence, the density of river routes is much lower than that of circular roads, which are based on an artificially-prepared roads, which allows the delivery of goods to the door of every potential customer. For this reason, the location of investments such as logistics centers, warehouses, factories, etc. may be located away from waterways because road transport is already so well-developed that it does not generate problems in the delivery of cargo. However, one should look at the original history in which river transport generated economic development. In regions where these natural roads existed, civilizations developed, along with goods exchange and transport. Water transport has been, and still is, an important element of the transport system because it is capable of moving large amounts of cargo which boosts trade. It can be seen that the majority of large agglomeration centers in Poland, Europe, and around the world are located in the basins of the main rivers, where ports and logistics centers are located (Skupień, Kuciaba & Gąsior, 2016).

Inland waterway shipping in the EU

Inland waterways shipping despite its enormous potential encountered on its way a serious barrier in the form of changes in transport demand. After World War II, the European economy was focused on a massive reconstruction; to achieve this, the rapid transport of large amounts of metal ores and industrial and mining goods was required, which was carried out mainly by inland waterways. Changes in customers' needs and demands were observed in the early 1980s. In most EU Member States, the structure of shipping changed from a large share of bulk to highly-processed goods, and this directly affected the change in demand for transport services.

Consumer demands have increased, and it has become standard to provide goods in a door-to-door manner. Due to the natural disposition and the vulnerability of transport, this is typically performed by roads. This increased demand resulted in a higher number of vehicles and gradually led to road congestion and transport overload. In addition, this also increased the pollution emitted by motor vehicles into the atmosphere. The result of the growth in demand for car transport is also an increased intensity of noise nuisances and a higher number of road accidents. The above-mentioned factors make up the external costs of transport, which are borne by society.

The goal of EU policy is to create a coherent, interoperable, and multimodal transport network with uniform, highly technical parameters. In a document that is an integral part of transport policy, called the White Paper of Transport from 2011, the European Commission developed a plan to create a single European transport area, whose main element is the network of basic trans-European transport corridors, the so-called AWNING. It is assumed that these corridors will allow efficient and low-emission transport of large, consolidated quantities of goods and passengers due to the widespread use of more efficient multimodal means of transport and advanced technologies. In addition, intelligent transport systems are also an integral component of the TEN-T network, the implementation of which contributes to improving network capacity, traffic safety, and reducing environmental pollution caused by transport. In 2013, the layout of the network of corridors passing through the territory of EU Member States was established. This system covers the core network, which is the basis for developing the transport network, on which EU activities are focused. In particular, this includes cross-border sections, missing links, multimodal connections, major bottlenecks, and a comprehensive network, ensuring

accessibility and connectivity of all regions of the Union. According to the assumptions, the development of the core network should focus on constructing missing connections, modernization of existing infrastructure, construction of multimodal terminals in sea and river ports, and on the creation of urban logistics consolidation centers (European Commission, 2013).

The TEN-T network includes river transport corridors, which are natural routes between major economic centers of Europe, which are incidentally the main transport routes. Unfortunately, over the years, they have lost their importance to other modes of transport. Some sections of the river trans-European transport corridors do not even meet international swimming standards. This means a huge backlog of others and the need to meet these standards. Therefore, the European Commission has taken thorough measures to promote and develop inland navigation so that it can meet the current requirements and is also compatible with other transport modes. Maintaining the position of inland waterway transport market requires a lot of work, especially in countries where it is neglected despite an attractive density of waterways. This is mainly the result of different waterway transport systems in individual European countries, which is reflected in diversified investment in their development (Skupień, Kuciaba & Gąsior, 2016). The share of inland navigation in turnover by mode of transport in the EU is only 0.5%. The Netherlands has the largest share of this transport – 3.28%. Poland ranks 18th with a 0.19% commitment. The density of inland waterways in the Netherlands is 150.7 km / 1000 km² and in Poland is 11.6 km / 1000 km². The EU average is 9.3 km / 1000 km² (Bawelska, Brzezińska & Radlińska, 2018). In addition, taking into account that the least ecological means of transport are motor vehicles, the share of road transport in the EU is 31.78% and in Poland is as much as 60% which is the highest in Europe (European Commission, 2018). In this situation, the works involving the inclusion of a waterway in support of new cargo and transport relations through the development of combined transport and the inclusion of inland navigation in the development of coastal transport. Transferring part of car transport to inland waterway shipping would significantly decrease the environmental problems facing the EU.

EU policy aimed at sustainable development focuses primarily on the effective use of resources, reducing carbon emissions, and reducing the consumption of non-renewable fuels. This is reflected in the adoption by the EU in 2007 of the “3 × 20”

package, which is committed to reducing greenhouse gas emissions by 20% from their 1990 levels, improve energy efficiency by 20%, and also increase the share of renewable energy sources by 20% (Ministry of the Environment, 2016). The next step in 2014 was to further reduce greenhouse gas emissions by 40% by 2030. The EU expanded its horizons and to consider the future of the 2016 Paris Agreement, and undertook actions to reduce carbon dioxide emissions by at least 60% by 2050. This is directly linked with the need to take action, especially in the transport sector, as it accounts for 24.3% of total greenhouse gas emissions in the EU. It is also the only area of the EU economy in which there has been an increase in greenhouse gas emissions (European Commission, 2016).

The effects of the promotion of inland waterway transport can be observed in EU countries where this type of transport, compared to other modes of transport, is used to a similar extent, primarily due to low pollution, low noise, and low energy consumption. In addition, linear river transport infrastructure does not require additional attachment sites, as in other types of transport, since waterways mostly result from the natural terrain (Świerczewska-Pietras, 2018). The average density of the network of waterways in the EU is 9.3 km / 1000 km². The highest waterway network densities are: the Netherlands (150.7 km / 1000 km²), Belgium (49.7 km / 1000 km²), Finland (24 km / 1000 km²), Germany (21.5 km / 1000 km²), Hungary (20 km / 1000 km²), and Luxembourg (14.3 km / 1000 km²). The waterway density in Poland is not bad and exceeds the European average with 11.6 km / 1000 km² of navigable waterways (Bawelska, Brzezińska & Radlińska, 2018). Table 1 summarizes the above results. This density also translates into a share of inland waterway transport to operate across the EU. According to statistical data published by Eurostat, the Netherlands has the largest share of river transport in terms of transport performance in km compared to other Member States – 43.1%, followed by Romania 29.7%, Bulgaria 26.6%, Belgium 15.6%, and Germany with less than 9%. Most EU Member States have a negligible share of this transport sector in their transport (European Commission, 2017). Such a result may depend on the geographical location of the above-mentioned countries, because their main European rivers, such as the Rhine or the Danube, run through their territory and eventually connect with seaports. This is an important point in the development of this transport sector because the change in demand from bulk and general cargo for

Table 1. The network density and length of inland waterways of selected EU countries in 2016 (Bawelska, Brzezińska & Radlińska, 2018, p. 9)

	AT	BE	BG	CZ	FI	FR	NL	LU	DE	EN	RO	HU	UK	IT
Length (km)	351	1516	470	720	8136	4733	6257	37	7675	3655	1779	1864	1050	1562
Road density (km / 1000 km ²)	4.2	49.7	4.2	9.1	24	7.5	150.7	14.3	21.5	11.7	7.5	20	4.3	5.2

container handling determines their further development and allows them to maintain their market position.

In order to increase the popularity of inland waterways, the EU, through its transport policy included in White Papers, introduced programs and development funds. For inland navigation, the essential development program is NAIADES – carried out in two stages in 2006–2013 and 2014–2020; for research and development, there is the HORIZON 2020 program. The main objectives of the NAIADES program are (Załoga, 2017) to:

- increase inland waterway transport,
- modernize river fleets,
- improve waterway infrastructure,
- improve the quality of service,
- reduce environmental emissions,
- reduce barriers to work,
- integrate inland waterway transport as part of multimodal logistic chains.

Some of the points listed above have already been implemented using financial instruments such as Marco Polo or the TEN-T. The current source of funding for the development of inland navigation may be implemented under the Cohesion Fund or the European Fund for Strategic Investment. The total value of the grant of the aforementioned funds is over 47 billion euros (European Commission, 2015). Examples of actions taken by EU Member States to promote inland waterway transport (Załoga, 2017) include:

- the use of low-emission engines, energy-saving investments,
- training of personnel for inland navigation,
- development of transport and combined transport terminals
- the provision of infrastructure and suprastructure,
- city logistics (waste management using barges),
- exemption from fuel excise tax,
- an industry shift to inland waterways.

Inland waterway state sector in Poland

Polish inland waterways, compared with those of the EU, are unfortunately barely significant. The Polish Statistics Report shows that all modes of

transport carried a total of 2,053.3 million tons of goods in 2017, of which only 5778 thousand tons were transported by inland waterways. This means that the share of this transport mode is less than 0.3%. The total transport work done in the amount of 434.9 billion tons – including inland waterways shipping in the size of 877 million ton-km, represents only 0.2% of the total (Statistical Office, 2018). Such a low marginal result reflects the importance of this mode of transport in the Polish transport system. The main reason for the low amount of inland waterways in Poland is the lack of maintenance and development of such. In addition, Polish rivers have a high seasonality, causing them to have a rain-snow regime, as they are supplied mainly from rain and spring thaws. As a result, during the year there are periods of very low and high water levels, and there is a small number of reservoirs. Another factor hindering natural navigation is the freezing of water in rivers, which determines the need to have in its fleet the icebreakers and ice-classed vessels (Piasiecki, Poloma & Skowron, 2015). In order to solve or eliminate problems caused by natural factors, actions should be taken to regulate river beds using existing infrastructure and building new hydrotechnical infrastructure. Figure 3 presents the remains of hydrotechnical infrastructure which was in constant use in the nineteenth century. Unfortunately, due to changes in demand and transport needs, these are



Figure 3. Unused lock in the Lower Oder Valley Landscape Park

neglected and are now part of a Landscape Park. Activation and modernization of old technologies already present on Polish rivers could increase their capacity, which would translate into increased interest in inland navigation and broaden its use. However, this is not an easy task because it requires significant modernization, deepening, environmental, and other works that require significant time and financial expenditures.

Insufficient development of inland waterways in Poland, in terms of their shipping performance, especially mucus dimensions, the depth and width of trails, reservoirs, and bridges affects the amount of shipping, which in turn determines its marginal importance in the Polish transport system. The state of the Polish inland fleet is also important because the poor technical condition of inland waterways means unprofitable investments in new means of transport. Statistical data published in Poland from 2018 shows that the greater part of the fleet has depreciated and requires repairs or replacement. The age of the river vessels exceeds the average lifetime because almost all barges and pushers of more than 72% were produced in 1949–1979. The lack of investment in new river transport modes has a detrimental effect on the environment, and also on the attractiveness of Polish shipowners. A reflection of this can be seen in statistical studies that state that, in 2017, inland shipping transported 5,777.5 thousand tons of cargo with a total transport performance of 877.3 million tkm, which is only 0.5% of the total weight and work done with all modes of transport in Poland (Bawelska, Brzezińska & Radlińska, 2018). The lack of appropriate works and investment behaves like a vicious circle in which, if the state of the river infrastructure is inadequate, fewer shipowners are interested in its operation, which causes less traffic on the rivers, which in turn leads to less maintenance work because this infrastructure is not used. The lack of infrastructure and shipowners also creates a lack of customers willing to transport their products by river. Therefore, there is a low demand that will not cover even the fixed costs of vessels.

The effects of years of neglect are best presented by comparing the condition of Polish river roads with European standards. According to the European Agreement on Main Inland Waterways of International Importance (AGN), which Poland signed March 6, 2017, the only routes having at least class IV navigability are considered to be international, as they allow for the operation of vessels of more than 1000 t. Table 2 shows the distribution of inland waterways navigable by size in Poland.

Table 2. Structure of inland waterways in Poland (Bawelska, Brzezińska & Radlińska, 2018)

Type of inland waterway	Inland waterway class	Length (km)	Participation in total
Total		3653.5	100%
Considered navigable waterways	Ia	1079.9	thirty%
	Ib	892.9	24%
	II	1070	29%
	III	396.6	11%
	IV	37.5	1%
	Va	55	2%
	Vb	121.6	3%

According to statistics, Poland has less than 3654 km of inland waterways, of which 2417 km are regulated navigable rivers, 644 km are canalized river stretches, 335 km of canals, and 259 km of navigable lakes. Of these, only 6% of their length (214.1 kilometers) satisfies the parameters necessary for modern navigation with minimum shipping and class IV (Bawelska, Brzezińska & Radlińska, 2018):

- Wisła from the Przemsza estuary to link with the Łączyński Canal – 37.5 km (Class IV),
- Wisła up to Płock – 55 km (Class V a),
- Martwa Wisła – 11.5 km (Class V b),
- Lake Dąbie up to the frontier with internal sea waters – 9.5 km (Class V b),
- Odra from the Ognica village to Klucz-Ustowo and continue to Regalica to the estuary of Lake Dąbie – 44.6 km (Class V b),
- Western Odra – 36.3 km (Class V b),
- River Parnica and Parnicki Piercing from Western Odra to a border with internal sea waters – 6.9 km (Class V b).

Such a small number of waterway sections with international parameters does not allow full use of whole transport even on a single river. Importantly, in the AGN agreement stands that 3 international inland waterways run through Polish territory (Bawelska, Brzezińska & Radlińska, 2018):

- E 30 – connecting the Baltic Sea with the Danube in Bratislava, including Odra from Świnoujście to the border with the Czech Republic;
- E 40 – connecting the Baltic Sea in Gdansk With the Dnieper in the Chernobyl area and continuing to the Black Sea, including in the Polish Wisła from Gdansk to Warsaw, the Narew and the Bug to Brest;
- E 70 – connecting the Netherlands, Lithuania, and Russia, and including Polish territory of the Odra

River from Havela canal to Warta's estuary in Kostrzyn, the Wisla-Odra waterway, and starting in Bydgoszcz Lower Wisla and Szkarpa.

Analyzing the above waterway sections that run through Polish territory, it may be noticed that the vast majority have not yet been adapted to international standards, which will require large investments in this area. Additionally, in the face of tightening regulations regarding the emission of harmful substances into the atmosphere by EU countries, Poland should make every effort to make transport more environmentally friendly. That is why actions to adapt the river road network to international standards are so important; this will result in an increase in traffic in the inland transport sector, and this involves the transfer of some transport from road to river.

Covering Polish rivers with the TEN-T network is also an opportunity for the development of river transport in Poland. A particularly important element of the Polish TEN-T network is the Oder Waterway because it is directly connected with the European inland waterway network that connects Scandinavian countries with Central Europe. Importantly, the EU indicates that the TEN-T core network corridors should have infrastructure for three transport branches, i.e. rail, road, and inland waterways. Economic and logistics centers are developing along the Oder, which would significantly relieve road transport due to the volume of demand for river transport. The construction of multimodal terminals next to the river, located near economic centers, would allow the use of many means of transport. This will result in the development of river ports and thus the development of regions; however, inclusion in this network is associated with the need to adapt river roads to international standards. In the case of Poland, this is crucial because, as indicated above, Polish river roads only have a navigability class that allows 5% international shipping service. This does not mean, however, that they have fully adapted to this. River waterways inscribed in the TEN-T corridor network are covered by EU standards, which means there is a need to adapt Polish river roads to these standards. Thus, there is an urgent need to undertake many modernization works in this area. This is a huge opportunity for development, especially for the regions through which the TEN-T river corridor network passes. Importantly, this will allow the transfer of many tons of loads from roads to river routes, which will ultimately translate into a reduction in road congestion and external transport costs.

Development perspectives of Polish inland shipping

In 2016, the Council of Ministers adopted Resolution No. 79 on the adoption of "Assumptions for the plans for the development of inland waterways in Poland for 2016–2020 with a perspective by 2030". It is a strategic document that defines the necessary actions for water transport development in Poland. It sets the main four priorities for the investments planned at that time, which include (Resolution, 2016):

- PRIORITY I – refers to the Oder waterway (E 30) and assumes international class navigability by eliminating bottlenecks, adapting to the parameters of class Va rivers, the construction of missing connections between the Danube, Odra, and Leba, and the construction of Silesia Canal;
- PRIORITY II – refers to a significant navigational improvement in Wisla waterways;
- PRIORITY III – relates to the combination Oder-Wisla-Zalew Wiślany and Warsaw-Brest, especially the expansion of waterways E 70 and E 40;
- PRIORITY IV – refers to the partnership and cooperation through inland waterways, including the implementation of River Information Services (RIS).

The assumptions also include investments to be implemented in the short term (by 2020), which will include (Resolution, 2016):

- removing the so-called bottlenecks by modernizing the hydrotechnical construction of waterways,
- preparation of feasibility studies for all planned long-term investments;
- developing the best investment financing methods, e.g., by raising funds from the European Fund for Strategic Investments;
- commencement of construction of water steps on the Oder – below Malczyce in Lubiąż and Ścinawa and on the Vistula – below Włocławek.

In addition, in 2016, the Minister of Maritime Economy and Inland Navigation appointed the Steering Committee for Investments on Inland Waterways, whose main task is to support the ministry in implementing the above-mentioned priorities (Ministry of Maritime Economy and Inland Navigation, 2016).

The committee involves key stakeholders of inland waterway transport in the planning, preparation, and implementation of the Ministry's investment objectives. In 2017, the working group of the Steering Committee for Investments on Inland Waterways developed the scope of a preliminary

feasibility study for investments on the Odra Waterway, which are currently used in the work carried out by the Szczecin and Świnoujście S.A. and the Port of Gdansk Authority SA. In December 2017, the Committee set up three additional thematic working groups for hydrotechnics and the environment, the economy, and for local and regional development and social affairs.

These groups are responsible, among others, for preparing and conducting cost-benefit analyses, strategic environmental assessments, and social communication of the project (Ministry of Maritime Economy and Inland Navigation, 2018). The establishment of such a commission allows for efficient, accurate, and rapid operations in inland navigation. The members of the Commission are specialists operating in the shipping sector: people with extensive experience, familiar with the market and realities, who know best what to develop, immediately improve, and what to do next. In addition, the Commission was appointed to prepare feasibility studies for investments in inland waterways that result from previously set assumptions; therefore, the Commission has a huge impact on the appearance and progress of works on Polish river routes.

In accordance with the set priorities, work began on the Odra Waterway. Telematics solutions are one of the interoperable elements of TEN-T corridors. In 2005, the EU introduced the River Information Unification Directives, or River Information Services (RIS). Pursuant to the RIS Directive, the Commission established technical guidelines and specifications for RIS. Among other things, the Directive implies the implementation by the EU Member States of an interoperable, open, and extensible river information system that will be compatible and consistent with transport management systems and commercial activities. System managers are required to provide RIS users with the data needed to plan their trips, including electronic navigational charts for waterways. Notifications to skippers should be provided in standard form, coded, and downloadable. The system should be compatible with the European Hull Database (EHDB), which contains selected information about inland waterway vessels, including their unique European ship identification number, name, dimensions, and an electronic copy of the ship's certificate (Directive, 2005). In Poland, the obligation to implement the RIS system covers only a part of the waterways of the lower section of the Odra River from Ognica to Szczecin, classified as Vb class waterways, which has a total length of 97.3 km. This represents 80% of the total length of

Vb class roads in Poland and only 2.5% of all Polish river roads (Urząd Żeglugi Śródlądowej, 2019).

Polish transport policy is consistent with the EU's plans for a unified European transport system; therefore, in the documents developed by the Central Statistical Office, there is detailed information about projects aimed at activating inland navigation in Poland. One study described inland waterways transport in Poland from 2014–2017 (Bawelska, Brzezińska & Radlińska, 2018), as well as a detailed description of the revitalization project of the international waterway E 70. This project connected Western Europe from Antwerp, through northern Poland, to the Kaliningrad region and further with the Neman River waterway system to Klaipėda. The section of the waterway passing through Polish territory includes 6 provinces, representing 41% of the country's area (Bawelska, Brzezińska & Radlińska, 2018). So far, the Polish section of the E70 waterway can be classed as Ib and II; therefore, it is necessary to modernize by expanding it to a minimum of class IV navigability. Furthermore, the program takes into account the sustainable development of regions along this waterway through the development of various forms of inland navigation. The main areas of work included in the program will be to restore navigation (Bawelska, Brzezińska & Radlińska, 2018).

Another perspective of the development of Polish inland waterways are EU programs to precisely support this mode of transport, such as the Navigation and Inland Waterway Action and Development in Europe – NAIADDES I and II. The first is to introduce a system of RIS, while the second is the overarching program of activities to promote inland navigation from 2014–2025. It focuses on introducing long-term structural changes in the IWT sector to make it more modern, innovative, and attractive. It aims to improve the quality of shipping by improving infrastructure quality, which is currently a serious barrier to its development. This relates directly to the so-called “bottlenecks” caused by the inadequate technical parameters of locks, bridges, and fairways. Moreover, inland waterway transport is an extremely environmentally friendly solution, as it emits the lowest amounts of harmful substances compared with other transport modes, as shown in the first part of the article. For this reason, the European Commission aims to create an innovative and environmentally-friendly transport sector. Additionally, steps have been taken to include inland waterway shipping into the multimodal logistics chain, which increases the demand for skilled workers (Tyc, 2015).

Therefore, in December 2017, the ministers of Environment, Ministry of Economy and Water, and the Ministry of Energy signed agreements for the construction of a water barrage on the Vistula below Włocławek. In August 2019, following the publication of a financial analysis of the construction of the Water Step in Siarzewo, together with all estimated costs, offers for investment implementation were accepted (Ministry of Maritime Economy and Inland Navigation, 2017). Therefore, one can expect construction works on the indicated section to begin. The construction of the barrage will significantly improve the navigability of the Vistula and will affect the water level in the river, which will allow larger vessels to cross safely.

In recent years, both EU and Polish governments have taken many actions that have sought and are still heading towards the activation of inland navigation in Poland. Actions to accomplish this include the appointment of the Minister of Maritime Economy and Inland Navigation, followed by the establishment of the Commission, the preparation of "Assumptions for plans for the development of inland waterways in Poland", the signing of the AGN agreement, introduction of RIS, and finally undertaking modernization works on sections of rivers. All these efforts and works should, as a result, give measurable benefits in the form of transferring some transport to greener modes of transport. This slogan has many related benefits, including a reduction in road and rail congestion, reducing road accidents, reducing harmful emissions into the atmosphere, activation of the market related to river ship services, the construction of ports, activation of regions, increase in international traffic in Poland, which will increase tourism opportunities, etc. In addition, activities aimed at including inland navigation into a multimodal logistics chain are associated with expanding the labor market requiring qualified employees and developing inland navigation issues in education.

Conclusions

Polish inland waterways have been neglected for many years, which ultimately led to the degradation of their assigned linear and point infrastructure. This resulted in a decrease in the share of this mode of transport against others, which have been intensively developed over this same period of time. This was largely the result of changes in the structure of demand from bulk cargo to more individualized, single-unit goods. It led to a more flexible means of transport, allowing for door-to-door delivery. After

many years, when concern for the environment began to take hold, the potential of inland navigation has finally been noticed. This will allow the transfer of part of the transport using vehicles with high emissions to river units, which are characterized by high capacity, low energy consumption, low emissions, and almost insignificant external costs. The density of the waterway network is essential for the development of inland waterway transport in Poland; since this is higher than the average, it greatly simplifies and expands the possibility of developing such means of transport.

Despite the large negligence and inadequate technical parameters, Poland, along with the EU, undertook the task of revitalization, rehabilitation, and integration of inland navigation in the overall transport system of the country. This task requires a significant amount of time and financial investment. Projects were created to bring the main Polish rivers up to international standards. Some of them have already been completed, while others are ongoing. Importantly, due to the anticipated economic growth, increasing transportation needs by about one-third of what will be the result of the activation of goods related to the enlargement of the EU with new waterways. This creates opportunities for Polish entrepreneurs to develop their businesses and to strengthen the position of Polish transit in Europe.

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On-water video surveillance: data management for a ship identification system

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Abstract

Video surveillance on both marine and inland waters still only plays a mainly auxiliary role in vessel traffic observation and management. The newest technical achievements in visual systems allow camera images to be used in more sophisticated tasks, such as automatic vessel recognition and identification in observed areas. With the use of deep learning algorithms and other artificial intelligence methods, such as rough sets and fuzzy sets, new functions can be designed and implemented in monitoring systems. In this paper the challenges that were encountered and the technology that has been developed in managing video streams are presented as well as the images needed for tests and proper operation of the designed Ship Recognition and Identification System (SHREC). The current technologies, typical setups and capabilities of cameras, with regard to existing on-water video monitoring systems, are also presented. The aspects of collecting the test data in the Szczecin Water Junction area are also described. The main part of the article focuses on presenting the video data pre-processing, storing and managing procedures that have been developed for the purposes of the SHREC system.

Introduction

The current achievements in the available image resolution and computing capabilities now allow the use of both machine learning (Lubczonek & Włodarczyk-Sielicka, 2018) and deep learning methods to process many types of image data (Połap et al., 2018). Surveillance systems are already using some of these methods to recognize cars, people (Połap, 2018) and phenomena in the world that surrounds us today. Theoretically there is no reason to not use it in video monitoring systems for ship traffic management (Wawrzyniak & Stateczny, 2018). Although several practical obstacles can be easily predicted: uncertain environmental conditions, changeable lighting, the very large number of possible objects to be classified and identified (Bloisi et

al., 2016); some issues still cannot be foreseen before the actual development of such solution. SHREC is a system that is being developed in order to ensure fully automatic recognition and identification of ships using the existing video monitoring that is part of the operating traffic information systems. Its focus is mainly on smaller nonconventional craft – that do not fall under the SOLAS International Convention for the Safety of Life at Sea (IMO, 1974) and cannot be identified by other existing identification systems. In the assemblies the SHREC system will use video streams from fixed cameras of one such system and process them separately to detect and classify ships that may appear in the recorded scene. Simultaneously the text detection and recognition module will extract the hull's inscriptions from a ship's image. Identification will be possible if the ship's class and

extracted hull data match the data in the data base of the overarching traffic system. Integration of the image and non-image information topic has been presented previously (Bodus-Olkowska & Uriasz, 2017). A more detailed description of the identification process in SHREC can also be found in the literature (Wawrzyniak & Hyla, 2019).

SHREC is thought of as a subsystem that will work primarily with either marine Vessel Traffic Services or inland River Information Services (Stateczny, 2017). Cameras are commonly used by these systems, especially in restricted areas (Stateczny, Granska & Motyl, 2018), and the video streams can be easily redirected and exploited by the SHREC subsystem for detection, classification and recognition of ships. Due to the existence of databases on ships in both systems (such as the Hull Data Base in RIS) the identification process can be automated using information from the DB as a reference that can then be compared with the results of the implemented method of identification. Then, the architecture of these systems allows a push notification of the identified vessel to be sent to different nodes or users of the VTS/RIS system. This will provide partial or full automation of the process of identifying ships, based on the visual information from the cameras.

In order to be able to develop such a system, a proper technology for managing the test and training data for the SHREC system had to be developed. For machine learning methods, a massive amount of source data is a crucial element that needs to be reasonably managed so that all parts of the system can learn and be tested in real conditions. Moreover the data must cover a large number of vessels types from different perspectives to allow good adjustment to the real working conditions of the RIS/VTS systems.

In this paper the challenges that have been encountered and the technology that has been developed when managing video streams and the images needed for tests and proper operation of the

designed Ship Recognition and Identification System (SHREC) are discussed. The scheme for managing the video stream data in the SHREC system, from setting the objectives to producing the final data sets that are ready for use in each system module, is presented.

The rest of this paper is organized as follows: Section II describes the current technology used in the video monitoring implemented in VTS/RIS systems. Section III presents three kinds of video stream acquisition for the purposes of the SHREC system. Section IV describes the processing and management of the acquired data. The conclusion and future works conclude the article.

Video surveillance of marine and inland areas

At present, a wide range of hardware and software solutions, constituting an integral system that is able to integrate and fuse the acquired data, is used to monitor marine and inland navigation (Möller et al., 2018). The regulations regarding the video surveillance equipment found in VTS specifications say that the scope of the VTS area should be taken into account with the necessary supervisory equipment. In principle, the equipment should be able to cover an area much larger than the designated VTS region, to allow observation even in bad weather conditions (IALA, 2016). Monitoring devices that are used for surveillance are mainly radar, automatic identification system (AIS) and CCTV systems. Although these complex systems also use other sensors such as sonar (Kazimierski & Zaniewicz, 2018), these systems are also intended to support the safety of navigation between vessels, but also to support supervision by the operators of the RIS or maritime VTS.

Companies producing monitoring systems have in their offering a number of solutions dedicated to

	DS-2CD4A26FWD-IZS/P ANPR Camera		DS-2CD6986F-H Panoramic Network Camera
Technical details:	– DarkFighter ultra-low light technology – 1/1.8" progressive scan CMOS sensor – Full HD 1080p – up to 60 fps – 120 dB WDR – Full smart feature-set – up to 50 IR range – up to 128 GB on-board storage – motorized lens with Smart Focus		– 4 × 1/1.9" CMOS sensors, 1-ch – 4096 × 1800 real time video output – 180 horizontal panoramic view – DarkFighter ultra-low light technology

Figure 1. CCTV cameras dedicated to maritime monitoring systems (Hikvision, 2017)

observing objects from the water side; one system is presented in Figure 1.

The strategic parameters when choosing a camera are: sensor type, matrix size, maximum resolution, sensitivity, viewing angle with the possibility of optical zoom and operation in night conditions. The minimum specification for cameras is their resolution standard, i.e. the number of pixels vertically and horizontally for digital cameras are 1920×1080 , a standard called 1080p or Full HD. The type of sensor used in cameras is CMOS (Complimentary Metal-Oxide Semiconductor) characterized by lower energy consumption and good image parameters, but it produces more noise in low light conditions. The size of the matrix affects the image quality – the larger the matrix the better the image quality, but also the smaller the depth of field. Sensitivity expressed in lux is the smallest amount of light that allows a picture to be registered – the smaller the value, the higher the sensitivity; the angle of view also affects the quality of the data received. The larger the angle of view, the smaller that objects in the center will seem and the more stretched the image will seem on the edges. For observing detail, a camera should be placed further away, with a smaller viewing angle, but with a larger focal length.

An example of a video monitoring system for inland areas is the RIS Center located in Szczecin. This unit is a part of the Inland Shipping Office in Szczecin and its main task is to provide navigation information to users of the inland waterway route and to ensure the safety of moving ships. In 2013, as a part of a pilot implementation of a RIS system for the Lower Oder area, a CCTV system was installed, consisting of 34 cameras deployed throughout the entire area of operation of the RIS Center. The cameras were located in places critical for shipping; mainly on bridges and in the places where the navigation route is delimited.

Video stream acquisition

In order to ensure proper and diverse sets of test and training data for the development of a ship classification and identification method, and later for implementation of the SHREC system, it was decided to obtain video streams from existing monitoring systems as well as to acquire our own recordings.

Thanks to the courtesy of the Inland Waterways Authority in Szczecin, image data was made available from the RIS monitoring system as part of an agreement on data exchange for the SHREC project. The video resources included data from 10 cameras operating in the Lower Oder Area. A simplified data exchange diagram for CCTV monitoring is presented in Figure 2. Cameras, mainly installed on bridges and masts, are connected to the platform with a switch device, and then the signal is transmitted via a radio network to the individual nodes of the system, which are concentrated on the EWA granary building. Direct transmission to the RIS Center server, which collects data, is done with the use of a fiber optic cable.

The server used to collect, view and manage the data was based on QNAP software, and in the following months it was exchanged for a NOVUS system. The data obtained for further analysis were mostly recorded with Funkwerk cameras, which were configured to transmit images in HD resolution (1280×720 or 1280×960), and the number of frames transmitted per second varied between 15 and 25. These values were still not achievable during live video playback, because the radio transmission network degraded the signal, which ultimately significantly reduced the number of frames recorded on the server. The best data set was obtained from a rotating camera located on the roof of the Office of Inland Navigation's headquarters. This camera with newer technology, when directly connected to the

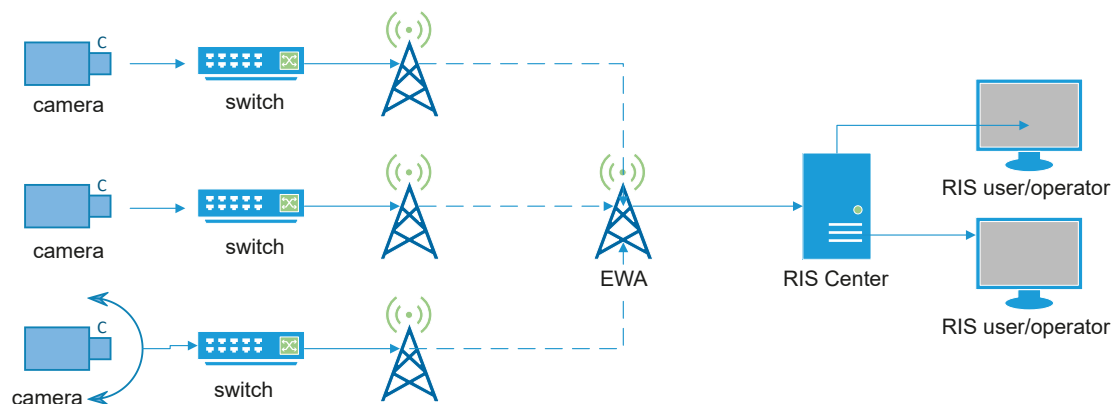


Figure 2. Simplified diagram of the CCTV data transmission in the RIS Center

Ethernet network, provided video streams in Full HD resolution with a guarantee of recording 25 fps. The quality of data obtained with a newer camera, with better parameters, gives better material for analysis, interpretation and processing. Still, assuming the planned replacement of other cameras in RIS with newer ones, the use of radio transmission technology will not increase the number of frames transmitted.

The second source of test data were publicly accessible data streams from webcams in maritime ports such as Rotterdam, Hoek van Holland, Dordrecht, Maassluis, and Vlaardingen; examples can be seen in Figure 3. These video streams made it possible to supplement the data collection with units less frequently occurring in the area of our own acquisitions on inland waters. The main interest was in large commercial seagoing vessels, cargo ships and other conventional vessels. Additionally, in situational terms, these cameras also represent different scenes and observation cases that provided valuable material for testing detection and recognition algorithms – busy waterway situations, port roadstead traffic, multiple ships passing in waterway nodes etc. (Figure 4). The obtained data was a total of 604 recordings reduced to 168 videos containing actual images of units.

The final and the biggest set of video data came from our own recordings. The cameras used in the SHREC project are GoPRO HERO6 Black with the possibility of configuring the recording resolution. For comparison purposes, there were two qualities of 4K and 1080p video recording at 30 fps that were used. Before the actual recordings, reconnaissance was carried out for the area of Międzyodrze and the Szczecin Water Junction. More than a dozen locations with a good view of the area and the vessels moving across it were found.

The chosen sites differed in terms of the observation angle, in order to capture vessels from all possible perspectives, as well as all possible types of ships; images of which could be recorded. Some of the stations were located near the Trasa Zamkowa route and the bridge – Most Długi. This section of the Western Oder is characterized by the presence of bigger ships, passenger ships, small motor yachts and motorboats available for rent; this is due to the touristic character of the surroundings. Different locations near the passage to Dąbie Lake allowed data on small leisure craft to be acquired, due to the proximity of lake marinas (Figure 5).

The data were collected in the period of time from the end of July to the end of September 2018.

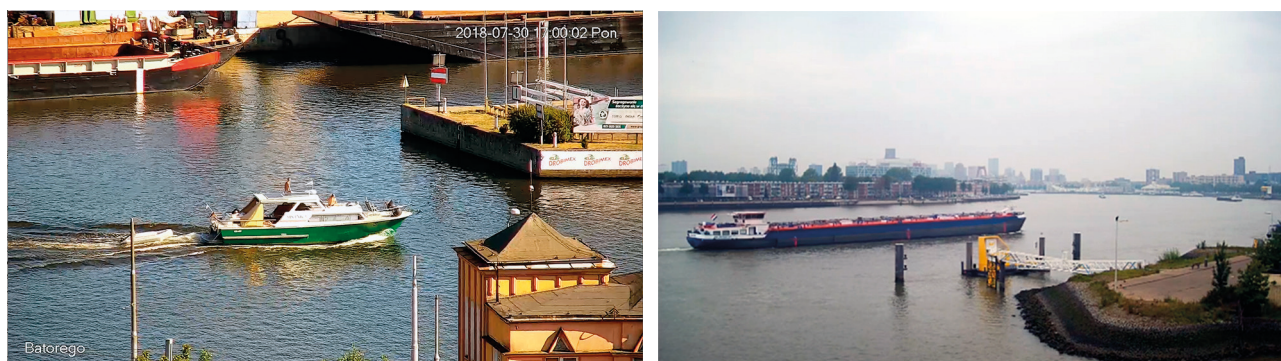


Figure 3. Representative camera images from external sources – the RIS of Lower Oder (left) and the Port of Rotterdam (right)



Figure 4. Map of locations near Castle Route in Szczecin (left) and an exemplary camera image from one of this locations (right)



Figure 5. Map of locations near the passage to Dąbie Lake (left) and exemplary camera image from one of this locations (right)

During the whole recording period, 381 videos were obtained from 659 units which were captured and described. The focus was mostly on small leisure craft, due to the fact that external sources covered other types of vessels such as conventional (under SOLAS), marine units (internet cameras in sea ports) and larger inland units (RIS cameras). When selecting the location, the distance from the passing vessels had to be taken into account. In the case of small vessels which are too far away from the camera, there is a problem with the verification of inscriptions and symbols marked on the ship's hull. The markings such as the registration number, vessel name, and home port or IMO number are essential for the identification process. Due to the technical possibilities, most of the unit's images are registered in profile, i.e. at the angles 90° or 270° . This was caused by observations on rivers with linear characteristics. However, frontal recordings are possible, for example, from bridges. Assigning a vessel to a particular type is not a clear situation. It is especially difficult in some cases, e.g. between a motor boat and a motor yacht, or a motor yacht and a large motor yacht.

The data acquisition stage was the first part of the second phase of the video and image data management process (Figure 6), which is described further on in this article. This phase had a great influence on the later performance of the designed, developed and tested methods for the detection, classification and identification of ships. The observed characteristics and the problems encountered allowed proper solutions to be designed during the process of determining the scope and operation of the algorithms.

Data processing and management

The whole process was divided into four main phases (Figure 6). The initiation phase consists of defining the process objectives, performing

reconnaissance and defining the best possible methods and sources of data collection. The expert knowledge used in this phase was transformed in the second phase, called acquisition and storage, to define the schemes in which the data will be collected and later processed. The acquisition process was described in the previous section and the accumulated video data was verified and organized. The main aspect of the verification was the quality of the recordings and their suitability for further processing, but also editing the recordings in order to eliminate unusable parts. Each video stream was described in a separate file according to a pre-determined scheme; this scheme later allowed the acquired data to be tested.

The description of the scheme of the recordings included:

- sequential numbering – numbering of successively qualified units, after editing the verified test recordings;
- naming the recording – numbering of the recordings assigned by the observer;
- background frame – information about the occurrence of a background frame, i.e. a frame in which the described unit has not yet appeared;
- number of vessels in a recording – information on the number of vessels in a particular recording;
- passing time – time from when a given unit appears in the frame and when it disappears from this frame;
- vessel type – the vessel type as defined by the observer in the previous stage;
- visible inscriptions on the vessel – inscriptions that could be read on the recordings, such as: the ship's name, home port, registration number, IMO number, shipowner's mark, trademark, and ENI.

From the recorded, described and ordered recordings, the next stage was to cut the individual ships out of the recordings in the form of bmp images. This process was carried out for a few classes, which had the largest number of collected

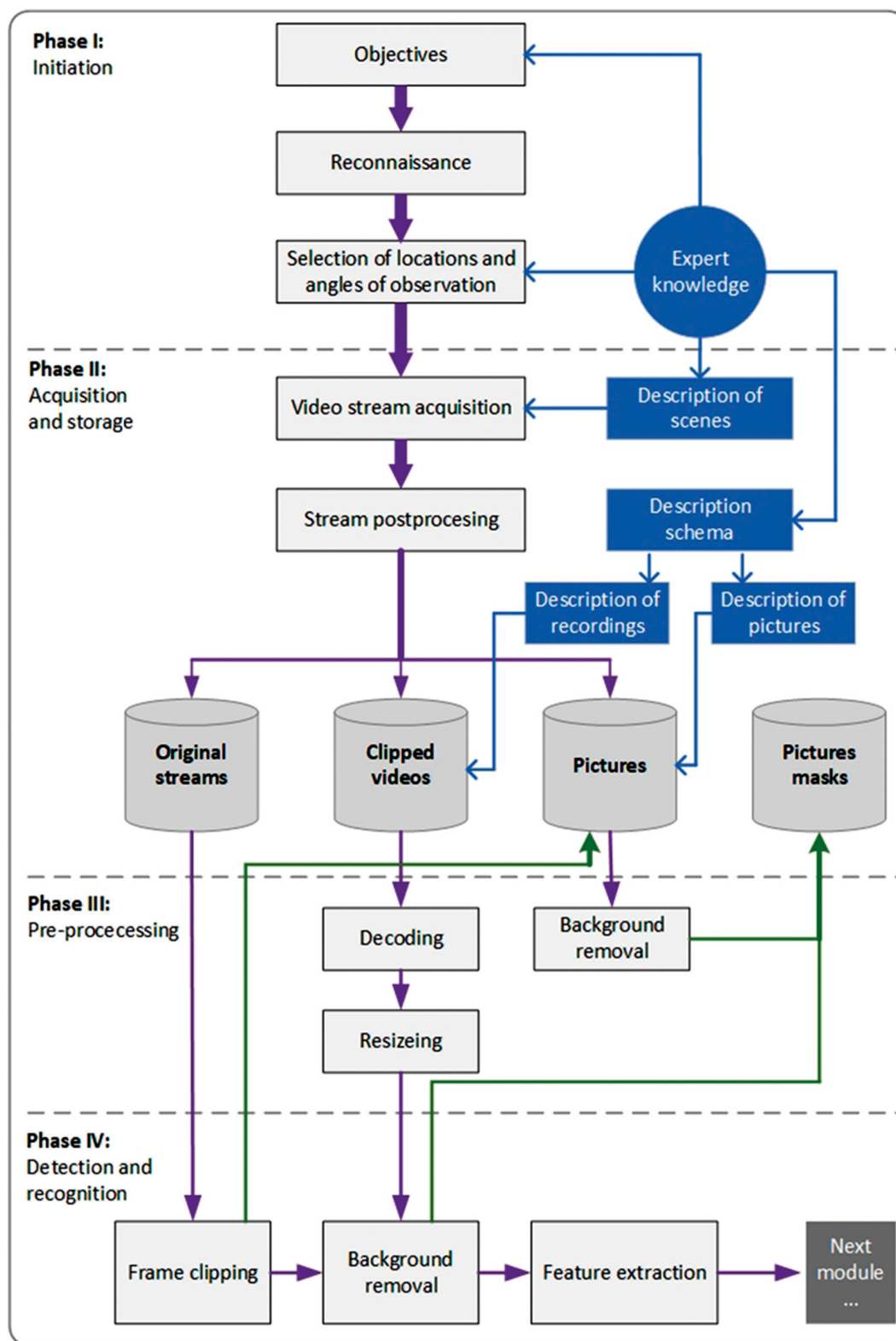


Figure 6. Scheme for the acquisition and management of the image data in the SHREC system

examples in their ranks. There was only one unit in the frame, captured at the best possible moment. The individual unit provided at least one picture, as it could appear from different perspectives while passing through the scene. The schema of the image description specified the:

- sequence number – numbering of a sequentially saved photo;
- name of the photo – numbering of recordings assigned by the observer;
- test number – this is the number which informs the system which unit from the recording is this

one; this number is adequate for ordinal numbers from the table of recordings;

- execution time – time on the described recording;
- observation angle – shows the perspective from which the unit is shown on a particular frame. Eight angle settings have been set, starting from 0°, which is the front of the ship in eight aspects – 45°, 90°, 135°, 180°, 225°, 270°, 315°.

In the pre-processing phase, the clipped videos are decoded and resized for the further detection algorithm that uses data in smaller resolution and, as an outcome of its performance, cuts the detected ship's images from the original streams and produces pictures masks; this defines what is actually a ship and what is only the background in each frame. A more detailed description of the detection process can be found in the literature (Hyla & Wawrzyniak, 2018). These picture masks are later used in the classification module. Some methods of feature extraction need such pre-processed information in order to facilitate the process (Bobkowska et al., 2017).

Throughout the whole process, the data is structured and transferred to the system server to create a test database. The server used in this project was a Dell Precision 36 30 MT. The disk space on the server was 8 TB, consisting of two 4 TB HDDs. The project used FTP protocol, which allows for two-way file transfer. Currently, the database contains about 600 GB of raw images and recordings that have been grouped and described according to the accepted guidelines. The amount of processed data is constantly growing with the development of the system's main methods.

Conclusions and future work

At this stage of the project's implementation it can be assumed that the data that has been referred to in this article are crucial for the further development of each partial submodule of the SHREC system. They allow the system's performance to be developed and later tested and verified with the use of the wide range of methods that use many pre-processed forms of the acquired data. Right now it seems that the most important parameter for interpretation is not the number of frames transmitted per second, but the quality – the resolution of the analyzed image. The settings of the camera itself and its aspect in relation to the moving vessel greatly influences the assumed identification or automatic reading of the vessels inscriptions. With ship detection and even tracking it seems reasonable to use images recorded

by different cameras, as long as their spatial configurations are known. It is important to emphasize the diversity of data that has been collected in order to create a database of objects. The latest technologies have been used in data acquisition (Full HD, 4K), but sources from older solutions that still perform their function of water monitoring, but have reduced image quality, have also been used to help build the system's data base. The authors plan to further expand the data base with new recording in the summer of 2019 to supplement the current data sets with video streams and images of types of ship that have not been recorded in sufficient numbers so far.

Acknowledgment

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An approximate method for calculating the resistance of a transport ship model

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Key words: friction resistance, total resistance, approximation of ship model resistance, autonomous ships, unmanned surface vessel (USV), ship model

Abstract

The article presents regression formulas for calculating the friction resistance R_F and the total resistance R_T of ship models in the 2.0–10.0 m range. The method for calculating the total resistance is novel and applies to the design models of an unmanned surface vessel (USV) for experimental testing of autonomous control. For both regression models (R_F and R_T), statistical and substantive tests were performed (the results of the calculations were compared with the experimental measurements). In both cases, convincing results were obtained, which have confirmed the possibility of their use at the preliminary design stage of unmanned ship models.

Introduction

In recent years, research and design work on unmanned ships has begun in earnest. These vessels are to be equipped with an on-board computer with the appropriate software for autonomous control. At the same time, these ships will be equipped with a system that will enable the operator to remotely control the system – the operator (navigator) of the system can take control of the ship in case of failure or difficulties in the autonomous control. Since autonomous control is still being developed and there are no regulations permitting unmanned ships to be used, testing of this type of ships is carried out on models, as shown in Figure 1.

When designing a ship model, as in the case of a full-size ship, one of the tasks is determining the propulsion power required for a given speed. In order to determine the propulsion power and design the propulsion system (propulsors) it is necessary to know the resistance of the model on calm water. The determination of the resistance can be made by:

- measuring it in the model basin,
- numerical calculation using the CFD method.

One and the other method (full and accurate geometry of the ship's hull model is required for such tests) is not used for cost reasons at the stage of designing the initial ship model.

An alternative is to use approximation methods to calculate the ship's resistance. Such methods exist for ships (Holtrop, 1984; Hollenbach, 1998), while, for models in the 2.0–10.0 m range, there is almost nothing in the literature on this subject. The publications in the literature contain tests and calculations of the resistance of a specific model using CFD methods and then these results were compared with experiment in a basin (Lohne et al., 2011; Ebrahimi, 2012; Moctar, Shigunov & Zorn, 2012; Sukas, Kinaci & Bal, 2014; Kinaci & Gokce, 2015; Ozdemir & Barlas, 2017). This information can only be used as an estimation of the resistance for a similar model.

The dependence of the friction resistance has been presented in the literature (Molland, Turnock & Hudson, 2011) in the form of the equation:

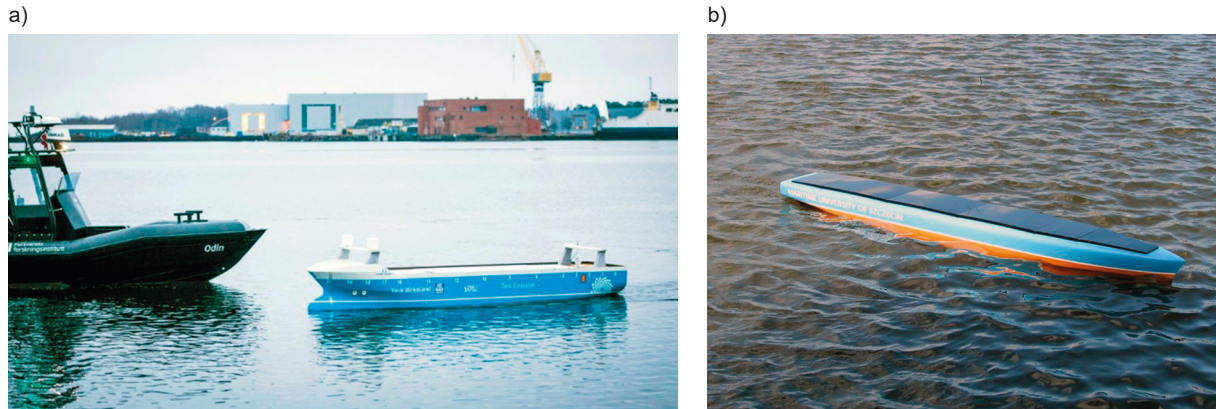


Figure 1. Models of unmanned ships: a) the model ship Yara Birkeland (Ocean News & Technology, 2017) b) model ship from the Maritime University of Szczecin

$$R_F = f \cdot S \cdot V^{1.825} \quad (1)$$

where:

- f – the correction factor that depends on the length of the model,
- S – the wetted surface area of the ship model,
- V – model speed.

Formula (1) only applies to the friction resistance R_F , and not the total resistance R_T ; in order to use it, it is necessary to know the wetted surface and the factor f for a ship model with a given length L .

The Hollenbach method (Hollenbach, 1998) can also be used to calculate a ship's total resistance, and an approximate residual resistance R_F has been developed for this method. Add frictional resistance calculated for an equivalent flat plate according to the ITTC (ITTC, 1957). However, the calculation of the total resistance in this way is too imprecise for a ship model and requires knowledge of many geometrical parameters of the hull (Hollenbach's method is used for ships with lengths of 50.20–224.80 m, and the size of the propeller's diameter is necessary for the resistance calculations).

Approximation formulas for barge models and inland ship models have been developed and described previously (Kulczyk & Słomka, 1988; Skupień & Prokopowicz, 2014). From these formulas, the total resistance R_T can be only calculated for inland watercraft models sailing on shallow water.

Purpose of the research

Due to the lack of satisfactory methods for calculating the total resistance R_T of a ship model, a study was carried out to develop an approximate method for calculating the resistance of a ship model. It was assumed that this method should be both as simple and accurate as possible, based on the basic

geometrical parameters of a ship model, which is known at the preliminary design stage.

To elaborate on this method, the results of the resistance measurements of ship models, made in various research centers, of ships designed in the Szczecin Shipyard in 1995–2010 were used. Resistance measurements and the geometric parameters of ship models included in the literature were also used.

The resistance of a ship model

The total resistance of a vessel R on calm water can be written as follows:

$$R = R_T + R_{AP} + R_{AA} \quad (2)$$

where:

- R_T – resistance of the bare hull (without appendage parts),
- R_{AP} – resistance of the appendage parts (keel, rudder, etc.),
- R_{AA} – air resistance.

The biggest share in the total resistance is the resistance of the bare hull R_T , which can be written as (Figure 2):

$$R_T = R_W + R_V = R_W + (1 + k) R_{F0} \quad (3)$$

where:

- R_W – wave resistance (pressure resistance),
- R_V – resistance due to viscosity,
- R_{F0} – frictional resistance of an equivalent flat plate,
- k – form factor taking into account the spatial flow around the hull of the ship model.

During resistance tests in the basin the resistance R_T of the model is measured, usually without any appendage parts. The result of the measurement, according to the appropriate procedure is converted

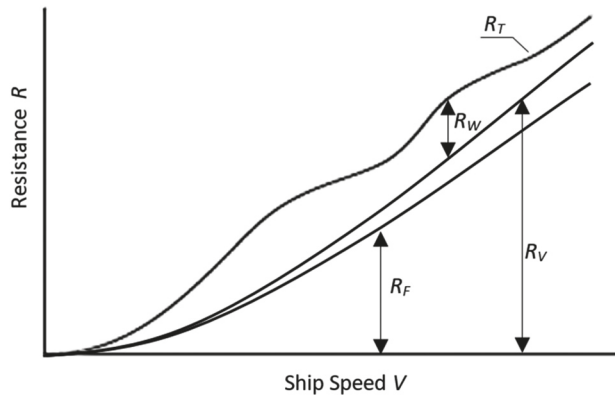


Figure 2. Resistance components R_T

for the real ship. In order to be able to calculate the resistance R_T , the k factor and the wetted area S of the ship's hull must be known.

The results of the resistance measurements for a given speed range (0.5–2.8 m/s) were used to develop an approximate method for calculating the total resistance of a ship model R_T . The scope of the geometrical parameters of the ship models that were used is shown in Table 1.

A typical regression method based on the least squares algorithm was used to develop an approximate method for calculating the total resistance R_T of a ship model. The choice of the method resulted, among others, from the assumptions that were made, i.e. the simplicity of the model. Regression dependencies can be easily used for calculations and implemented in simulation programs.

The set of results of the total resistance measurements for ship models was divided into two subsets – the main subset was used to develop the method for calculating the resistance, and the second (smaller set) was used for substantive tests of the developed method.

First, an approximate method for calculating the friction resistance R_F for ship models was developed (for ship models this component of the total resistance is decisive).

Secondly, an approximate method for calculating the total resistance R_T for ship models was developed.

When developing both methods, the algorithm that was used was as follows:

1. Determination of a set of geometrical parameters that will significantly affect the described size (resistance of a ship model).
2. Developing a set of geometrical values, velocities and resistance of ship models (a ship model database).
3. Selection of representative models for substantive verification.
4. Searching for the approximation function model.
5. Determination of the function that approximates the resistance of a ship model based on the selected parameters – estimation.
6. Statistical verification of the approximation function obtained on the basis of statistical analysis (significance tests, analysis of the variance, residual analysis, etc.).
7. Substantive verification of the approximation function; obtained on the basis of a comparison of the results obtained from the estimation with the model tests for the model ships of the reference vessels (relative and absolute error).
8. The final choice of the model – the form of the approximation function.

The received objectives

Approximation of the friction resistance R_F for ship models

From the regression analyses that were performed, the best formula for approximating the resistance R_F has the following form:

$$R_F = a_1 \cdot \frac{S^{0.99}}{L_{WL}^{0.15}} \cdot V^{1.8} \quad (4)$$

where, $a_1 = 2.2652197$, and L_{WL} – length of the model on the waterline.

The measure that allows the degree of fit of the model to the empirical data to be assessed is the R^2 coefficient of determination; i.e. the ratio of explained volatility to total volatility – the adjusted R^2 coefficient is usually taken into account. The standard estimation error provides information about the average magnitude of the empirical deviations of the values of the dependent variable (explained) from the values that are calculated from the model.

Table 1. Range of the geometric parameters of the ship's hulls

	L_{WL} [m] length on waterline	B [m] breadth	T [m] draught	C_B [–] block coefficient	∇ [m ³] displacement	S [m ²] wetted surface	L_{WL}/B	B/T
max	9.174	1.288	1.169	0.837	3.232	13.121	7.853	4.600
min	2.236	0.380	0.083	0.593	0.046	0.892	5.405	0.707

Experimental method

For the presented model, these values are at a very good level: A value of $R^2 = 0.9999$ means that 99.99% of the total resistance variability is explained by the model, the standard error of the estimation is small and amounts to $Se = 0.366$.

The results of one statistical test are shown in Figure 3.

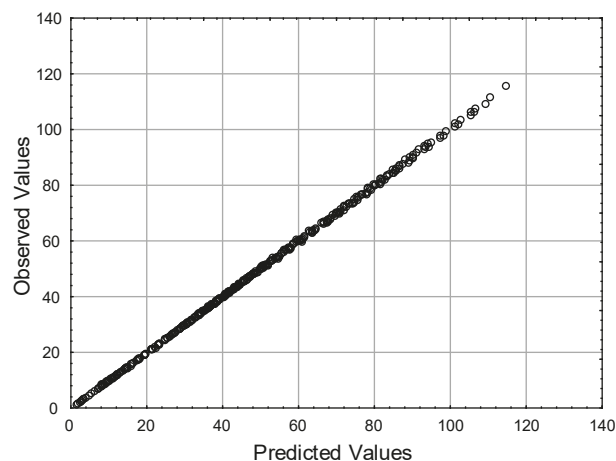


Figure 3. Chart of the observed values versus the predicted values

Substantive tests were performed for ships M1, M2 and M3, whose geometrical parameters and resistance model tests were not used to develop the formula (4). The test results for the ships M1, M2, and M3 are shown in Figures 4–6 and in Tables 2–4, respectively.

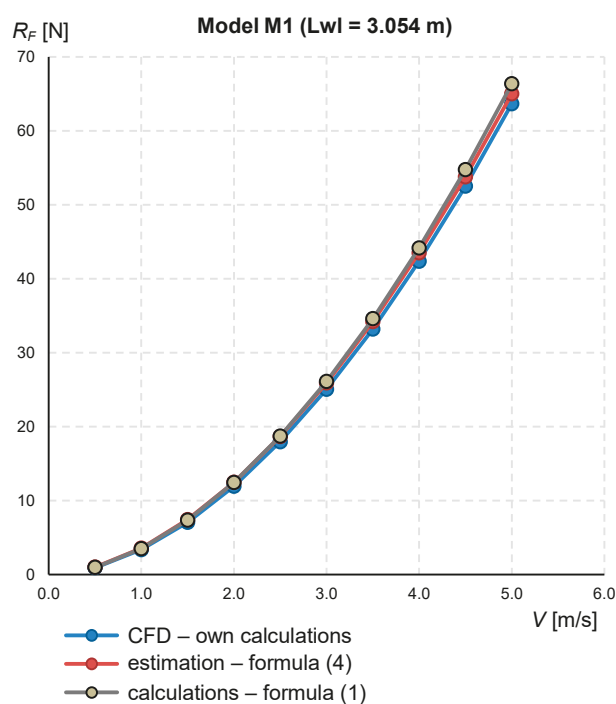


Figure 4. Substantive test of the developed method for the M1 ship model

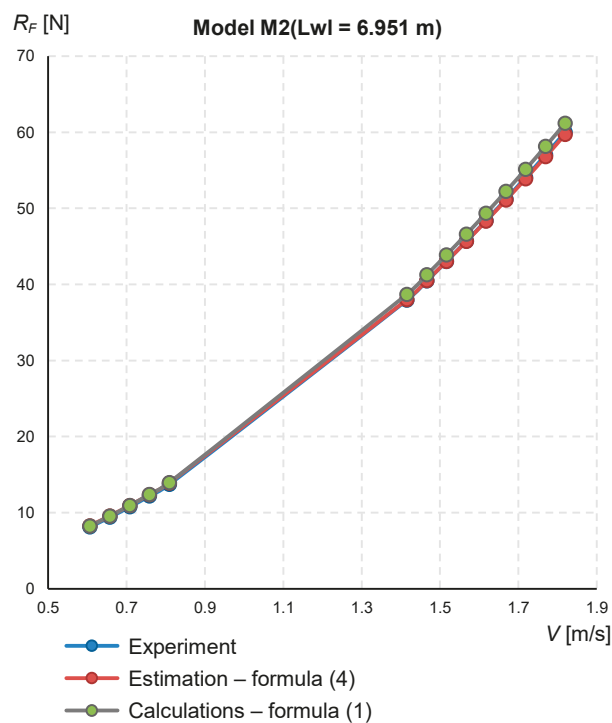


Figure 5. Substantive test of the developed method for the M2 ship model

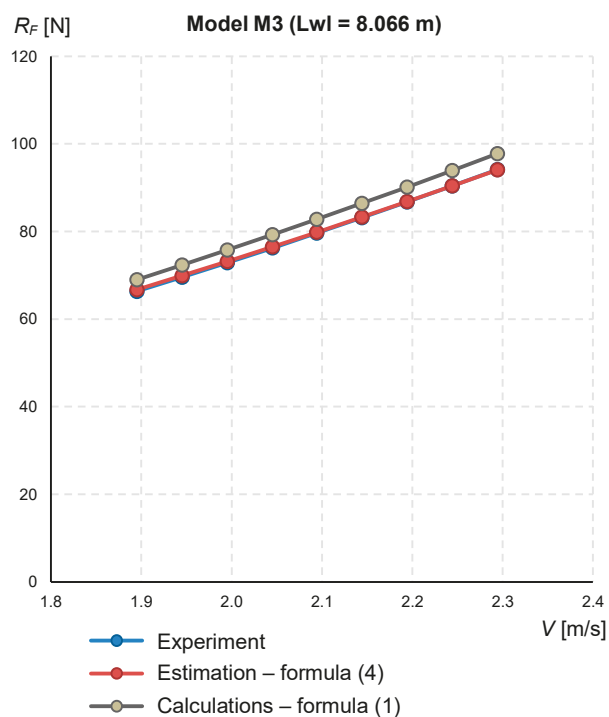


Figure 6. Substantive test of the developed method for the M3 ship model

Table 2. Parameters of the M1 model and the results of the R_F estimation in the form of the relative error value

Parameters of the M1 model			CFD – own calculations		Estimation (formula (4))		Calculations from formula (1)	
L_{WL} [m]	S [m ²]	V [m/s]	R_F [N]		R_F [N]	error [%]	R_F [N]	error [%]
3.054	1.885	0.5	0.95		1.03	–8.48%	0.99	–4.56%
		1.0	3.38		3.59	–6.17%	3.52	–4.12%
		1.5	7.08		7.45	–5.16%	7.38	–4.18%
		2.0	11.96		12.50	–4.49%	12.47	–4.26%
		2.5	17.97		18.67	–3.92%	18.74	–4.27%
		3.0	25.07		25.93	–3.42%	26.13	–4.24%
		3.5	33.21		34.22	–3.04%	34.62	–4.26%
		4.0	42.38		43.52	–2.68%	44.18	–4.24%
		4.5	52.54		53.79	–2.38%	54.77	–4.25%
		5.0	63.68		65.03	–2.11%	66.39	–4.25%

Table 3. Parameters of the M2 model and the results of the R_F estimation in the form of the relative error value

Parameters of the M2 model			Experiment		Estimation (formula (4))		Calculations from formula (1)	
L_{WL} [m]	S [m ²]	V [m/s]	R_F [N]		R_F [N]	Error [%]	R_F [N]	Error [%]
6.951	12.313	0.606	8.121		8.255	–1.65%	8.229	–1.32%
		0.657	9.402		9.548	–1.55%	9.536	–1.43%
		0.708	10.767		10.923	–1.45%	10.930	–1.51%
		0.758	12.184		12.351	–1.37%	12.380	–1.61%
		0.809	13.713		13.886	–1.26%	13.942	–1.67%
		1.415	37.921		37.988	–0.18%	38.676	–1.99%
		1.516	43.005		43.007	–0.01%	43.862	–1.99%
		1.617	48.377		48.301	0.16%	49.341	–1.99%
		1.718	54.038		53.867	0.32%	55.110	–1.98%
		1.769	57.009		56.779	0.40%	58.133	–1.97%
		1.819	59.984		59.701	0.47%	61.166	–1.97%

Table 4. Parameters of the M3 model and the results of the R_F estimation in the form of the relative error value

Parameters of the M3 model			Experiment		Estimation (formula (4))		Calculations from formula (1)	
L_{WL} [m]	S [m ²]	V [m/s]	R_F [N]		R_F [N]	Error [%]	R_F [N]	Error [%]
8.066	13.073	1.895	66.303		66.684	–0.57%	68.969	–4.02%
		1.945	69.544		69.885	–0.49%	72.326	–4.00%
		1.995	72.854		73.152	–0.41%	75.755	–3.98%
		2.045	76.238		76.485	–0.32%	79.256	–3.96%
		2.094	79.611		79.815	–0.26%	82.756	–3.95%
		2.144	83.131		83.278	–0.18%	86.398	–3.93%
		2.194	86.721		86.807	–0.10%	90.110	–3.91%
		2.244	90.380		90.400	–0.02%	93.893	–3.89%
		2.294	94.109		94.058	0.05%	97.746	–3.87%

Approximation of the total resistance R_T for the ship models

From the regression analyses that were performed, the best formula approximating the resistance R_T has the following form: $R_T = f(L_{WL}, B, T, C_B, V)$:

$$R_T = a_1 L_{WL} + a_2 B^{13} + a_3 T^{0.67} + a_4 C_B + a_5 V^{-2.85} + a_6 L_{WL}^{0.98} B^{0.02} + a_7 L_{WL}^{0.6} T + a_8 (\ln(L_{WL}))^3 C_B^{4.65} + a_9 \left(\frac{1}{4}\right)^{L_{WL}} V^{0.04} + a_{10} B^{0.99} T^{0.73} + a_{11} B^{10} C_B^{15} +$$

$$+ a_{12} \frac{(\ln(V))^2}{B^{0.05}} + a_{13} (e^T)^2 e^{C_B} + a_{14} T^{5.15} V^{15} + a_{15} (\ln(C_B))^7 V^{11} + a_{16} \frac{T^{1.45}}{L_{WL}^{11} \cdot B^9} + a_{17} B^{4.1} T^{0.75} C_B^{0.89} + a_{18} T^{2.6} C_B^{1.35} V^6 + a_{19} \frac{L_{WL}^{14} (e^T)^3}{B^9 C_B^{2.8}} + a_{20} \frac{T^{2.15} (e^{C_B})^2 V^{10}}{B^{1.15}} + a_{21} L_{WL}^{0.35} B^{1.4} T^{0.7} (e^{C_B})^3 V^{2.75} \quad (5)$$

where, the values of the coefficients a_1 – a_{21} are given in Table 5.

The developed regression model includes cases where the individual ship models differ only in the value of one of the parameters that describe its geometry, e.g. the C_B coefficient; therefore, the pattern that was obtained is complex.

For the presented model, the values of the determination coefficient at the level $R^2 = 0.9994$ and the standard estimation error $Se = 1.885$ are satisfactory. Correcting the obtained model, e.g. by reduction of some of the elements, caused an increase in the standard estimation error to a large extent. Student's t-statistic with the significance level p (Table 5) indicates that all the explanatory variables are significant.

Table 5. Values of the estimation coefficients for the regression dependency (5) and results of the statistical tests

	Beta	Std. Err. of Beta	Value t df = 408	p-level
a1	-4143,03	153,98	0,00 00E-01	
a2	-4,54	0,20	0,00 00E-01	
a3	-95,31	23,65	0,00 00E-01	
a4	593,71	27,19	0,00 00E-01	
a5	-4,34	0,27	0,00 00E-01	
a6	4362,74	161,97	0,00 00E-01	
a7	404,77	16,17	0,00 00E-01	
a8	-72,13	3,45	0,00 00E-01	
a9	-4903,43	252,11	0,00 00E-01	
a10	-2298,66	81,42	0,00 00E-01	
a11	-21,80	2,96	0,00 00E-01	
a12	33,77	1,97	0,00 00E-01	
a13	-334,61	13,16	0,00 00E-01	
a14	-0,00	0,00	0,00 00E-01	
a15	0,42	0,01	0,00 00E-01	
a16	11215,23	494,00	0,00 00E-01	
a17	448,03	17,03	0,00 00E-01	
a18	-4,24	0,08	0,00 00E-01	
a19	0,00	0,00	0,00 00E-01	
a20	0,03	0,00	0,00 00E-01	
a21	0,86	0,02	0,00 00E-01	

The statistical test for dependence (5) is shown in Figure 7.

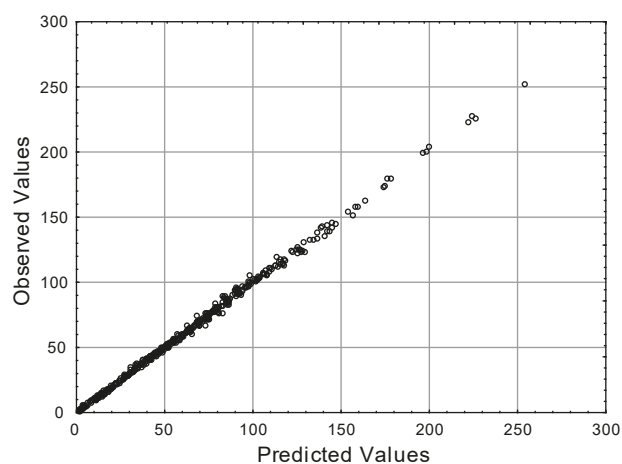


Figure 7. Chart of the observed values versus the predicted values

Substantive tests for the M2 and M3 models are shown in Figures 8 and 9 and in Tables 6 and 7 respectively.

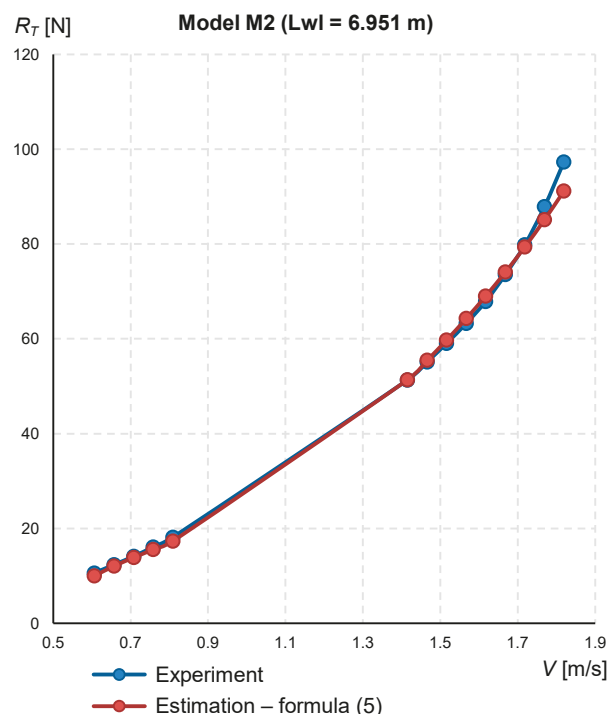


Figure 8. Substantive test of the developed method for the M2 ship model

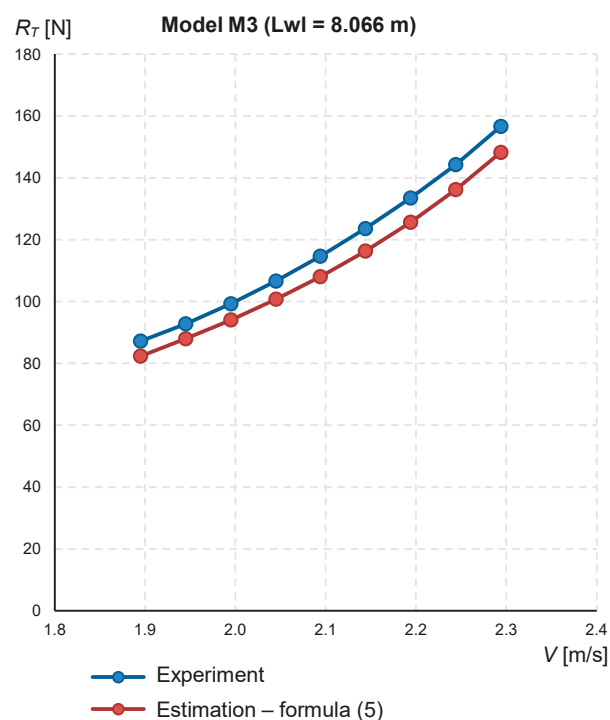


Figure 9. Substantive test of the developed method for the M3 ship model

Table 6. Parameters of the M2 model and the results of the R_T estimation in the form of the relative error value

Parameters of the M2 model					Experiment	Estimation (formula (5))	Error
L_{WL} [m]	B [m]	T [m]	C_B [-]	V [m/s]	R_T [N]	R_T [N]	[%]
6.951	1.197	0.463	0.7880	0.606	10.591	10.0106	5.48%
				0.657	12.356	12.08202	2.22%
				0.708	14.121	13.88313	1.68%
				0.758	16.083	15.57349	3.17%
				0.809	18.142	17.33425	4.45%
				1.415	51.288	51.35704	-0.13%
				1.466	55.113	55.48478	-0.67%
				1.516	59.035	59.73804	-1.19%
				1.567	63.252	64.30059	-1.66%
				1.617	67.861	69.01283	-1.70%
				1.668	73.549	74.09097	-0.74%
				1.718	79.825	79.37231	0.57%
				1.769	87.867	85.11746	3.13%
				1.819	97.281	91.16327	6.29%

Table 7. Parameters of the M3 model and the results of the R_T estimation in the form of the relative error value

Parameters of the M3 model					Experiment	Estimation (formula (5))	Error
L_{WL} [m]	B [m]	T [m]	C_B [-]	V [m/s]	R_T [N]	R_T [N]	[%]
8.066	1.213	0.451	0.6740	1.895	87.180	82.34676	5.54%
				1.945	92.770	87.94258	5.20%
				1.995	99.242	94.04162	5.24%
				2.045	106.597	100.745	5.49%
				2.094	114.639	108.0179	5.78%
				2.144	123.563	116.2998	5.88%
				2.194	133.467	125.6214	5.88%
				2.244	144.254	136.1838	5.59%
				2.294	156.611	148.2213	5.36%

Discussion of the received results

The formula obtained to approximate the friction resistance R_F (4) of ship models is simple and is the product of the model's velocity V , two geometrical parameters (L_{WL} , S) and a constant coefficient (a_1); this is due to the fact that $R_F(V)$ is a parabolic function. The determination coefficient (R^2) is very high, with a value of $R^2 = 0.9999$, and the standard error is small ($Se = 0.366$). The comparison of the resistance values that were obtained shows that the approximation (4) is definitely better for most model speeds than in the case of approximation (1) from the literature (Molland, Turnock & Hudson, 2011). Only for low speeds was the approximation (4) slightly worse than approximation (1) – it should be noted, however, that the relationship (1) produces different values of the factor f depending on the ship model's length. However, the dependence (4) is the same for the entire assumed length range of the ship models.

The formula approximating the total resistance R_T (5) for ship models is more complex and consists

of 21 elements that encompass various geometric parameters of the ship models; this is due to the fact that the course $R_T(V)$ (Figure 2) is not a parabolic function. The tests that were carried out showed that the calculated resistance R_T differs by only a few percent (maximum of 6%) from the value of the total resistance R_T measured in the model pool. Therefore, it can be concluded that the R_T approximation that was obtained will be useful in the preliminary design stage for calculating the resistance and power of a ship model's propulsion.

Conclusions

The paper presents two approximation functions – one, the friction resistance R_F , and the other the total resistance R_T of ship models.

The approximation of the friction resistance R_F that was obtained produces better calculation results than the approximation presented in the literature (Molland, Turnock & Hudson, 2011), although it is a family of approximation formulas that are used for ship models of different lengths.

The approximated total resistance R_T that was obtained is more complex than in the case of R_F . This is due to the fact that the wave resistance R_W (Figure 2) changes within a large range (rising or falling) depending on the speed of the model. Such “wave” changes are difficult to approximate using a simple function for the full range of the length and speed of ship models, especially when considering the possibility of changing only one geometric parameter of the hull.

The tests carried out showed that both approximation functions (R_F and R_T) are sufficiently accurate and that they may be useful for the design of experimental ship models, including unmanned ships.

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Environmental Engineering, Mining and Energy

Investment risks in financing pro-ecological projects – the dilemmas

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Abstract

Environmental protection has increasingly adopted economic dimensions, and the environment is treated as a “capital” that can be used for economic and social development. This capital must be preserved for future generations, which is why increasing attention has been paid to taking pro-ecological actions to protect the environment. In order to improve the quality of the environment, it is necessary to make various types of investments in it. The Sustainable Development Initiative assumes that the economic growth of countries should be implemented in a manner consistent with the natural conditions of nature. The aim of this study was to identify and present the current possibilities of financing sustainability in Poland after joining the European Union, taking into account the risk of undertaking such an investment.

Introduction

Increasing attention has been devoted to environmental protection, and pro-ecological activities have begun to play a significant role in modern enterprises, which spend enormous resources on development and investments to ensure environmental protection. In the era in which economies are based on knowledge and other intangible factors, the topics addressed by this article are current and necessary. Economic growth and civilizational development inevitably lead to the destruction of the natural environment, which contributes to vast ecological losses and the emergence of a variety of problems that cannot be ignored. Countries worldwide have begun to focus on the state of the environment and have increasingly expressed the need to start actively working towards eliminating and limiting growing environmental threats. It has become obvious that international cooperation should be established to protect the natural environment because environmental issues have reached a global scale. Matters of sustainable development were discussed

internationally for the first time in 1972 in Stockholm, as part of a UN conference. The sustainable development initiative assumes that the economic growth of countries should be implemented in a manner consistent with the natural conditions of the environment.

Excessive exploitation of the natural resources, along with excessive growth of consumer lifestyle, may lead to a situation in which future generations will lack proper conditions to function. Countries with a degree of development greater than that in Poland have begun to make changes related to environmental protection. Adaptation to the concept of sustainable development in Poland requires great effort and financial resources, as well as a proper awareness and appropriate environmental policy. Implementation of pro-ecological projects in the country mainly depends on the state authorities' interest in the issue, on the policy pursued, and on the involvement of all citizens. After joining the European Union, Poland gained enormous opportunities to raise funds to carry out tasks leading to sustainable development.

The aim of this study was to identify and present the current possibilities of financing sustainable development in post-EU-accession Poland. The study also aims to present data, analyze the statistical results showing the expenditures on pro-ecological investments, and provide future recommendations. The research methods used in this article include document analysis, logical and construct analysis, and case studies analysis.

The article concerns the development of environmental protection investments in Poland from 2014–2020. A SWOT analysis of the subject matter, as well as the investment risk associated with task financing, have been presented, and the paper ends with recommendations. The research methods primarily involved studying documents and analysis and logical construction. The sources that were used to write the article largely consisted of subject literature, national and foreign scientific publications, legal acts, and source materials on the implementation of environmental policies in the European Union.

Literature review

The environmental protection priorities in the European Union involve combating climate change, reducing pollution, protecting biodiversity, and better use of existing natural resources. The accession of Poland to the European Union in 2004 positively impacted residents' standard of living and the environment. EU membership stimulated the economy, which over the last several years has grown at a rate exceeding the average of the Organization for Economic Cooperation and Development (OECD). The difference in incomes, in relation to the OECD average, the poverty, as well as the income inequality, have decreased more than other OECD countries. The gross domestic product (GDP) per capita, however, is one of the six lowest in the OECD (OECD Stat, 2019). Differences between a country's regions and within the regions themselves are also noticeable (OECD, 2015). Despite progress in distributing the pressure in matters of 'the environment vs. economic growth,' Poland has one of the most carbon-emissive economies due to its high dependence on coal. Although Poland has reduced its greenhouse gas emissions, its emission level still exceeds the requirements set by the Kyoto Protocol (Journal of Laws, 2002).

Since Poland's accession to the EU, its environmental law and environmental policy have been primarily indicated by EU environmental law.

Responsibility for implementing environmental policies lies with lower-level authorities. The elected representatives of regional authorities are responsible for regulatory issues, such as the issuing of permits, and provincial inspectorates are in turn responsible for ensuring compliance with environmental regulations. The Regional Directorates under the Ministry of Environment are responsible for assessing environmental impact (Filipiak, Kochański & Szczypa, 2010, p. 55). Ecological goals, which are one aspect of sustainable development, play an important role in Poland's development policy. This has been emphasized in Article 5 of the Constitution of the Republic of Poland, according to which "the Republic of Poland shall safeguard the independence and integrity of its territory and ensure the freedoms and rights of persons and citizens, the security of the citizens, safeguard the national heritage and shall ensure the protection of the natural environment pursuant to the principles of sustainable development" (Journal of Laws, 1997).

While environmental objectives were generally not realized during the initial years of systemic transformation in Poland, after the accession to the EU, this situation area changed dramatically. The primary objective of the state's ecological policy is to ensure the ecological security of the country – its inhabitants as well as the social infrastructure and the natural resources. This assumes that the sustainable development strategy of Poland will allow the implementation of a model that will ensure effective regulation and control of environmental exploitation. The type and scale of exploitation should not threaten the quality and durability of natural resources (Szopik-Depczyńska et al., 2018). The overriding premise of sustainable development is to conduct such policies and activities in given sectors of the economy and social life, so as to preserve the resources and values of the environment in a state that will provide permanent, unprotected opportunities to use them by present and future generations. In addition, it also mandates maintaining the durability of natural processes and natural biodiversity, at the species, the gene, the landscape, and the ecosystem levels (United Nations, 2015). The essence of sustainable development entails equal treatment of social, economic, and ecological rationales, which requires integration of environmental issues with policy in various areas of the economy. When implementing the state's environmental policy, the principle of sustainable development is supplemented by a number of auxiliary and concretizing principles.

The current system of environmental protection financing in Poland constitutes a constant part of the country's financial system. It entails a set of rules and regulations that define the manner and mode of collecting and redistribution of the funds for pro-ecological undertakings. It was formed before the integration of Poland with the European Union and is somewhat based on various philosophies and sources of law. European Union regulations are characterized by a technological approach, imposing on environment users an obligation to strictly comply with product and emission standards. In turn, Polish law defines the activities related to environmental protection as those focused on environmental effects (Poskrobko & Poskrobko, 2012, p. 36). The funding for environmental protection includes expenditures for current protection, on activities of all environmental protection services, as well as on financing pro-ecological investments (Małachowski, 2011, p. 89).

The implementation of each investment project involves some risk. The risk in investment projects lies in the possibility that the actual investment outlays/outcomes will deviate from the ones originally planned; however, these deviations may have a positive or negative impact on the investing enterprise (Marcinek, 2001, p. 80).

The main factors that may impact investment projects are: economic, macroeconomic, and political (Rogowski & Lipski, 2018, p. 198). They may emerge as soon as the project starts. Economic factors are also referred to as project risks, because they are directly related to the implementation of the project. Macroeconomic factors are associated with risks that are related to general economic aspects such as inflation, exchange rates, or interest rates. Political factors are equated with a country's risk because it determines the effects of governmental policies of individual countries in connection with implementation of various types of projects.

The possible size of deviations reflects the size of the potential risk. Investment risks can emerge from both external and internal conditions. In order to correctly assess the risk, an analysis should be carried out, which may refer to a specific project, to the impact the project has on the company's business activity risk, as well as to the impact of the project's risk on shareholder decisions (Jajuga & Jajuga, 2008, p. 358). Investments in environmental protection are specific investments that are often not directly related to the main goals of the company's business operations; nevertheless, an analysis of the risk level should also be made.

The degree of risk depends on the type and class of the assets that constitute the object of investment. Before making an investment decision, in addition to the potential profit forecast, the risk factors that may be associated with the investment should also be specified. Investing in financial instruments involves the possibility of losing part or all of the originally invested funds. In the case of derivative instruments, there is a risk of incurring a loss that exceeds the investor's original contribution. Archival results from investments made, mainly those with a high rate of return, do not guarantee similar returns in the future. Investment risk is the risk of incurring a loss on the investment or the risk of realizing a lower return rate than the one expected by the investors.

The types of investment risk factors in financing investment tasks include (Rogowski & Michalczewski, 2005, p. 37):

- Interest rate risk;
- Exchange-rate risk;
- Liquidity;
- Credit risk;
- Political risk;
- Financial risk and business;
- Financial leverage risk.

The European Commission highlights the fact that the financing of environmental protection activities should become more of an investment process. Unfortunately, investing in environmentally-friendly projects is less attractive and less predictable, and therefore riskier for investors. Often, the technologies associated with environmental protection are not advanced enough to provide investors with quick profits.

Risk analysis in pro-ecological projects is not easy. Potential investors do not always have relevant information on the project, which can directly impact the accuracy of an analysis. The scale of risk, in the case of a specific project related to environmental protection, depends not only on the duration of the entire project, but also on the characteristics of this investment, the stage of work of the pre-investment phase, and the persons implementing the investment (Czarnek et al., 2010, p. 128).

From the 1990s to 2012, environmental planning was based on cyclically-adopted special documents referred to as the 'Environmental Policy of the State' (EPS) (the original title of the document issued by the Ministry of Environment in Poland is "Polityka Ekologiczna Państwa"; the English translation of the document title is used in this article). Every four years, the Council of Ministers, together with the Sejm, approved the new EPS while providing

the Ministry of Environment with political support, along with a mandate to oversee the implementation of the policy. Reports on the progress of the work were regularly submitted to the Sejm.

In 2009, the approach to development planning was changed. It currently focuses on three overarching development strategies, along with nine strategic policies. Environment has been included in one of the strategic policies – the ‘Energy Security and the Environment – the 2020 Perspective’ (ESE) (the original title of the document issued by the Ministry of Environment and the Ministry of Economy in Poland was “Bezpieczeństwo Energetyczne i Środowisko – perspektywa do 2020 r.” The English translation of the document title is used in this article). The strategy is supervised by the Ministry of Economy, in cooperation with the Ministry of Environment. One of the biggest challenges for Poland is to balance economic growth with care for the environment. The goal of a sustainable development strategy is “to ensure a high quality of life for current and future generations, by taking into account environmental protection and creating conditions for sustainable development of a modern energy sector that can provide Poland with energy security and a competitive and efficient economy” (Monitor Polski, 2014).

For the mechanism to function effectively, it is necessary to implement effective processes that enable coordination, monitoring, and correction of environmental policy. The main ESE assumption, with regards to environmental protection, entails activities aimed at reducing air pollution, as well as reformation of water management systems, and rational exploitation of natural resources (GIOŚ, 2017). The most important objectives of the ESE strategy are presented in Figure 1.

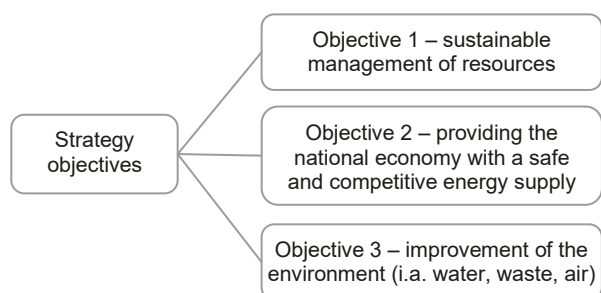


Figure 1. Objectives of the ‘Energy Security and the Environment’ Strategy (based on the data from (GIOŚ, 2017))

In 2018, a draft of ‘Environmental Policy of the State 2030’ (EPS 2030) was proposed, which was prepared in accordance with the provisions of the

Act on the Principles of Conducting Development Policy (MŚ, 2018). Ultimately, the proposed ESP was meant to replace the existing ‘Energy Security and the Environment – the 2020 Perspective’ strategy. Implementation of the ESE, until 2018, indicates that not even half of the assumed indicators were achieved (6 out of 15 indicators were implemented).

Implementation of the objectives set by the ESE strategy (as well as of the planned EPS 2030) requires various types of investments – both at the national and the regional levels, or even at the level of individual entities. The financial resources to implement pro-ecological investments are divided into (Barczak & Kowalewska, 2014, p. 39):

- funds from the central budget and from the budgets of local government units;
- funds from foreign sources (mainly from the EU);
- private funds (personal funds, credits, loans, etc.).

This article mainly involves environmental investments financed using EU funds. One of the basic assistance programs supporting pro-ecological investments is the Operational Program Infrastructure and Environment (OPI&E) which defines the directions of support for activities in the fields covered by the EU’s multiannual financial framework from 2014–2020 (previously for 2007–2013). According to the definitions set out in the Strategy, sustainable development means building a sustainable and competitive economy that efficiently uses resources. One of the main elements of the Strategy entails one of its main projects – a version of Europe that efficiently uses resources. The structure of the Program consists of four main thematic objectives:

- a low-emission economy,
- counteraction and adaptation to climate change,
- environmental protection,
- transport and energy security.

Program activities have been selected to contribute to the main goal of supporting the sustainable development of an economy that efficiently uses resources, is environmentally friendly, and promotes territorial and social cohesion. On the one hand, the Program should implement the assumptions defined by EU strategic documents, and on the other, by the goals set by Poland’s strategic documents in the areas it covers.

The legal basis is a forecast of the impact the Operational Program Infrastructure and Environment 2014–2020 will have is the act of November 3, 2008 on sharing information about the environment and its protection, the public participation in environmental protection, and environmental impact assessments (in short, the Environmental Impact

Assessment Act) (Journal of Laws, 2008). This Act contains an adaptation to the Polish legislation, of the Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 concerning the assessment of the environmental impact of certain plans and programs.

The Strategy is based on the principle of an entire country's sustainable development, on the economic, social, environmental, and territorial dimensions. It recognizes that it is important to properly shape the relationship between economic competitiveness, care for the environment, and quality of life. The document sets the goal of preserving and developing the environmental potential for the future generations, through an innovative approach and appropriate management of resources. The measures to improve the environment can improve the quality of life and health of a society.

As part of the strategic assessment of the environmental impact, the Forecast of the environmental impact was prepared for the Operational Program Infrastructure and Environment 2014–2020 in accordance with applicable regulations and arrangements. It was developed to comprehensively analyse the possible impacts on individual elements of the

environment that are provided in the Program, to assess the cumulative impact, to analyse the possibilities for using alternative solutions, and to provide compensatory measures. The Forecast is aimed at defining directions to support activities in the areas covered by the EU's multiannual financial framework from 2014–2020. On the one hand, the objectives that are defined by the EU strategic documents should be implemented; on the other, the objectives set by Poland's strategic documents, in areas related to the Program, should also be pursued. The main objective of the OPI&E is to support the implementation of the basic EU strategy 'Europe 2020', i.e. the Strategy for intelligent and sustainable development that is conducive to social inclusion, as well as supporting the implementation of the objectives set out by the Member States (EC, 2010). With the definitions contained in the Strategy, sustainable development consists of building a sustainable and competitive economy that efficiently uses resources.

The OPI&E, which resulted from the provisions referring to the strategic assessments and arrangements with the General Director for Environmental Protection, the Chief Sanitary Inspector and the relevant directors of maritime offices as well as from

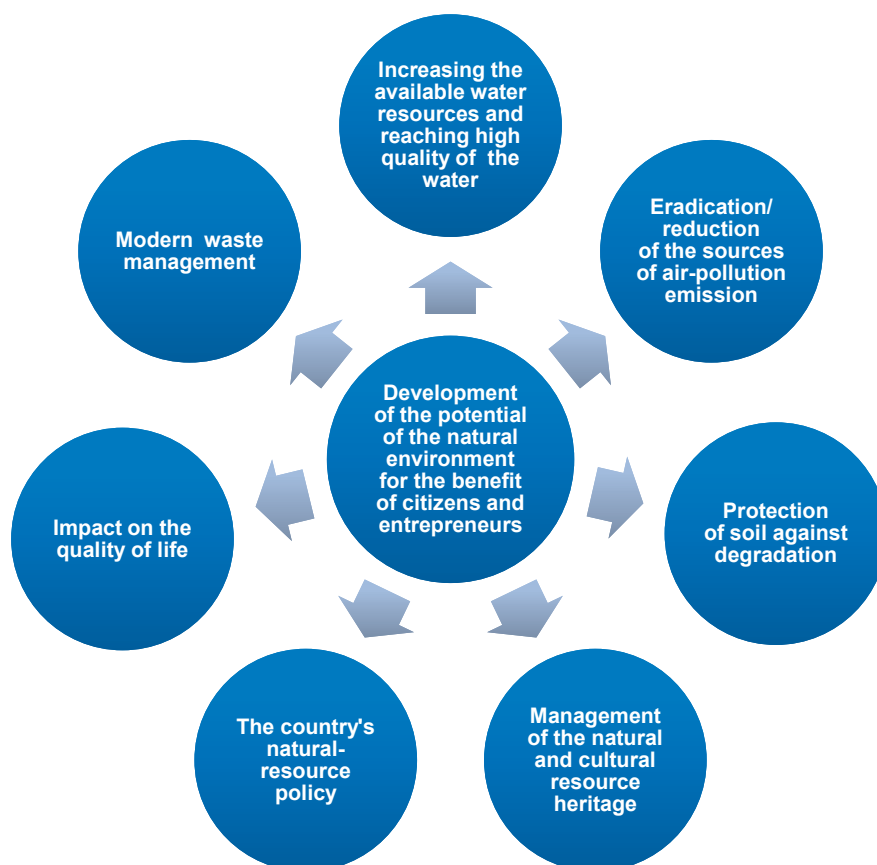


Figure 2. The intervention directions defined in the Strategy for Responsible Development (based on the data from (GIOŚ, 2017))

the guidelines set out by the Ministry of Regional Development, the guidelines regarding integration of the issues pertaining to the climate change and biological diversity into the strategic evaluations, as well as from own experience. After defining the scope of the environmental impact Forecast, it has been assumed that the initial elements to be evaluated will involve (EC, 2013):

- an analysis of the Operational Program project (OPI&E),
- an analysis of the actual state of the environment.

The first stage of the OPI&E project was analyzed, which covered the Program's fundamental structure, based on which conclusions were drawn from the general observations of the support areas regarding the actual activities that can be supported by the Program in order to clarify their possible environmental impacts. These activities were divided by the similarity of their environmental impacts, while the initial imaging, within the scope of the possible negative impacts, was made with regard to the type of project. Table 1 presents grouped projects.

Table 1. Priority projects from 2014–2020 (based on the data from (Atmoterm, 2013))

I Priority Axis	Reduction of the economy emissivity
II Priority Axis	Environmental protection, including adaptation to the climate change
III Priority Axis	Development of environmentally-friendly transportation infrastructure, which is important on the European scale
IV Priority Axis	Increase of accessibility to the European transportation network
V Priority Axis	Improvement of energy security
VI Priority Axis	Protection and development of cultural heritage
VII Priority Axis	Strengthening the strategic health-protection infrastructure
VIII Priority Axis	Technical support

The amount of funds allocated for environmental protection is presented in Table 2.

Table 2. II priority axis – Environmental protection (based on the data from (Atmoterm, 2013))

Eligibility period	January 1, 2014 – December 31, 2023
The name of the fund and the amount in €	FS, 3 508 174 166
The Managing Authority	The Ministry of Development

With regard to the Program, environmental changes can occur by such phenomena as: transformation of land, gradually increasing urbanization, new communication solutions, changes in climatic

conditions, changes in wind conditions, changes in water conditions, natural disasters, industrial catastrophes, transportation accidents and disasters, or emergency situations. Table 3 summarizes the analysis of the environmental impact of individual actions, which are specific to the Program within particular axes. Additionally, the probability of environmental changes gaining strength in the relations between the axes was assessed. There is high probability of occurrence of a change in the environment for axes II, III, IV, and V; an average probability for axes I and VI; a small probability for axis VII. Combined impact may also occur, particularly when activities under axes II – III – IV – V unfold at the same place and time.

Table 3. Matrix of the impact that project objectives under individual have on environmental changes (L - large, M - medium, S - small) (based on the data from (Atmoterm, 2013))

	Axis I	Axis II	Axis III	Axis IV	Axis V	Axis VI	Axis VII
	1	2	3	4	5	6	7
Axis I		M	M	M	M	S	S
Axis II	M		L	L	L	M	S
Axis III	M	L		L	M	M	S
Axis IV	M	L	L		L	M	S
Axis V	M	L	L	L		S	S
Axis VI	M	M	M	M	S		S
Axis VII	S	S	S	S	S	S	

As part of the study, an analysis of the OPI&E was carried out, with regards to internal cohesion, compliance with the EU strategic documents, and compliance with Poland's strategic documents. The aim of the analysis was to determine to what extent an OPI&E project implements the objectives set out in these documents and whether it is consistent with those objectives. Additionally, a review of the implementation indicators of the abovementioned documents was carried out from the perspective of the indicators of OPI&E implementation. During the course of the study, the results of positive implementation of the Program were also analyzed, primarily from the perspective of environmental protection and sustainable development. These conclusions were necessary for further work on the Forecast.

Analyzing the current state of the environment was performed next, and a leading baseline document was used for this assessment. The analysis mainly covered the areas of possible support in the field of environmental protection, from the perspective of the demand, and the possible impact of the OPI&E implementation. The general approach, remodified

depending on the specificity of a given environmental element, entailed a comprehensive assessment of the state of the matter, the change trends listed, the actions undertaken at the national level, and the effects of that activity. It also analyzed compliance with the necessary regulations e.g., in the air quality, as well as conclusions on the most important issues. The next stage consisted of a detailed analysis of the impact that individual groups that will be supported by the Program have on selected environmental elements. The starting point for the analysis was to determine the assessment criteria. This was done by analyzing the state of the environment and the most important problems, the legal requirements, the conclusions from analyzing the strategic documents, and from an analysis related to the evaluation questions. A GIS application was used to compare precise support areas with the current state of environmental protection (e.g., by overlapping maps of projects in communication areas with maps of protected areas). Independently, the cumulative impact of the entire OPI&E on individual elements of the environment were also analyzed, and preventive measures limiting the negative impact were indicated. When analyzing the environmental impact, the conditions of the cumulative impact of the activities included in the OPI&E and other known projects planned for implementation, were taken into account. As a result of the aforementioned analyses, the purposefulness and possibilities of using alternative solutions were considered. The effects, in the case of an absence of the Program, were also assessed.

Based on the estimation of the possible impact of the OPI&E on the environment, the following conclusions were drawn (Atmoterm, 2013):

1. It is estimated that implementing the entire Program will have a positive impact on the environment and will help solve many problems concerning the improvement of the environment.
2. Assessing the environmental benefits due to implementing the Program indicates that it solved environmental problems and supported financing environmental activities implemented in the country.
3. Without implementing the Program, national measures to protect the environment would have to be significantly reduced due to insufficient national resources.
4. The analysis of internal coherence, carried out with regards to the main objective of supporting an economy that efficiently uses resources, is environmentally friendly, and conducive to territorial and social cohesion (i.e., clean and effective energy, adaptation to climate change, and competitiveness) with the thematic objectives and to cohesion between the activities implemented under the axes concerned, demonstrated the Program's overall internal compatibility. A significant part of the investment priorities within the given axes complements and/or strengthens each another.
5. Based on an analysis of the objectives contained in the EU strategic documents, it has been found that the Program accomplishes the objectives contained in these documents. Slight differences and conclusions in this respect were included in the recommendations.
6. An analysis of the objectives contained in Poland's strategic documents showed that the Program accomplished these goals.
7. To limit the negative environmental impacts of the Program's, rules and recommendations have been proposed to monitor the effects of implementing the Program, as well as providing alternative solutions.

In addition, detailed recommendations have been formulated and proposed to be included in the documents detailing the scope of the Program or in the criteria used to select projects, i.e.:

- 1) As part of the Investment Priorities (IP) 6.5, it is proposed to promote integrated projects.
- 2) The content of IP 6.5 includes activities related to reducing pollution generated by industry, mainly by requiring an integrated environmental permit.
- 3) Many areas of support covered by the Program include the impact on air quality improvements, and lack a comprehensive approach to this problem and satisfactory support.
- 4) It is proposed to include support for such activities in the field of value analysis of ecosystem services and for activities involving the popularization of knowledge on this subject.
- 5) Educational activities should receive greater attention and comprehensive approaches in the Program. In the first place, the Program should include projects that cover civic education as effective forms of activities in the field of education and information.
- 6) In the Program, there is a lack of a need to rationalize the activities from the perspective of sustainable development with regards to the impact of reducing the consumption of fossil raw materials, waste reduction, and burning.
- 7) It is recommended to emphasize the advisability of using and promoting innovative solutions.
- 8) It is proposed to emphasize the advisability of energy support.

- 9) It is recommended that the managing, the intermediary, and the implementing institutions pay special attention to the correctness of EIA procedures.
- 10) Recovery of energy from waste should be limited to non-recyclable materials.
- 11) Support for the construction of municipal waste incineration plants should depend on developing a waste incineration concept, e.g., on a national scale.
- 12) Lack of activity to support a reduction in noise nuisances.
- 13) At the stage of project selection, it is recommended that all newly-developed projects supported in the Program are included in the strategic assessments prepared for these documents.

Conclusions

Structural funds constitute an important part of present-day enterprises. The current system of financing environmental protection in Poland provides funds for the implementation of many pro-ecological investments that have led to a serious improvement in the environment. Recently, innovative legal requirements, supported by a huge financial approval of the European Union, have turned out to be an unprecedented stimulus for changes and have increased environmental awareness in Poland. Currently, financing environmental protection investments in Poland is a growing area of activity for many institutions. Organizational units, institutions, and all entities implementing sustainable development and environmental education tasks in Poland can use financial assistance from structural funds, earmarked funds, foundations, and banks.

The Programs implemented using the European Regional Development Fund include the Operational Program Infrastructure and Environment, and the 2007–2013 budget amounted to EUR 28.3 billion. Both in the previous and the current perspectives, the largest investments carried out with the OPI&E funds included the construction of sewage systems and sewage treatment plants, the modernization of landfill sites, the development of waste utilization and recycling plants, and the modernization of heating and power plants. These investments are all very expensive, which is why support from the EU funds is so important. In turn, from 2014–2020, the environmental-protection budget planned from the OPI&E Program was EUR 27.5 billion (IBnGR, 2016).

Managing investment risk, in particular correctly identifying and properly measuring, is a multi-stage process. In order to guarantee correct risk identification, a reliable and thorough data analysis and the proper selection and interpretation of selected indicators is necessary. Proper measurement of investment risk and the EU financing of investments enables conscious selection of the proper strategy for credit portfolio management and the application of appropriate methods and tools to reduce risk. Investors must operate under strictly-defined economic, social, political, and legal conditions. In the contemporary market, which is characterized by high volatility, intensifying competition, and pressure from time and the globalization of processes and structures, investments and financing are always accompanied by risks of variable natures and scales, which can cause failure or loss. Investment companies bear inherent investment risks associated with running a business. There are, however, many other types of risks that are characteristic of business operations, including those implementing pro-ecological investments, such as credit risk, market risk, operational risk, liquidity risk, and legal and regulatory risks.

The hypotheses were confirmed, but there is still a need to deepen the research on the risk of pro-ecological projects. Ecological projects are often time-consuming and ultimately provide a smaller return for the investor than commercial investments.

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Verification of equivalence with reference method for measurements of PM₁₀ concentrations using low-cost devices

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Abstract

This study presents an assessment of the equivalence of measurements of particulate matter PM₁₀ concentrations using a low-cost electronic device as compared to the reference method. Data for the study were collected in accordance with the guidelines for research equivalence of the two devices operating in parallel. On this basis, a model correcting raw measurement results was developed. The best results were obtained for the model having the form of a second degree polynomial and taking into account air temperature. Corrected measurement results were used in the equivalence testing procedure. As a result, confirmation of equivalence was obtained for the vast majority of data sets generated from original measurements. This confirms the usefulness of the device as a tool for monitoring air quality.

Introduction

Correct measurement of concentrations of environmental pollutants is currently one of the biggest challenges of air monitoring. Measurements of particulate matter concentrations in ambient air play a special role. Increasing numbers of measurements contributes to a significant increase in the precision of emission forecasts but results in a need to reduce costs. The usual proper method for this type of measurement is the gravimetric method. It is quite expensive, requires cooperation with a specialized laboratory, and results may not come until several weeks after the measurement, while the measurements themselves are carried out with accuracy for one day at a time. This method cannot therefore be used to create a relatively cheap network monitoring concentrations of pollutants, for which the

measurements need to be available in real time. Alternatives to the gravimetric method include low-cost measuring devices that use a variety of methods to assess air quality. They eliminate all disadvantages of the reference method, but they also introduce their own problems (Owczarek & Rogulski, 2018; Owczarek, Rogulski & Badyda, 2018; Rogulski & Badyda, 2018; Sówka et al., 2018; Szulczyński & Gębicki, 2018).

Using an alternative to the gravimetric method yields different results. It is therefore necessary to assess whether the results obtained are sufficiently close to those expected. Are they random and what are the errors? Depending on these considerations, the results obtained with the alternative method may be considered equivalent to those from the reference method. The study of the equivalence of methods for assessing air pollution monitoring devices is

described in “Guide to the Demonstration” (GDE) (Dorozhovets, 2007a; Dorozhovets, 2007b; EC Working Group, 2010; Gębicki & Szymańska, 2011; PN-EN 12341, 2014).

The methodology for demonstrating device equivalence proposed by GDE has two stages: demonstrating the repeatability of measurements for at least two tested candidate devices, and examining and assessing the sizes of the differences between concentration measurements from the candidate devices versus the reference method. These differences are examined using a tool called measurement uncertainty, the results of which can be understood as the probability of obtaining results that are significantly different from the real ones. In addition, it is required that the equivalence test is carried out repeatedly (at least twice) and under different weather and field conditions, and that the data are collected from devices in close proximity (EC Working Group, 2010).

Aim of the study

The devices used in this study had not yet been tested for equivalence with the reference method for measuring PM₁₀ concentrations. It was therefore uncertain whether the results obtained from the devices were correct. There are a few publications on this device, for example (Owczarek & Rogulski, 2018; Owczarek, Rogulski & Badyda, 2018) but the scope of the collected data did not allow a full equivalence test; there was too short a period of measurement and the placement of devices did not fully comply with the guidelines for equivalence testing.

This study aims to demonstrate the equivalence of PM₁₀ measurements made using low-cost sensors compared to the reference method, and the usefulness of these sensors for measurements outside the State Environmental Monitoring system. These results will allow one to apply for a certificate of compliance of equivalence with the reference method for these devices.

The additional purpose of the test is the construction of a uniform function correcting the raw measurements of the analyzed devices to comparable values. This function could be placed in device controllers and could correct the received measurements on an ongoing basis.

Therefore, two questions were asked:

1. Is it possible to construct an effective corrective function and what is its form?
2. Is the device equivalent to the reference method after implementing this function?

Answers to these questions will have a significant impact on the further development of the tested device.

Measurement data

This study concerns measuring devices containing low-cost PM sensors using the optical method. The sensors suck outside air into a chamber, illuminate it with laser light, and then assess the concentrations of pollutants in the air by counting the number of reflections. Each sensor of this type, depending on the type of laser used and wavelength of the reflected light, can analyze the content of various pollutants in the air. This study focused on concentrations of particulate matter PM₁₀, i.e. dust with a diameter of no more than 10 µm.

Measurements of PM₁₀ concentrations were conducted in Nowy Sącz between February and July 2018. We used a measuring device containing two low-cost PM sensors located a few meters from the measuring station belonging to VIEP. The intakes of the measuring device belonging to VIEP and the low-cost sensor devices were at the same height. The device using low-cost sensors generated measurements of PM₁₀ concentrations every minute. These measurements were then aggregated to hourly averages and later daily averages. After removing unreliable observations from the sample using the Grubbs test, 129 observations were obtained from which two measurement campaigns were distinguished: winter, consisting of 47 measurements from February 1st to March 28th, and spring-summer, including 50 measurements from May 11th to June 30th. The results are presented in Figures 1 and 2 (Grubbs, 1950; ECS, 2013; GIOŚ, 2019).

Based on Figures 1 and 2, clear differences in the concentrations obtained by the reference method and the candidate method can be stated. These differences are particularly pronounced on days with low average daily air temperature. It is therefore necessary to correct measurements obtained from the tested devices in order to obtain comparable results. Many different functional correction models were tested using various independent variable vectors. The coefficient of determination and residual variance were used as measures to assess the quality of models. The best results of such correction were obtained with the model using a second-degree polynomial based on the indications of the candidate device and average air temperature (Boggs & Rogers, 1990; Myers, 1990; Leng et al., 2007; Green, Fuller & Baker, 2009; Czechowski, 2013).

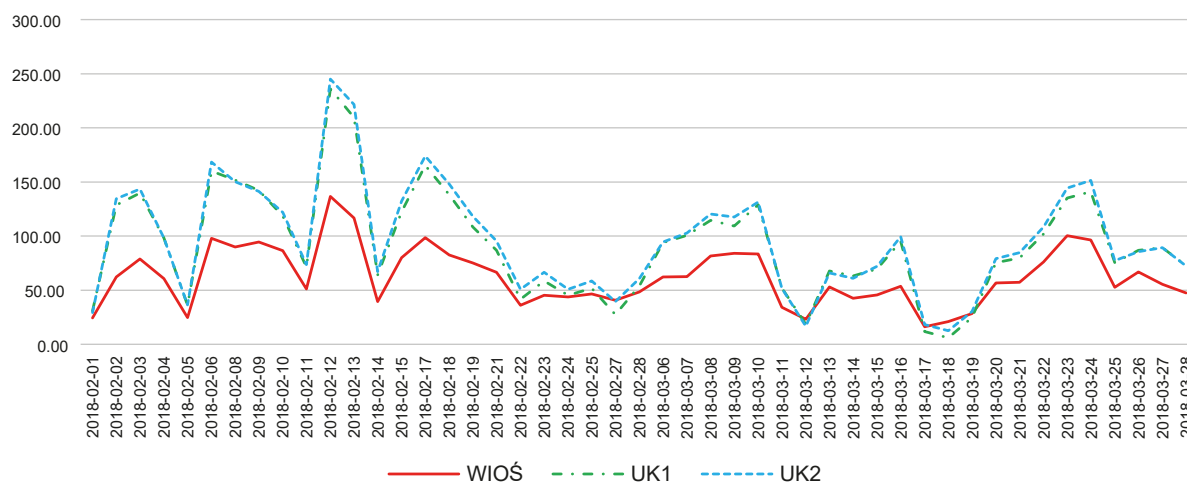


Figure 1. PM₁₀ concentrations (in µg/m³) from the reference method (VIEP) and tested devices (UK1 and UK2) in the winter campaign

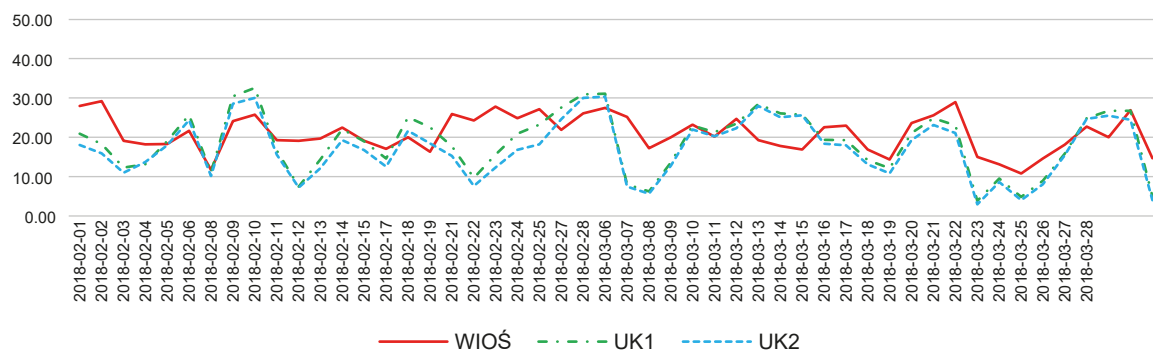


Figure 2. PM₁₀ concentrations (in µg/m³) obtained by the reference method (VIEP) and with tested devices (UK1 and UK2) in the spring-summer campaign

Ultimately, the correction model took the form:

$$y_{Ki} = 14.337 + 0.53 \cdot y_i - 0.0002 \cdot y_i^2 + 0.027 \cdot T_i \quad (1)$$

where: y_i – measurement values of the tested device on the i -th day, T_i – average temperature on that day.

The correction function could be implemented in the device driver using low-cost sensors, thanks to which it will be possible to use the obtained results

without further processing. The adjustment of measurements from the electronic device after correction to the reference data is presented in Figures 3 and 4.

Methodology

After correction, a satisfactory concentration adjustment was obtained (Figure 3 and Figure 4).

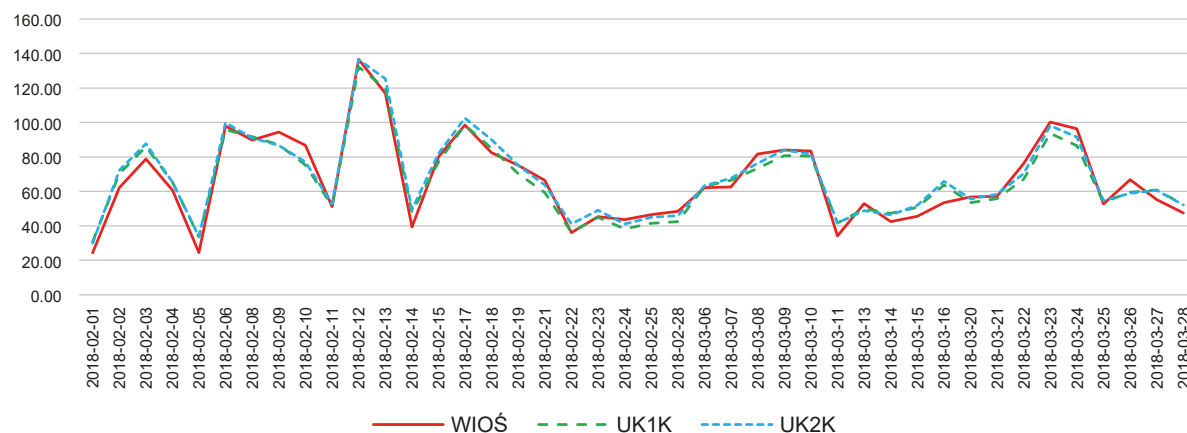


Figure 3. PM₁₀ concentrations (in µg/m³) obtained by the reference method (VIEP) and with tested devices (UK1 and UK2) after correcting the results with a second degree polynomial in the winter campaign

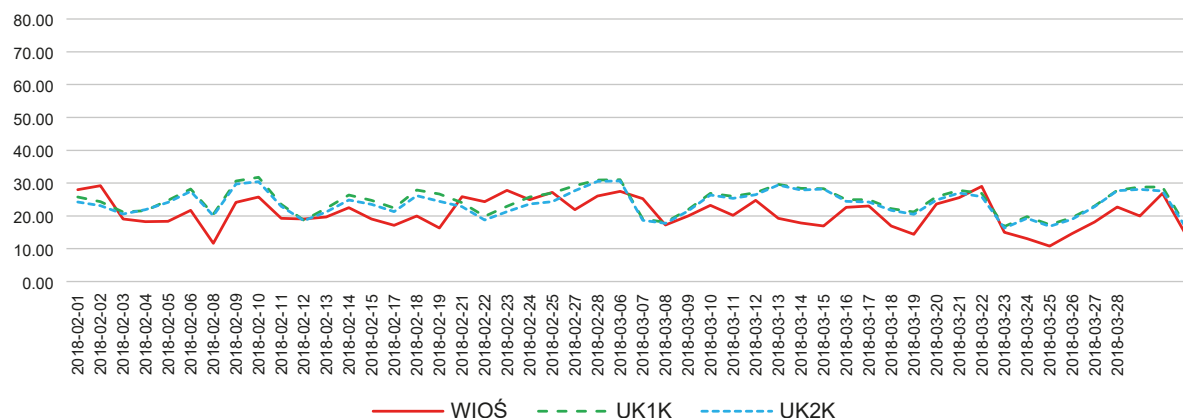


Figure 4. PM₁₀ concentrations (in µg/m³) obtained by the reference method (VIEP) and with tested devices (UK1 and UK2) after correcting the results with a second degree polynomial in the spring-summer campaign

This allowed for an equivalence procedure. First, the repeatability of results obtained by both tested devices (after correction) was examined. For this purpose, the concept of uncertainty between rehearsals (*between-sampler/instrument uncertainty*) was used, as described by the formula:

$$u_{BS}^2 = \sum_{i=1}^n \frac{(y_{1,i} - y_{2,n})^2}{2n} \quad (2)$$

The uncertainty of measurements is satisfactory if it does not exceed $u_{BS} = 2.5 \mu\text{g}/\text{m}^3$ and should be tested for all observations, and separately for observations above $30 \mu\text{g}/\text{m}^3$ (high concentrations of PM₁₀). In both cases, the values of the calculated uncertainty does not exceed the limit value.

Uncertainty for all observations is $u_{BS0} = 1.527$ while for high concentrations $u_{BS30} = 1.977$. On this basis, it can be concluded that the devices work and give similar results, recorded PM₁₀ concentrations are reproducible, and differences in observed measurements are small.

The reference method was then compared with the candidate devices. The comparison is made for all collected data, broken down into measurement campaigns, and separately for observations with concentration values greater than or equal to $30 \mu\text{g}/\text{m}^3$.

It is also assumed that each of the mentioned sets should include at least 40 observations.

The basic measure used to compare candidate devices with the reference method is the total uncertainty of measurements. It contains estimates of all sources of measurement errors occurring in the equivalence testing process and can be expressed by the formula:

$$u_{CM}^2(y_i) = \frac{RSS}{n-2} - u^2(x_i) + [a + (b-1) \cdot x_i]^2 \quad (3)$$

where:

$u^2(x_i)$ – the measurement uncertainty of the reference method, most often $0.67 \mu\text{g}/\text{m}^3$;

$[a + (b-1) \cdot x_i]^2$ – the measurement uncertainty arising from the deviation of the linear regression

$$y = a + b \cdot x \quad (4)$$

between the results of the reference and candidate methods from the identity function (it is assumed that in this model a is statistically insignificantly different from 0, while the directional factor b is statistically insignificantly different from 1);

$RSS/(n-2)$ – the rest variance of the linear model.

Based on the total uncertainty (3), the relative total measurement uncertainty is constructed:

$$w_{CM}^2(y_i) = \frac{u_{CM}^2(y_i)}{y_i} \quad (5)$$

and extended measurement uncertainty:

$$W_{CM} = k \cdot w_{CM} \quad (6)$$

assuming y_i and 50 for PM₁₀, and k equal to the critical value in the t distribution for the corresponding number of degrees of freedom (GUM, 1999; Dorozhovets, 2007a, 2007b; EC Working Group, 2010; Working Group, 2013).

The candidate method may be considered correct if the value of the expanded uncertainty W_{CM} does not exceed the assumed level of allowable uncertainty for devices measuring PM₁₀ set at 25%.

If the limit value is exceeded by the uncertainty (6), it is possible to use a calibration function built on the basis of a linear regression function (2) of the form:

$$y_{CAL} = \frac{y - a}{b} \quad (7)$$

to correct the concentration values obtained from the candidate method. After its application, the total measurement uncertainty can take the form depending on the significance of regression parameters (2):

$$u_{CM}^2(y_i) = \frac{RSS}{n-2} - u^2(x_i) + [c + (d-1) \cdot x_i]^2 + [u^2(a) + x_i^2 \cdot u^2(b)] \quad (8)$$

where $u(a)$ and $u(b)$ are standard errors of estimation of parameters a and b for function (2) and c and d are parameters of the new regression function calculated after calibration.

If the value of the expanded uncertainty W_{CM} still does not meet the criterion of 25% of the allowable uncertainty, the candidate method cannot be considered equivalent to the reference method.

Obtained results

In accordance with the “Guide to ...” (EC Working Group, 2010) methodology, the values of extended measurement uncertainty were calculated for all data groups, i.e. for each candidate device and for all measurements, broken down into measurement campaigns, and for observations with values greater than 30. The calculations were repeated in all cases where it was necessary to use a calibration function. The results are shown in Table 1.

The analysis shows that device U1 successfully passed the equivalence test for all generated data sets. The values of expanded uncertainty were between 0.195 and 0.241 and were definitely lower than the allowable value of 0.25.

In the case of device U2, the tests carried out for all data and for the winter campaign gave positive results (expanded uncertainty values 0.21 and 0.22, respectively). In the case of the spring-summer campaign, the equivalence test result was negative. The value of expanded uncertainty (0.283) for

uncalibrated data slightly exceeds the allowable value. Unfortunately, the use of the calibration function not only did not improve uncertainty, but rather significantly worsened it. A similar situation occurred for the data set containing observations over $30 \mu\text{g}/\text{m}^3$ for device U2. The original uncertainty value (0.262) and the value after calibration (0.274) slightly exceed the limit-value.

It can be assumed that both negative equivalence test results were caused by imperfections of the corrective function (1). It will be necessary to further improve it using more data.

Conclusions

For the analyzed low-cost devices it is necessary to apply a correction function. This study showed that the function can be based on a second-degree polynomial using PM_{10} concentrations and temperature values. This function has the form:

$$y_{Ki} = 14.337 + 0.53 \cdot y_i - 0.0002 \cdot y_i^2 + 0.027 \cdot T_i$$

The correction function should be integrated into the device controller so that the device results will more closely match the reference values.

The tested devices passed the equivalence test with the reference method in most of the tested data configurations, which should be considered satisfactory. It can be assumed that the PM_{10} concentration values obtained from mobile devices after correction well approximate the concentration values obtained by the reference method. The values of expanded uncertainty were from 0.195 to 0.241. Only in the case of a campaign covering warm days did the uncertainty expand to a negative value of 0.614 for the U2 device. Thus, the study showed that it is possible to apply for a certificate of equivalence for the tested devices.

It is necessary to continue research on devices containing low-cost optical sensors in order to

Table 1. Results of equivalence tests for low-cost measuring devices for all data groups

Device	Feature	All	Campaign 1	Campaign 2	Greater than 30
U1	Expanded uncertainty	0.195	0.218	0.201	0.241
	Calibration function	is not necessary	is not necessary	is not necessary	is not necessary
	Expanded uncertainty after calibration	–	–	–	–
	Result of the equivalence test	Passed	Passed	Passed	Passed
U2	Expanded uncertainty	0.210	0.220	0.283	0.262
	Calibration function	is not necessary	is not necessary	$y_{CAL} = 1.443y - 13.303$	$y_{CAL} = y - 4.307$
	Expanded uncertainty after calibration	–	–	0.614	0.274
	Result of the equivalence test	Passed	Passed	Not passed	Not passed

improve them. It is also necessary to carry out equivalence tests in other locations to verify equivalence for them.

The data obtained in this way should also be used to further improve the internal correction function so that the measurements obtained will be equivalent to those of the reference method under all conditions.

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Management and Quality Science

Sustainable development reporting of selected socially responsible listed companies

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Abstract

The RESPECT Index (RI) is the first index of socially responsible companies in Central and Eastern Europe and has been operating in Poland since 2009. In accordance with its philosophy, the RI includes listed companies showing the highest standards of quality in corporate governance and information governance regarding their impacts on the natural environment, society, and employees. Do the non-financial reports of these companies confirm that they meet these standards? This article attempts to answer that question, which aim can also be described as the qualitative assessment of the non-financial reports of the largest listed Polish companies in the RESPECT Index, with particular emphasis on analyzing the structure and content of the companies' non-financial information disclosures. In order to achieve this goal, the paper first defines non-financial information and its usefulness to stakeholders in modern enterprises. Secondly, the paper discusses problematic aspects of non-financial reporting. And the third part of the paper is a qualitative analysis of the non-financial reports of 12 out of the 31 Polish companies in the RESPECT Index. Finally conclusions are that the research conducted confirmed a wide variety of these companies' disclosures, and on the other hand, exposed some deficiencies in published reports, including their narrative character, limited comparability across time and space, and lack of external verification. All this shows that it is not enough to be a socially responsible company; you must also report this activity skillfully. This study used the following research methods: literature review, analysis of legal regulations, desk research, and inductive and synthetic reasoning strategies, in order to formulate conclusions.

Introduction

In the society of the age of information and in light of the idea of sustainable development, accounting, understood as an information system of enterprise, has faced the need to revise its current method of communication with its environment – that is to say, financial reporting. The response of corporate accounting to growing demands for economic, social, and environmental information, posed by various groups of stakeholders, has become 'non-financial reporting,' also called 'sustainable development,' 'social,' or 'business' reporting. In Poland, the disclosure of extended non-financial

information became mandatory in 2017. Long before that, the good practices of listed companies and their care for lasting relations with stakeholders resulted in the Warsaw Stock Exchange announcing the first index of responsible companies in Central and Eastern Europe, the so-called RESPECT Index (RI), in 2009. The condition for inclusion in this elite group is a detailed three-stage verification process conducted by the WSE and the Association of Listed Companies Issuers. As of January first, 2019, the RESPECT Index included 31 companies.

The purpose of this article is the qualitative assessment of the non-financial reports of the largest listed companies on the RESPECT Index, with

particular emphasis on analysis of the structure and content of non-financial information disclosures by the surveyed entities. In order to achieve this goal, the following research hypothesis was adopted: The growing value placed on sustainable development requires increasing the utility of non-financial reports to stakeholders.

The analysis here presents itself as a contributing voice in the discussion of non-financial reporting in Poland. The presentation consists of three parts. The first part defines non-financial information and its usefulness for stakeholders of modern enterprises. The second part discusses problematic aspects of non-financial reporting. The third presents a qualitative analysis of the non-financial reports of the largest listed companies in the RESPECT Index, leading to a synthetic assessment of the companies included in the study.

The following research methods were used in this study: study of the literature, analysis of legal regulations, desk research of non-financial reports, and inductive and synthetic strategies in order to formulate conclusions.

The essence of non-financial information and its usefulness to users

‘Non-financial information’ is a commonly used term in both business theory and practice. The disclosure of non-financial information has in recent years become a global phenomenon (and recently regulated by law in Poland), which is a response to the constantly evolving information needs of stakeholders. Nevertheless, there are still significant difficulties in defining non-financial information. In the *strict* sense, financial information is expressed in monetary units and generates financial consequences if disclosed in non-financial statements. Therefore, non-financial information should be presented in non-monetary units, and not directly cause financial consequences when presented in non-financial statements. According to J. Krasodomska, the concept of non-financial information should include all information (descriptive and numerical) disclosed (obligatorily or optionally) as part of annual reporting (in addition to financial statements and auditors’ opinions and reports). One can find more on non-financial information in: (Krasodomska, 2010; Walińska, 2013; Kamela-Sowińska, 2016; Zyznarska-Dworczak, 2016; Waniak-Michalak, 2017). This paper underlines the following features that distinguish non-financial information from financial (Krasodomska, 2014, pp. 26, 28):

- its youth (it has been disclosed for slightly less than 25 years, as compared to financial information, which has been disclosed for 500 years),
- the possibility of including prospective data for a wider group of users,
- high levels of subjectivism (with no obligation to be verified by certified auditors).

This definition is based on the criterion of place of disclosure. As indicated by the authors of this paper, the criterion of satisfying the information needs of users is equally important, according to which financial information satisfies information needs regarding financial and property situations and performance, while non-financial information is that which satisfies users’ information needs regarding activities impacting employees, society, the natural environment, respect for human rights, and counter-acting corruption.

Regardless of its financial or non-financial nature, information should be of adequate quality (usability). The European Commission on Communication Guidelines for non-financial reporting (methodology for reporting non-financial information) (European Commission, 2017) presents optional qualitative attributes for non-financial disclosures. They are presented in Table 1.

It can be assumed that all qualities of non-financial information presented in Table 1 ultimately affect its usefulness. The greater the usefulness of information in the *strict* sense, the higher the ability to satisfy the information needs of users on the one hand and to more effectively implement information-decision processes on the other hand. In the *broad* sense, the greater the usability of the non-financial information, the potentially higher the quality of the non-financial reporting.

Selected aspects of non-financial reporting in Poland

Non-financial reporting is not a new phenomenon resulting from current trends. Although the obligation to implement it by public unit trusts was legally sanctioned in Poland in 2017 and stems from EU regulations (Directive, 2014), by the end of 2016, more than 300 reports had been published voluntarily. Although managers’ awareness in this area is constantly growing, the lack of appropriate standardization and harmonization results in great variation among submitted non-financial reports in terms of content and form, thus limiting the possibility of comparison across time and space. Furthermore, it should be noted that the disclosure of non-financial

Table 1. Desirable quality and characteristics of disclosed non-financial information (derived by authors from: European Commission, 2017, pp. 5-9)

No.	Quality	Description
1.	Materiality	Non-financial information should allow (to the extent necessary) understanding the development, performance, and situation of the company and the impact of its activities. Material information is information that, when omitted or improper, may affect decisions made by users. It is therefore crucial to disclose sufficient information on issues likely to result in major risks associated with severe outcomes, as well as information regarding outcomes that have already occurred. The company should assess which information is material based on analysis of the relevance of the information to understanding the company's development, results and situation, and the impact of its activities. Such assessment should take into account endogenous and exogenous factors, including the company's business model, strategies and their main risks, main sectoral issues, interests and expectations of relevant parties, and the impacts of activities with factors related to public policy and legal regulations.
2.	Fairness, balance, and understandability	A non-financial statement should give fair consideration to favorable and unfavorable aspects, and information should be assessed and presented in an unbiased way, clearly distinguishing facts from views or interpretations. The statement should consider all available and reliable data, taking into account the information needs of different users. Users of information should not be misled by material misstatements, omission of material information, or the disclosure of immaterial information. The fairness, balance, and understandability of information can be increased by, among other factors--appropriate corporate governance arrangements, reliable evidence, internal control and reporting systems, effective party engagement, independent external assurance, and the use of plain language and consistent terminology, avoiding boilerplate terms and providing definitions for technical terms.
3.	Comprehensiveness and conciseness	A report on non-financial information should include information relating to, at a minimum, environmental, social, and employee matters, respect for human rights, anti-corruption and bribery matters, and any other relevant information. Its disclosure is expected to provide a comprehensive picture of a company during the reporting year. At the same time, the breadth and depth of information provided should depend on its significance. A company should focus on providing the breadth and depth of information that will help users understand its development, performance, position, and impact. The non-financial statement is also expected to be concise and avoid immaterial information. Generic or boilerplate information that is not material should be avoided, and internal cross references or signposting should be used in order to be as concise as possible and limit repetition.
4.	Strategy and forward-looking	The statement is expected to provide insights into a company's business model, strategy, and implementation, and explain multi-scale implications of the information reported, as well as the company's strategic approach to relevant non-financial issues regarding its business profile, goals, and activities. This approach ensures monitoring of commitments and progress in achieving objectives and increases transparency to interested parties. Goals and benchmarks can be presented quantitatively or qualitatively, including scientific research. Forward-looking information enables users to better assess the resilience and sustainability of a company's development, position, performance, and impact over time. It also helps users measure the company's progress towards achieving long-term objectives.
5.	Interested party orientation	It is important that the statement provide information that takes into account the needs of all relevant parties. This means focusing on the information needs of groups rather than individuals or only typical parties, or those with unreasonable information demands. These groups might include, among others, investors, workers, consumers, suppliers, customers, local communities, public authorities, vulnerable groups, social partners, and civil society. Companies should provide relevant, useful information on their engagement with relevant parties, and how the information needs of those parties are taken into account. The desired action is for the company to disclose information about its engagement with interested parties and explain how it influences company decisions, performance, and impact.
6.	Consistency and coherency	A non-financial statement is expected to be consistent with other elements of the management report. That way the information is more useful, relevant, and consistent. The management report should be viewed as a single, balanced, and coherent set of information. Explaining key linkages makes it easier for interested parties to understand material information and inter-dependencies. The content of the non-financial report should be consistent over time. This enables users of information to understand and compare past and present changes in a company's development, position, performance, and impact, and relate reliably to forward-looking information. Consistency in the choice and methodology of key performance indicators is important to ensure that the non-financial statement is understandable and reliable. However, constant monitoring and updates may be necessary.

information is often carried out for a different purpose than originally expected. This is related to the problematic aspects of non-financial reporting discussed here below.

The first of the problematic aspects is the phenomenon of *greenwashing*, identified and described

in 1986 by environmentalist Jay Westervelt (who discovered that the hotel industry falsely promotes the reuse of towels as an environmental protection strategy, whereas in fact, it is simply a form of savings). One can often get the impression that non-financial reporting is used primarily as a marketing

tool. Its content, in spite of compliance with applicable laws and norms, in some sense misrepresents the activities conducted and/or their impact on the natural environment, society, employees, respect for human rights, and opposition to corruption.

In practice, the following forms (sins) of *greenwashing* can be distinguished as part of non-financial reporting (Baack, Harris & Baack, 2013, p. 181):

- hidden trade-off – highlighting the seemingly pro-ecological characteristics of products while marginalizing (hiding) attributes that are not environmentally friendly or even non-ecological;
- no proof – presenting claims and assumptions that cannot be substantiated by publicly available evidence or certificates provided by independent entities;
- vagueness – using vague and imprecise expressions that are irrelevant and often deliberately misleading, e.g. about the green character of the product;
- false labels – using artificially created ecological labels that could lead consumers to believe incorrectly that the product has been certified by an independent entity;
- irrelevance – underlying and highlighting the environmental issues taken into account by the product, as if they are company's unique accomplishments, when they are legally imposed;
- the lesser of two evils – giving consumers a sense of environmental friendliness with products that do not benefit the environment, and often harm it;
- fibbing – presenting ecological claims that are partly or completely untrue.

The indicated sins of *greenwashing*, in the area of environmental protection, are also committed by dishonest companies regarding issues impacting society, employees, respect for human rights, and corruption. In such cases, the narrative nature of non-financial reporting is exploited in a form of aggression against the ideal of sustainable development. *Greenwashing* also contributes to the creation or deepening of another problem, i.e. information gaps in financial statements. It is an aspect of broadly understood reporting (including non-financial reporting) consisting of information asymmetry, i.e. differences between information possessed and information that can be obtained, which does not fully satisfy the information needs of stakeholders. In the *strict* sense, the asymmetry of information can be understood as the state of having information of an inadequate usability level, i.e. information that, in the non-financial dimension, lacks the characteristics of quality presented in Table 1.

Inadequate satisfaction of information needs causes distortion of information and decision-making processes, resulting in low effectiveness of decisions, and thus inefficient management. The information gap in, on the one hand financial statements, means lack of full information about the economic position, financial situation, and company performance and, in non-financial statements on the other hand, inadequately useful, standardized information on activities regarding the natural environment, society, employees, respect for human rights, and counter-acting corruption.

These information gaps, and the simultaneous desire to harmonize frameworks for financial and non-financial reporting, result in a dilemma regarding the scope of disclosed information. The principle of relevant and faithful representation in the IFRS (International Financial Reporting Standards) conceptual framework (Conceptual Framework, 2018) stands, in part, in opposition to the features of significance and brevity emphasized in the Communication of the European Commission. Moreover, although the obligation of financial and non-financial reporting results from the same legal act, i.e. the Accounting Act, the provisions regarding non-financial disclosures are relatively liberal, which is selectively illustrated in Table 2.

To summarize, Table 2 represents selected clauses in Article 49b of the Accounting Act, which according to the authors of this paper, can be synthesized as follows:

- clause 1 – obligation to submit non-financial reporting by all entities to which the Act applies;
- clause 2 – more detailed specification of the scope of information that must be disclosed by the entities distinguished in clause 1;
- clause 5 – indication of the minimum policies necessary to be applied by the distinguished entities;
- clause 8 – specification of an exhaustive list of regulations as the basis for disclosing non-financial information;
- clause 9 – unification and parameterization of forms for non-financial reports for specific groups of entities, e.g. in the form of subsequent annexes to the Act;
- moreover, introducing an obligation to certify, for example, by an expert auditor, financial and non-financial reports (More about this assurance in: The External Assurance of Sustainability Reporting, 2013).

The presented suggestions synthesize both the literature analysis and legal acts, as well as the selected non-financial reports discussed in the next section.

Table 2. Characteristics of selected provisions of the Accounting Act regarding non-financial reporting (derived by authors from: (Journal of Laws, 2019, Article 49b))

Article 49b, clause:	Description
1.	The obligation to disclose extended non-financial information concerns public unit trusts, i.e. entities in which, for two consecutive years, the average annual employment is over 500 people and one of two criteria has been exceeded – total balance sheet assets exceed 85 million PLN or net revenue from sales of goods and products exceeds PLN 170 million.
2.	The statement must include at least: a) a concise description of the entity's business model; b) key non-financial performance indicators related to the company's operations; c) a description of the policies used by the entity with respect to social, employment, and environmental issues, and issues related to respecting human rights and opposing corruption and bribery, and a description of the results of applying those practices; d) a description of due diligence procedures; e) a description of major risks that may have an adverse impact on the company's operations, including a description of the management of such risks.
5.	If an entity does not apply the policy to one or more social, employment, or environmental issues, or issues related to respecting human rights, or opposing corruption and bribery, or does not include a description of the results of applying those practices in the non-financial reporting, the entity shall give reasons for doing so.
8.	When reporting non-financial information, an entity may apply any rules, including their own rules, and national, EU, or international standards, norms, or guidelines. The entity shall include information about the principles, standards, norms, and guidelines applied in the statement.
9.	An entity may choose not to report non-financial information if they produce a report on non-financial information together with the management report and publish it on their website within six months of the balance sheet date.

This approach potentially limits the phenomenon of *greenwashing* by ensuring proper standardization, harmonization, and assurance. According to the authors of this paper, financial and non-financial information are closely related and their simultaneous presentation gives a multi-dimensional picture to stakeholders.

Qualitative analysis of non-financial reports of the largest listed companies in the RI

The RESPECT Index (RI) is the first index of responsible companies in Central and Eastern Europe, which has been operating in Poland since 2009. As a result of verification of the fulfilment of the adopted criteria, the RESPECT Index only includes listed companies operating in accordance with the best management standards in the field of corporate and information governance and in relationships with investors, as well as in the areas of ecological, social, and employee impacts (Respect Index, 2010). In order to be included in this prestigious group, the candidates undergo a three-step verification. First of all, only companies with the highest liquidity, i.e. those included in the indices, WIG20, mWIG40, or sWIG80, can apply to RI. Secondly, the company's practices in the field of corporate and information governance as well as relationships with investors are subject to verification. The current and periodic

reports are reviewed in detail. The third stage of verification is the completion of a questionnaire aimed at assessing the company's level of maturity in sustainable development. This questionnaire consists of 49 questions divided into three areas: Environmental (environmental factors), Social (social factors), and Governance (economic factors).

In the newest, 12th edition of the competition, 31 entities entered the RESPECT Index. The largest companies, i.e. those included in the WIG-20 index, were selected from this group for further research. An enumerative list of the 12 companies whose reports were accepted for further examination is presented in Table 3.

The research covered non-financial reports for 2017. It is worth mentioning that the analysis of reports for 2018 was not possible due to the open reporting period at the time of writing the article. Assuming that the financial year coincides with the calendar year for the preparation of financial statements, including non-financial information for 2018, companies have until the end of March 2019, while annual reports should be approved by June 30, 2019 at the latest (Accounting Act, Article 52 (1) and 53 (1)). The basic characteristics of the non-financial reports adopted for the audit – the names, places of publication, legal bases, lengths, and external verifications of the reports – are presented in Table 4.

Table 3. List of quoted companies listed simultaneously on WIG-RI and WIG-20 (based on (GPW, 2019))

No.	Company's name	Sector	Stock Market Sector Index
1.	Bank Pekao S.A.	Commercial banks	WIG-BANKI
2.	CCC S.A.	Clothing and shoes	WIG-ODZIEŻ
3.	Grupa LOTOS S.A.	Extraction and production	WIG-PALIWA
4.	Jastrzębska Spółka Węglowa S.A.	Coal mining	WIG-GÓRNICTWO
5.	KGHM Polska Miedź S.A.	Metal mining	WIG-GÓRNICTWO
6.	mBank S.A.	Commercial banks	WIG-BANKI
7.	Orange Polska S.A.	Telecommunications	WIG-TELEKOMUNIKACJA
8.	PGE Polska Grupa Energetyczna S.A.	Energy	WIG-ENERGIA
9.	PGNIG S.A.	Extraction and production	WIG-PALIWA
10.	PZU S.A.	Insurance companies	WIG-MS-FIN
11.	Santander Polska S.A.	Commercial banks	WIG-BANKI
12.	Tauron PE S.A.	Energy	WIG-ENERGIA

Table 4. Characteristics of non-financial reports for 2017 of the largest listed companies in the RI (based on (GRI, 2019) and (CSRinfo, 2019))

No.	Company's name	Name of non-financial report	Publication place of the report			Legal basis	Report page count	External verification of the report
			Web-site	CSR-info	GRI Database			
1.	Bank Pekao S.A.	Statement on non-financial information	yes	no	no	GRI-G4	47	no
2.	CCC S.A.	Towards sustainable development. The first non-financial report	yes	yes	no	GRI Standards-Core	68	no
3.	Grupa LOTOS S.A.	Integrated annual report	yes	no	no	GRI-G4	193	no
4.	Jastrzębska Spółka Węglowa S.A.	Report on sustainable development	yes	yes	no	GRI Standards-Core	116	no
5.	KGHM Polska Miedź S.A.	Report on non-financial information	yes	yes	yes	GRI-G4 – Core	114	no
6.	mBank S.A.	Integrated report	yes	yes	yes	GRI-G4 - Core	232	no
7.	Orange Polska S.A.	Integrated report	yes	yes	yes	GRI Standards-Core	160	yes
8.	PGE Polska Grupa Energetyczna S.A.	Report on non-financial information	yes	yes	yes	GRI-G4	65	no
9.	PGNIG S.A.	Annual report	yes	no	yes	Non GRI	97	no
10.	PZU S.A.	Report on non-financial information	yes	no	yes	Selected guidelines of GRI	79	no
11.	Santander Polska S.A.	Report on sustainable development	yes	no	no	GRI-G4 - Core	The html format with hyperlinks	yes
12.	Tauron PE S.A.	Integrated report	yes	yes	yes	GRI-G4 - Core	The html format with hyperlinks	yes

A preliminary analysis of the reports showed a certain arbitrariness in their naming. The three prevailing terms are: 'statement / report on non-financial information,' 'report on sustainability development,' and 'integrated report.' The last one occurs in the cases of four surveyed companies and, as already mentioned, is an advanced form of reporting, being a compilation (integration) of financial and non-financial information, which justifies the above-average volume of these reports. As of June 1, 2019, all

companies included in the study placed their non-financial reports on websites. Access to them was not difficult. Some of them additionally posted reports in the largest Polish Register of Reports run by CSRinfo (7 companies) and in the international GRI Sustainability Disclosure Database run by the Global Reporting Initiative (seven companies). It is also worth emphasizing that almost all of the surveyed entities eleven out of twelve companies) prepared reports based on GRI regulations (GRI-G4 or GRI

Table 5. Qualitative analysis of non-financial reports for 2017 of the largest listed companies in the RI

No. Company's name	The scope of disclosures in the report			The form of disclosures in the report			Comparability	
	Economic issues	Environmental issues	Social issues	Narrative information (verbal description)	Information in graphic elements	Information expressed numerically or as percentage	Comparability of information across time	Comparability of information across space
1. Bank Pekao S.A.	a	a	a	a	c	c	c	c
2. CCC S.A.	a	a	a	a	b	b	c	c
3. Grupa LOTOS S.A.	a	a	a	a	a	a	a	b
4. Jastrzębska Spółka Węglowa S.A.	a	a	a	a	b	a	a	b
5. KGHM Polska Miedź S.A.	a	a	a	a	a	b	b	b
6. mBank S.A.	a	a	a	a	b	b	a	b
7. Orange Polska S.A.	a	a	a	a	a	a	a	b
8. PGE Polska Grupa Energetyczna S.A.	a	a	a	a	a	a	b	b
9. PGNIG S.A.	a	a	a	a	a	a	a	b
10. PZU S.A.	a	a	a	a	a	b	a	b
11. Santander Polska S.A.	a	a	a	a	a	b	a	b
12. Tauron PE S.A.	a	a	a	a	a	a	a	b

a = high grade, b = mean grade, c = low grade

Standards), which are considered the most flexible (Leoński & Beyer, 2016, p. 70), transparent (Boiral, 2013, p. 1041), and useful (Wilburn & Wilburn, 2013, p. 64) model of non-financial reporting in the world. Noteworthy is the fact that only three companies, i.e. Orange Poland, Santander Poland and Tauron PE, decided to perform independent assurance for published reports. External verification of the report, although giving only limited certainty, legitimizes the information contained therein and testifies to the reliability of the audited company.

In order to assess whether the companies included in the RESPECT Index indeed meet the highest standards of quality for non-financial reporting and verify the research hypothesis set out in the introduction, a detailed analysis was conducted, the results of which are summarized in Table 5. The subjects of assessment were the scope of disclosures, their form, and comparability of the presented information.

An initial qualitative analysis of all adopted reports confirmed a wide range of disclosures for sustainable development, i.e. economic, environmental, and social information. All companies obtained very high marks, which justifies their presence in the RESPECT Index. However, it should be emphasized that these companies represent various sectors of the economy and only sectoral analysis would allow detailed inferences in this matter.

The second stage of the research was analysis of the types of disclosures in terms of their form. Forms

of information distinguished were subjective narrative (verbal description), user-friendly graphical elements (charts, infographics), and the most objective information expressed numerically or as percentages (e.g. the number of employed women). According to the authors of this paper, five of the surveyed companies – Grupa Lotos, Orange Polska, PGE Polska Grupa Energetyczna, PGNIG and Tauron PE – maintained a good balance between forms of submitted information. Thanks to that, their reports were clear, distinct, and understandable. The reports of other companies were dominated by verbal description, and the number of disclosures in graphical, numeric or percentage form was assessed as insufficient.

The last stage of analysis concerned the possibility of comparing non-financial information across time (e.g. the presentation of the same numerical data for two consecutive years) and space (the possibility of comparing the same indicator for two or more companies). The results of the analysis in terms of comparability of information across time were mediocre; only 8 out of 12 companies presented data for 2016. Moreover, comparability of reports across space was difficult and sometimes even impossible. The freedom in the presentation of non-financial information allowed by Polish law results in a non-uniform structure of disclosures, which significantly limits their comparability.

In summary, the analysis on one hand, confirmed the high scope of the disclosures by these companies,

and on the other hand, exposed some deficiencies of published non-financial reports. This means that the research hypothesis stated in the introduction – that the growing importance placed on the idea of sustainable development requires increasing the utility of non-financial reports for their stakeholders – has been positively verified. The narrative nature, limited comparability, and lack of external verification are just some of the dysfunctions / deficiencies of the analyzed reports. Similar conclusions have been reached by, among others, (Sikacz & Wołczek, 2017, p. 178; Kutera & Zyznarska-Dworczak, 2018, p. 108; Rubik, 2018, p. 219). It is not enough to be a socially responsible company, you must also skillfully report this activity.

Conclusions

The growing value placed on the idea of sustainable development is so strong now that it constitutes a strategically important element of the company's communication with its environment. The fundamental tool in this area is non-financial reporting. The research conducted for this paper clearly shows that reliable presentation of non-financial data requires giving non-financial information attributes of financial information. Therefore, the following conclusions / recommendations are made:

1. The freedom allowed by Polish law in the presentation of non-financial information results in a heterogeneous structure of disclosures, which significantly limits their comparability in both time and space. Recommendation: Increasing the comparability of non-financial reports requires legislative actions to clarify guidelines and parameterize the structure of reports.
2. The narrative, subjective nature of non-financial reports should be treated as aggressive reporting which, through *greenwashing* opposes sustainable development. Recommendation: True and reliable images of companies in non-financial reports require report approval by external and independent audit companies.

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Innovations in e-commerce: value proposition for e-buyers

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Abstract

Development and innovation in the e-commerce sector over the last decade have been extremely dynamic. Market development has increasingly been driven by the changing behaviour of consumers shopping online and the growing number of e-stores. This article identifies the pro-innovation areas and actions which are creating special value propositions for e-buyers in Poland and assesses their impact on shopping decisions for each generation (X, Y, and baby boomers) by assessing the impacts of differences in the preferences of the generations regarding e-commerce. Each generation differs significantly from the others in terms of work, education, security, success in professional and personal life, and in terms of consumption. The characteristics of the individual generations and the levels of their digital competencies impact significantly on the ways in which a given generation makes purchases and what they expect during the purchasing process. In order to establish the key determinants of online purchasing decisions and attitudes towards innovation in e-commerce, an online survey was conducted. The sample included three generations of Polish internet users: 260 people at ages between 25 and 37 (generation Y); 200 people at ages between 38 and 50 (generation X) and 100 people at ages between 51 and 70 (the baby boomers' generation). The structure of the article includes presentations of the problem against the background of relevant literature, the theoretical assumptions of the research, and its findings and conclusions.

The definition and classification of innovations

The source literature recognises various categories of innovations, each characterised by a different set of features, which in turn are dependent on conditions that affect them. The Office of National Statistics classifies innovations as technological (describing products and processes) and non-technological (organisational and managerial).

Technological innovation, according to the Oslo methodology, takes place when a new or improved product is introduced to the market. It also occurs when a new or improved process is applied to production, providing that the processes or products are new at least from the point of view of the business (company) introducing them. This also applies to the tourism business.

On the other hand, non-technological innovations are defined as any innovative activities of a business that do not include and are not related to developing new or significantly modified products, introducing new or substantially modified products to the market, or implementing new or substantially modified processes. Non-technological innovations include the implementation of advanced management techniques, new or significantly changed business strategies, implementation of significantly modified management techniques, and activities related to changes in organisational structures.

The study of non-technological innovations also acknowledges marketing innovations – defined as significant changes in the business's marketing concept or strategy or aesthetic character of the brand and modifications or other creative changes to the business's products not classified as technological

innovations. An innovative business is characterised by a strong ability not only to create and introduce innovations but also to adapt them from exterior sources.

One classic definition of innovation is proposed by J. Schumpeter: the introduction of a new product or new production method, opening a new market, acquiring a new source of materials, or introducing a new type of business organisation (Schumpeter, 1960). According to P.F. Drucker, however, innovation is a specific means by which entrepreneurs convert new developments of any kind into an opportunity to start a new business or provide new services (Drucker, 1992).

There are many other definitions of innovation. For example, according to Kotler innovation refers to a product or idea perceived by someone as new, which means that it may have existed for a long time and is only a new for some individuals (Kotler, 2004).

In a narrower definition, an innovation is the first launch of a new product, process, or system to the market (Jasiński, 2006).

From a technological point of view, innovation is defined as a desire to move away from existing technologies and practices for the adoption of new ones, including in order to adapt to changing external circumstances.

In addition to definitions describing innovations from technical, economic, marketing, or organisational points of view, innovation can be defined in a way which cuts across these aspects of commerce, such as, for example, in a behavioural approach – focusing on changes in the behaviour of individual consumers or businesses, in comparison with other

market participants, that indicate readiness to accept new ideas (Goławska, 2004).

Based on the aforementioned definitions, it is evident that the term ‘innovation’ can be understood or defined in a variety of ways, which derives from differences between various styles of business management.

The features of innovations most commonly found in the source literature, are shown in Figure 1.

As shown in Figure 1, innovation depends not only on technological know-how but also other forms of knowledge such as experience, knowledge of suppliers and customers through interaction or study, and observation of the competition.

Taking the above into consideration, we are led to the conclusion that, when competing for a client, businesses should rely on sustainable values, selecting a sequence of actions that will allow them to create overall, unique value from the customer’s point of view. Therefore, skills that meet the needs of the selected group of clients in a distinctive way by offering a unique set of benefits that help overcome the actions of competitors, become keys to success (Oniszczyk-Jastrzębek et al., 2018).

It should not be forgotten that every innovation – especially product innovation – greatly depends on consumers’ reactions to it and, therefore, the greater the degree of novelty, the greater the degree of risk and uncertainty. Should the customers not accept a product innovation, it will not be economically or commercially successful. That is why it is extremely important to conduct regular market research and take into account the outcomes and conclusions of the research when making decisions related to product development.

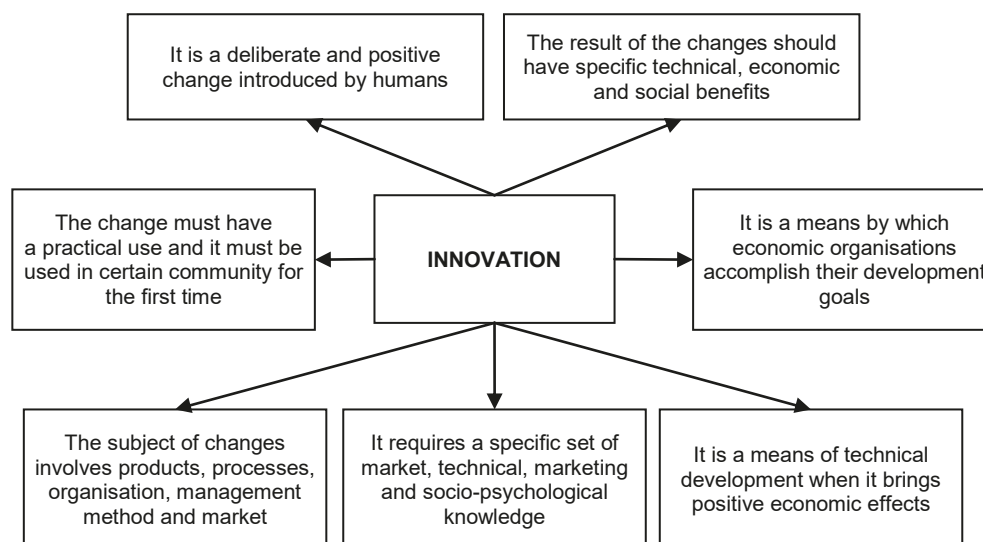


Figure 1. The most common features of innovations

Innovation in e-commerce and the creation of value propositions for buyers

E-commerce is itself an area of innovation; not only is it constantly changing, but it is also the main reason the entire market is changing in this era. The last few years have seen radical growth in e-commerce. Both buying and selling have never been easier. With the growing experience of e-buyers as well as an increase in the number of online shops, however, the expectations, needs, and demands of customers are also growing. This creates a need for continuous development, improvement, and innovations in this area. Such improvements or solutions – whether in product, process, organisation, or marketing – should create specific value propositions for potential buyers.

It should be acknowledged that innovations in e-commerce are understood here as the implementation of solutions specific to and related to the process of running an e-commerce business. This approach is a very broad one; on the one hand it allows the recognition of any given solution as an innovation and, on the other hand, it introduces three precise criteria for innovations: having connections with an e-commerce business, implementation of the innovation in the business, and being a novelty for that particular business (Stanisławski & Szymański, 2015). From the point of view of the e-commercial sector, 'innovation' should refer to the practical use of any solution, providing it is new for that particular business. Freedom of interpretation allows it to refer to the product, the business itself, or a variety of actions related to running an e-business.

In scientific publications referring to e-commerce, the term 'innovation' is first of all linked to the possibilities generated by new (or relatively new) technologies. Using technologies such as big data, artificial intelligence, and machine learning may determine and define the future of the e-commerce sector since they enable precise determination of business strategies and prediction of customer reactions. Thanks to tools using these technologies, we are already better able to predict purchasing trends, optimise price levels, and personalise customer communications, as well as to afford far-reaching automatisa-tion of customer service processes. Online shopping, however, is becoming a much more complex experience for sellers, especially due to ever-increasing competition.

In line with the dominance of competition, product and delivery prices are stressed by many authors as the two main economic factors conducive to

generating online purchases in the early stages of online marketing (Dębicka, Gutowski & Borodo, 2018).

But in the current era, competing only through prices is simply not enough. Customers' expectations must be attended to and nurtured at every step of the buying process. In a survey carried out by the authors of this article in 2018, on a sample group of 600 participants, only 37 of them recognised the prices of the products as an advantage of online shopping. (Dębicka, Gutowski & Borodo, 2018).

Taking this into account, innovation in the e-commerce industry should be approached as innovation in value, requiring analysis of consumers' needs, overcoming patterns in design, courage, and consistency in creating new solutions that offer more value to the customers. Such an approach to innovation is consistent with the concept presented by the authors of Blue Ocean Strategy – W. Chan Kin and Renée Mauborgne – who emphasise that innovation means creating new value for customers and one's own business, thus creating a new market space. (Chan Kin & Mauborgne, 2005).

In this light, the competition becomes less relevant and businesses can exploit their innovations to the fullest extent in order to determine their positions in the market. The essence of this strategy is the innovation of value – the creation of new value propositions for customers and one's own business (Chan Kin & Mauborgne, 2017).

Such an understanding of the innovative approach to e-commerce implies several strategic areas, defined in this article as pro-innovation areas:

- building of a brand community,
- high-level product presentation,
- personalisation,
- customer retention,
- use of social media as a tool,
- omnichannel (multiplatform),
- advanced search mechanisms.

The term of strategy 'building a brand community' should be understood to include all activities related to that goal. In order to develop the best strategy, it is essential to analyse the initial situation, specify the target, set goals, select the right tools, create a schedule of activities taking the budget into account, implement the strategy, ascertain its results, and draw conclusions.

The keys to building a community around a brand could be the following rules: ensure the highest quality of the information offered consumers, give consumers personalised experiences, and communicate with stakeholders who want to have their say about

content – who want to influence promotion and management of the brand in general and want their comments listened to and their opinions taken into consideration.

For an entrepreneur it is vital to know which tools to use. Tools typically used to build a brand community include the following: discussion groups, mail-list discussion groups, discussion forums, IRC channels, chats, portals, vortals, and blogs.

Muniz and O’Guinn define a brand community as a specialised (its centre being a product or a service) and geographically unrelated community based on a structured set of connections between the brand’s adherents. Members of such a community express a common interest (fascination) for a given brand, which leads to the creation of a parallel reality (sub-culture) with its own myths, values, rituals, vocabulary, and hierarchy (Muniz & O’Guinn, 2001).

Table 1. Typology of innovations according to Oslo Manual 2005 and pro-innovative areas in e-commerce (OECD iLibrary, 2005)

Innovations	Pro-innovation areas in e-commerce
Product Innovations	Customer retention Personalisation
Marketing Innovations	Activating brand community High level product presentation Personalisation Customer retention Use of social media as a tool Advanced search mechanisms
Process innovations	High-level product presentation Omnichannel (multiplatform) Activating the brand community Personalisation Use of social media as a tool Advanced search mechanisms
Organisational Innovations	Omnichannel (multiplatform) Activating the brand community

Innovative actions taken in each pro-innovation area derive from both new opportunities generated by technological progress and adaptation to changes in consumer behaviour. One of the leading drivers in the field of value innovation is the goal of making customers’ lives easier. For example, the Blue Apron store offers prepared sets of products essential for cooking specific dishes. The sets are delivered directly to customers together with a printed recipe and the specified amounts of individual ingredients already measured and ready to use. The store also provides detailed cooking instructions on its website, with instructive photographs. For another example, in the Andi Swim shop, a customer can find a fun ‘configurator,’ which facilitates choosing

a perfect swimming costume. What deserves special mention, however, is the content and visual design of the configurator.

An important issue is the fact that a pro-innovation strategy for creating new value propositions must be flexible and dynamic because its value disappears as soon as another business adopts the ‘new’ ideas. Hence it is vital to constantly look for new inspirations, monitor other industries/brands/businesses, and look for the opportunities that grow on the edges of new trends.

Research methodology and population sample

The main objectives of this research were to identify the pro-innovation areas and actions that create special value propositions for e-buyers in Poland and assess their impacts on shopping decisions for representatives of each generation. The study was carried out with the help of CAWI (Computer-Assisted Web Interview) dynamic questionnaire forms. The data was collected throughout July 2018. Interviews with 560 participants were analysed. The sample included three generations of Polish internet users: 260 people aged 25–37 (generation Y); 200 people aged 38–50 (generation X) and 100 people aged 51–70 (the baby boomers’ generation). The 25 to 37-year-olds were 50.8% women and 49.2% men. The 38 to 50-year-olds, 46% women and 54% men. And the oldest age group (51–70) was 56% women, 44% men. In order to guarantee high quality data, only fully finished surveys were included in analysis. The aim was to discover answers to various questions related to customers’ preferences when shopping online, especially relative to innovation.

Businesses from every sector and industry must constantly take up challenges in diagnosing the needs and preferences of consumers. Such a diagnosis should begin with recognising the goals and motivations that shape consumers’ purchasing decisions. Whether the product proves attractive to the recipient or not can be determined by many different factors, the most important being those of an innovative nature.

These innovative factors include that the products on offer provide the customer with real, significant benefits that they will perceive as unique, that the offered products are introduced to the market in the time frame expected by customers, and that all values unique to the customers are accessible, which should be reflected by costs customers can accept and cover in the moment of purchasing a product.

This issue refers mainly to purchases made using the so-called traditional method.

Innovation-related questions related to purchasing includes especially those concerning payment methods and methods of distributing purchased products.

One of the first questions asked concerned how frequently subjects make purchases over the internet. The answers varied by age group. Among participants up to 37 years-old (age group I), exactly half of the respondents admitted to shopping online at least once a month. Among 38–50 year-olds (age group II) this was 33% of participants, and in the age group III (51–70), it was only 14%. The obtained values are consistent with general assumptions about internet use and age.

Respondents also evaluated the level of difficulty they experience when shopping online. Among the participants from age group I, over 98% responded that shopping online does not cause any difficulties. In the second age group, that percentage was slightly above 86%, and among respondents from the third age group there is a further 10% drop. Again, these outcomes, according to the authors of this article, agree with popular assumptions about age and online shopping.

Another aspect of the questionnaire focused on payment options, and those used by the respondents. The variety of responses included payment on delivery (cash on delivery), online transfer, Blink-like online payments, PeoPay, debit/credit card payment, and virtual wallets such as Masterpass, Visa Checkout, Google Wallet, Android Pay, and Apple Pay.

The percentage of innovative payment methods used, out of a group of mobile payments, decreased depending with the increasing age of the respondents. It reached the highest value among the youngest respondents – 30%, dropped down to 11% in age group II, and in age group III, it was only 8%.

As evident from the above results, payment methods such as Blink, PeoPay, etc. are moderately popular and more frequently used than virtual wallets. The latter were used by only a few respondents.

Findings and conclusions concerning innovative solutions

The last section of the questionnaire included a group of questions related to respondents' feelings about the methods of innovative solutions. The innovative solutions concerned issues such as the delivery, ordering, payment, and personalisation of products. Each of the aforementioned influences

consumers' shopping and purchasing patterns in specific ways.

The survey shows clearly that consumers' purchasing decisions are probably not based on the time it takes to deliver goods. Total responses emphasising this factor were below 9%. A much larger percentage was interested in whether the service of bringing the goods into their homes is available.

The responses to the question about this issue are quite interesting. Among the youngest respondents, over 68% were interested in whether the goods would be delivered inside their homes or not, while in the older age groups, only 50%. This may serve as evidence of increasing importance placed on convenience by the youngest age group of consumers.

Respondents in multiple age groups point to the relatively high importance of the personalisation of goods in making their purchasing decisions. This element was most important among the oldest age group. However, those responses totalled only seven (there were only 100 subjects in the group, versus over twice as many in groups I and II). The numbers recognising this factor as important in age groups I and II were 20 and 14, respectively. This seems indirect proof of growing interest – which increases with the age of the respondents – in personalised goods, which may distinguish them from other goods that fulfil the same function.

The originality of visual elements seems increasingly desired by consumers, who presumably want to be unique and stand out from others. In addition to consumers, producers are also responsible for this state of affairs, as they have been offering increasingly newer and more original products. This causes consumers to become more demanding as they set market trends.

Answers to other questions related to innovation concerned specific products. The first question was about the Family Hub fridge, which first appeared on the market in 2016. This unique household appliance makes purchases by itself; the fridge orders missing products and pays for them with the owner's credit card. There is no need, therefore, for traditional transactions when using this product. The question posed to respondents concerned their opinions on such an innovative way of ordering products. The answers to the question of whether such a process is acceptable were as follows: in the age group up to 37 years-old the answer, 'I like this solution the most' was given by eight respondents, in the second group, of 38–50 year-olds there were 12 positive answers, whereas in the group aged 51–70, only three answered positively. We conclude that

the automatically purchasing 'intelligent fridge' is not yet a popular solution. Although, this response might also indicate that consumers are not familiar with this appliance, have not come across it, or have merely not had an opportunity to use it yet.

The next question, also related to ordering goods, concerned using voice assistants. Such a solution is popular in the USA in particular, but has not established itself on the Polish market yet. The introduction of the first voice assistant using Polish is planned for later this year. Nevertheless, respondents, when answering the question of whether they would like to order products through a voice assistant, gave 14 positive answers in each of the two younger age groups, while among respondents over 51 years old there were only five positive responses. These results do not reflect the goals set by those who have decided to implement voice assistants for purchasing. Due to its versatility, the voice assistant was intended for many target groups, with a special focus on the elderly. They represent a specific social group, for members of which using a traditional computer might be difficult or even impossible. However, the research does not confirm the assumption that voice assistants would be embraced by the elderly. It can be assumed that information about the possibility of using voice agents to order products has not become widely available or is not popular yet among the elderly.

Another modern solution in ordering products through the use of everyday appliances is the innovation of washing machine models equipped with the Dash Replenishment Service system. This system enables you to order detergent and softener with one push of a button. These washing machine models register the washing cycles and based on this information anticipate when the washing powder and softener will run out. The washing machine then displays this information and sends an alert about the supplies running low, allowing the user to place an order for the missing products automatically. The question in the survey asked participants whether this kind of solution would be acceptable. Ten respondents each from both age groups I and II confirmed that they like this solution. On the other hand, in age group III, only three respondents shared this opinion. These findings prove that this way of ordering products is not yet popular among members of the oldest age group, whereas among younger age groups it is a well-known and accepted solution.

The last question concerning innovation related to new payment methods using fingerprint recognition, head movement activation, facial recognition,

or eye retina recognition. Answers confirming these payment methods as appealing came from members of the youngest and middle age groups (ten positive answers in each group). Among the oldest respondents were only three positive answers. As in the case of previously analysed responses, we might suspect that whereas these methods are known to respondents from age groups I and II and recognised by them, those methods are unknown or not very popular among consumers over 51 years of age.

Respondents' answers relating to the broadly understood concept of innovation confirm that the newest payment methods and solutions for ordering products are not popular just yet. This applies mainly to respondents age 51 or over. A relatively low number of positive responses among younger participants suggest that these solutions have only recently begun gaining followers. With the rapid development of technologies enabling innovative e-commerce practices, they are likely to become more popular in the near future and widely used by online shoppers.

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Employees as key stakeholders in 21st-century enterprise: good practices

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Abstract

This article presents topics related to the main stakeholders of enterprises in the 21st century – employees operating in a market dominated by globalization and technological progress. To a large extent, they determine the competitive position of their organizations. To this end, the author describes the expectations of Polish employees as key stakeholders of the organization in which they are employed. Moreover, the author defines and describes the conditions that must be met to optimize the use of their potential. Good relations with this group of stakeholders is the basis for creating business strategies in the 21st century. The author also presents a description of his own research, which concerns the analysis of actions taken by companies aimed at creating optimal working conditions for their employees; this is also the main goal of this article. The analysis of source materials and research results indicated that employees played a large role in organizations and the need to implement dedicated tools and management methods. It should be obvious that the new economic realities force companies to invest in intangible resources, as it is thanks to them that it is possible to achieve market success. The main feature of companies that seek to achieve success is social sensitivity, which is manifested by a series of actions aimed at meeting the expectations of employees.

Introduction

Economies in the 21st century are becoming increasingly dynamic, which creates new challenges for enterprises. Their management, in the face of globalization, or the age of knowledge, requires decision-makers to seek new development strategies. It has become clear that the new economic realities are forcing companies to invest in intangible resources necessary to achieve market success. Therefore, enterprises that are focused on success are concerned with social sensitivity, which manifests as a series of actions aimed at meeting the expectations of employees.

Therefore, the aim of this article is to analyze the actions taken by companies that aim to create optimal working conditions for their main stakeholders – employees. Of course, the article will verify and

describe the criteria and methods of effective cooperation with employees. Examples of good practices from Polish companies will also be provided. Common interactions occurring between an enterprise and its employees require knowledge about their expectations and the conscious shaping of relations between them. An important element in the process of learning about their expectations is the fact that this group of stakeholders, unlike clients, often has different expectations of their employer.

The research objectives will be achieved based on an analysis of theoretical materials and empirical research conducted by the author in 2019 (10 large enterprise companies from the Pomeranian Voivodeship). The first stage of research was designed as a standardized questionnaire that described the subject. The second stage was an individual interview with managers at various

levels (32 persons) and employees (300 persons) from the surveyed entities.

The basic result of the analysis conducted in the article, including the results of the research, is the characteristics of the expectations of Polish employees as key stakeholders of the organizations in which they are employed. Moreover, the article defines and describes the conditions that must be met in order to attempt to make optimal use of employee potential. This is all the more important because the analyses performed in this article clearly indicated how important they are in the final market success of an enterprise. The proper arrangement of relations with this group of stakeholders became the basis for the creation of business strategies in the 21st century.

Stakeholder theory

Different entities, groups of persons, or even individuals who may be interested in the functioning of a given organization in the market, fit perfectly into the concepts of interest groups – otherwise known as stakeholders. This concept was developed in the 1980s, and it emphasizes all entities that can influence economic entities. It was created by R.E. Freeman (Freeman, 1984), who used it to refer to individuals or groups that can influence the activities of an organization or who are influenced by the activities of an organization.

In the literature, on the subject, there are now many definitions of stakeholders. K. Obłój (Obłój, 2007) defines stakeholders as institutions and organizations that meet two conditions: they have their own stake in the organization's activity (in decisions and effects) and are able to exert effective pressure on the organization. It proposes to include the following issues in the analysis of stakeholders: the pressure of stakeholders (power), legitimacy of stakeholders, and urgency of stakeholder demands. Ch.W.L. Hill and G.R. Jones (Hill & Jones, 1995, p. 45) have a different view of stakeholders and claim that these are diverse groups of individuals or individuals with claims against the enterprise. Laszlo (Laszlo, 2005, p. 17) defines stakeholders as individuals and groups of individuals who contribute to an enterprise's ability to generate wealth. They are potential beneficiaries with an interest in the tasks that the company carries out and/or the risks of its actions.

However, according to T. Donaldson and L. Preston (Donaldson & Preston, 1995), stakeholders are individuals or groups that have direct or indirect contact with an organization. Using this definition to broadly define a contract as a certain informal and

formal agreement binding both parties (analyzed by us, the organization, and the stakeholder), we can conclude that a stakeholder can be practically any element of the environment closer to, as well as further from, an organization. However, a specific situation context is of great importance in the interpretation of the stakeholder's influence on an organization. We must also mention that an organization as a whole is not always the subject of the stakeholders' influence – very often it is a specific process, system, or project (Smolska, 2016, pp. 311–312).

The situation is similar in the case of stakeholder classification – there are many types of classifications in the literature. For example, there are internal stakeholders who are members of the organization who can participate in the implementation of company projects (Grzeszczyk, 2006). There are also external stakeholders who are not members of the organization, and their impact on the company is more representative than direct (Grucza, 2012). On the other hand, according to a more extensive classification, taking into account the types of relations between stakeholders and the company, the following stakeholder groups can be distinguished (Paliwoda-Matiolańska, 2005):

1. Substitute stakeholders who co-create a company by engaging their own capital or labor (e.g., shareholders, owners, and employees).
2. Contract stakeholders who are bound to the enterprise by formal relationships based on contracts (e.g. customers, suppliers, competitors, and allies).
3. Context stakeholders who expect the company to engage in social and environmental projects.

When taking into account all the above theories and others available in the literature, we should pay attention to very important and frequently repeated conditions (Frączkiewicz-Wronka 2012):

- the organization is part of a network of relationships with many stakeholders who influence its decisions and who are in turn influenced by it;
- the nature of these relations is very important, taking into account both processes and effects of activities for the organization and its stakeholders;
- the interests of all mandated groups are of significant value;
- the key theoretical aspect of the practice is to determine the conditions for making managerial decisions in terms of stakeholder influence.

Based on the literature analysis, we can state that the stakeholders of a given enterprise may be individuals, groups of individuals, as well as various other organizations that operate inside or outside an

entity. Their interests are to varying degrees related to the functioning and management of the enterprise, and they are connected with the management of the company and may influence its operation directly or indirectly. Of course, they are also subject to the company's influence. In relation to these definitions, we can see that it is the workers who have become the main stakeholders in all companies in the 21st century. The reason for this is simple: they are the ones who operate within the company, and their interests are directly linked to the management of the company. After all, it is the employees who influence the operation of the company and are directly influenced by it – and at the same time bear quite a high risk. They determine whether the enterprise will be successful on the market or whether it will suffer a spectacular defeat, which is nowadays the most important capital of enterprises. Therefore, according to the author of the article, one of the most important challenges for company management is to learn to expect that employees should be fulfilled in an optimal way so that their satisfaction is involved as much as possible in the work.

Employee expectations as stakeholders

It is no secret that every employee has different expectations for his or her employer. This is usually the result of various needs that each employee wants to satisfy at work. Of course, as time goes by and conditions change, the expectations of employees are often referred to – individual values for different employees are usually important to different degrees. There are people for whom the most important is a sense of security (own comfort) and stability at work, and these are able to accept lower salaries. On the other hand, there are employees for whom the highest possible salaries are the most important, and they are ready to accept even large inconveniences at work. The most important thing, however, is that the needs and expectations of the employee are at least in part consistent with the conditions that can be offered by the employer. If this happens, an employee should be satisfied with his or her work, which usually translates into expected effectiveness.

On the labor market, there are currently members of four generations: baby-boomers, and generations X, Y, and Z. In the literature, it is assumed that workers of different generations have different expectations towards work. For example, members of generation Y are in favor of work-life balance. For Generation X, the motto is “I live to work”, and for Generation Y, “I work to live”. Large organizations

are usually managed by representatives of generation X and baby boomers, who influence the results of the enterprise, not only of an economic but also a social nature. The representatives of generation Y are social activists who want to introduce social changes together with the company. This generation has been described as “the Re-generation” from the words: responsibility, renewable energy, recycling, reducing carbon emissions, and resource limitations. Its members pay attention to responsibility, renewable energy, CO₂ emission reduction, and resource reduction (Zaleśna, 2018).

However, analyzing the research conducted by Sedlak & Sedlak (Sedlak & Sedlak, 2017) reveals a slightly different picture of the expectations of Polish employees than the one related to the characteristics of particular generations:

1. The basic expectation of working Poles towards their employers is attractive remuneration.
2. Slightly less important, is the atmosphere in the workplace.
3. The competences of superiors are also very important for many respondents.
4. An interesting job, sense of the tasks performed, access to courses and training, balance between professional and family life.
5. The least important expectations were caring for the environment and society and diversity management.

According to the author, employees in Poland expect above all that their salaries will guarantee a good quality of life. This is probably a result of the economic situation in a country whose economy is constantly developing and trying to catch up with developed countries. Of course, this situation is dynamic and constantly changing, which is clearly shown by the data from the briefly described survey; increasingly often, employees expect a good workplace atmosphere that is conducive to achieving the desired results.

Since employees are key stakeholders in a company and have varying expectations, it is important to maintain a constant dialogue with them in order to better identify their expectations and take them into account in the company's activities. Such behavior will result in the employees being more involved in the company's activities (Wachowiak, 2014, p. 293.)

Job satisfaction

Satisfaction is most often associated with pleasure or just a sense of happiness. It is certainly a subjective feeling and is fully dependent on the

person, what expectations we have, or a system of values. There are different theories in the literature about how to determine the criteria for a level of happiness. Two general approaches are considered. The first one assumes that one should take some sort of determined, external absolute value, not related to the subjective feeling of the individual and compare the life of a given person to it (it is assumed that the closer it is to a certain value, the more it is considered happy). In the second approach, the concept of happiness is identified by a subjective sense of satisfaction and a subjective opinion of the individual. It should be stressed that most quality of life research focuses on subjective assessments of satisfaction levels, including job satisfaction (Sak-Skowron & Skowron, 2017).

Of course, whether an employee will be satisfied with his or her job also depends on the subject (personality, knowledge, skills of the individual) and environmental variables (working conditions, relations with co-workers and superiors, cultural factors, conditions of functioning on the labor market) (Springer, 2011).

There are many definitions of job satisfaction in the literature. These may be feelings related to an employee's professional duties (Schulz & Schulz, 2002, p. 296) or a set of feelings and attitudes of an employee towards work (Wexley & Youkl, 1984). D. Lewicka (Lewicka, 2010) believes that this term means a positive attitude of employees towards their duties, co-workers, and their working environment – accompanied by a feeling of satisfaction. In turn, A. Springer (Springer, 2011) suggested warning about job satisfaction from the perspective of attitude towards this job (and not feelings), assuming that this attitude was the result of many partial attitudes towards the profession, co-workers, or an organization.

To sum up, job satisfaction is simply the satisfaction of an individual/employee, a positive attitude, or a sense of fulfilment. It is a belief that the professional work performed in a given organization makes sense and brings us closer to achieving the assumed goal, even in the case of barriers and complications, which can be overcome.

On the other hand, the level of job satisfaction is affected by many factors, which may include (Gros, 2003):

- organizational factors – directly related to the work performed, i.e. the type of tasks performed, remuneration (its adequacy to the employee's duties and involvement), promotion prospects, work safety, the organization's functioning policy

(the level of care for employees and their needs) and the company's development policy;

- social factors: organizational climate, respect at work, relations with superiors and co-workers, relations with customers;
- personal factors concerning individual employee characteristics, i.e. age, gender, race, cognitive abilities, professional experience, personality traits, work status;
- factors directly shaping satisfaction: at the employee level – employees' needs and their individual features; at the organizational level – organizational features of the organization, i.e. mission, objectives, development strategy, organization resources, organization size (Bartkowiak, 2009);
- factors indirectly shaping satisfaction: at the employee level – qualifications, skills, competencies acquired by the employee; at the organizational level – organizational features, i.e. the organization's requirements, relations with customers, the environment, public opinion, etc. (Bartkowiak, 2009).

Analysis of research results

This research is a continuation of a 2017 research process dedicated to identifying key employees in companies. This time, the main objective is to analyze the actions taken by enterprises, which aim to create optimal working conditions for their main stakeholders – employees. Of course, the author will verify and describe the criteria and methods of effective cooperation with employees, and also give examples of good practices of Polish companies. Such defined goals determined the whole research process, and the following research methods were used:

1. Literature analysis – systematization of the language of terms used in the concept.
2. Comparison to indicate characteristic features and ways to understand defined terms.
3. Interview – including, in particular, a structured interview with senior managers and employees in the surveyed entities.

The research was conducted in 2019 in 10 randomly selected large enterprises based in Pomorskie Voivodeship, and a total of 332 people took part in the survey. At the research planning stage, the author intended to apply a purposefully random sample selection based on the information on enterprises in this sector contained in Polish statistical data. Due to limited resources, the author adopted

a selection principle based on his own declaration of participation (questions were sent to 35 entities interested in participating in such an undertaking). Unfortunately, the research sample did not reflect the assumed characteristics of the whole group for this region. Therefore, the presented results can only be a complete set – they are the basis for extending the research process in the future to the whole country's region. For the time being, we can only consider this as a pilot study.

The first stage of the research was designed as a standardized questionnaire, which described the surveyed entity. In the second stage, it was an individual interview with managers (32 persons) and employees (300) from the surveyed entities. Sample selection was based on the following criteria: the status of a large company with a registered office in the Pomeranian Voivodeship and an HR department (this was to make it easier to obtain information about the actions taken). Calculations and statistical analyses of empirical material collected during the course of the research were performed by the author using Statistica statistical program and Microsoft Excel.

As a research method, the author chose individual interviews – other techniques provided partial data which was less reliable and fragmented. This method will allow only the most suitable information to be obtained.

At the beginning of the analysis of the research results, the author wants to draw attention to the first positive phenomenon, which occurred in all the companies participating in the research, i.e. the permanent activity of conducting a dialogue with employees, which was usually aimed at:

- providing information on the company's activity – in 9 surveyed entities;
- getting to know employees' opinions on the functioning of the company – in 8 surveyed entities;
- determination of employees' expectations – in 8 surveyed entities;
- determination of the degree of fulfilment of employees' expectations – in 7 surveyed entities.

Below, the author describes examples of good practices to ensure the effectiveness of dialogue with employees, which are used in the surveyed entities:

- system of complaints, which gives employees the opportunity to express their opinions at any time;
- ambassadorial movement, where employees actively participate in solving key challenges faced by their companies;
- employee satisfaction management program, consisting of an employee satisfaction survey, workshops defining employee initiatives, and

monitoring actions taken to improve employee satisfaction;

- cyclical meetings of employees with the board of directors;
- internal Internet portals for employees, which enable the creation of a community of a given company.

We need to know that dialogue with employees cannot be conducted ad hoc – it is a long-term investment in building lasting relations and a chance to optimize the effectiveness of company decisions. It is very important, which results from the above data that companies use available IT tools for communication during this process. On the other hand, companies must not forget about direct contacts, including regular meetings with the most important people in the company because this builds team morale. Of course, there can be no lack of continuous monitoring of employee satisfaction from work in this process – results and conclusions should be discussed with employees, and based on them jointly draw conclusions to implement corrective actions.

Another important element of the survey was a question concerning the opinion of managers from the surveyed enterprises on the conditions that were created for employees. The respondents had at their disposal a scale from 1 to 5 – where 1 represents a very poor condition, and 5 is a very good condition. Bearing in mind the previous material, the answers provided make up a rather positive picture of the surveyed entities – detailed information on the distribution of answers is presented in Figure 1.



Figure 1. Evaluation of the conditions created for employees

It is difficult to talk about building relations with employees in the case of poor evaluation of working conditions, which are created for employees who are

supposed to work optimally. An equally important issue in the process of building relations with the main stakeholders of enterprises is to broaden their qualifications and diversify their work. In Figure 2, the author presents the actions listed by the respondents with a percentage of responses, influencing the development of employee potential.

The main activities applied by enterprises in the above areas were teamwork (30 indications), participation in management (29 indications), and very flexible working time (27 indications). Another quite important activity is the extension of the scope of tasks of employees and management by objectives and results. The situation looks a bit worse when it comes to creating a career path, coaching, and mentoring – it is a confirmation of dysfunctions in the Polish conditions of human capital management. This fact also confirms the inadequacy of organizational structures to the requirements of the modern market – there were only 2 indications for work in project teams.

Another important factor influencing effective cooperation with employees is the use of various

motivators, which are not always related to cash. However, in Polish economic practice, it turned out that bonuses are still the most frequently used – 232 indications (Figure 3).

Based on the analysis of the conducted research, it can be stated that the main activities used to build positive relations with the main stakeholders, i.e. employees, include dialogue and enable the professional development of the staff. The second level supporting this process, within organizational solutions, is the possibility of working in a team, participation in management, and flexible working time. Of course, financial support could not be lacking, but most often in the form of bonuses, and not participation in financial results. It is unclear whether this is enough or if it builds optimal relations with the most important capital in the 21st century. We must remember to apply systemic solutions, starting with changes in organizational structures and cultures. This undoubtedly constitutes a starting point for analyzing the distance in the issue of human capital management, which separates Polish enterprises from enterprises in developed countries.

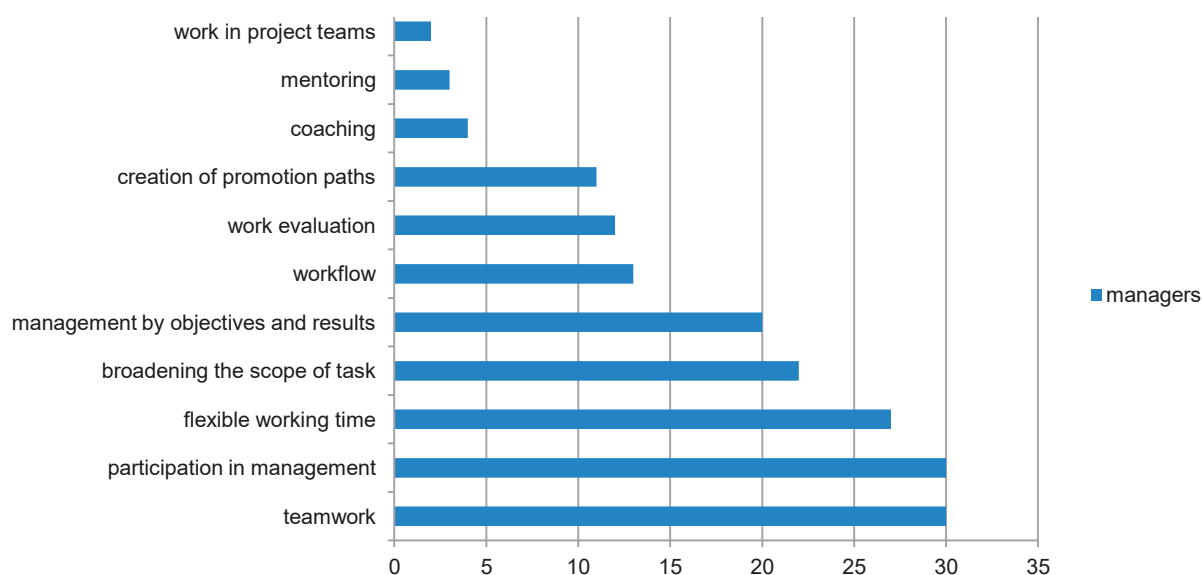


Figure 2. Activities aimed at improving the qualifications of employees in the surveyed entities

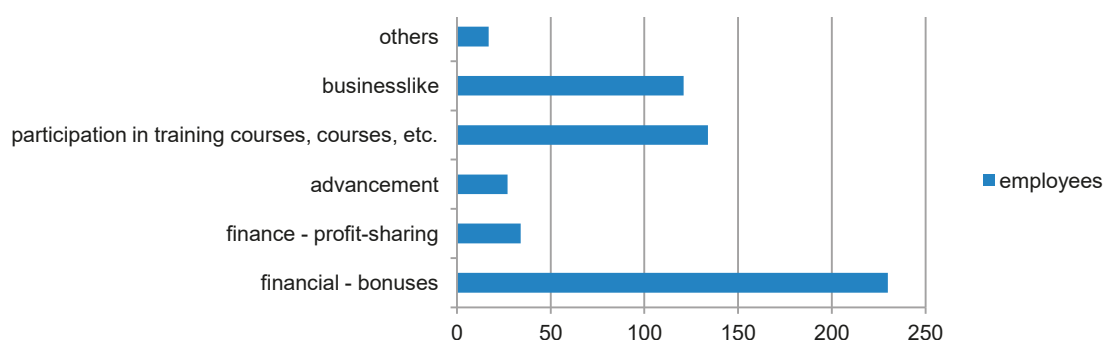


Figure 3. Methods of employee motivation

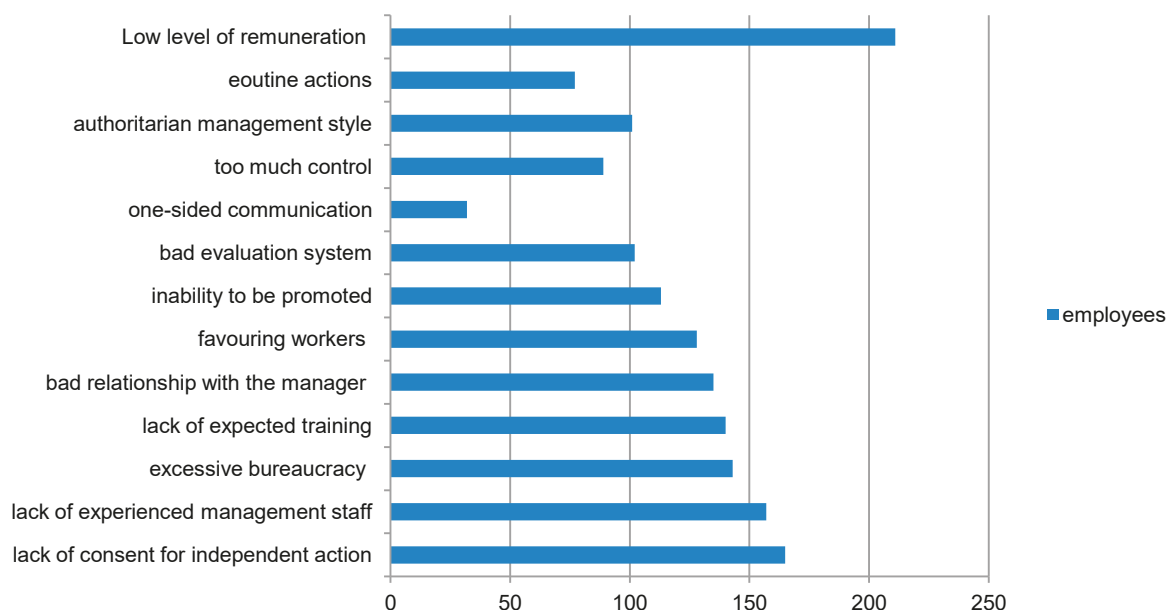


Figure 4. Errors committed by undertakings

When analyzing the collected data, it was apparent that many mistakes were made by enterprises, including a lack of consent for independent operation, lack of experienced management staff (this causes a lack of recognition among employees), excessive bureaucracy, or lack of expected training – the detailed scope of the answers is presented in Figure 4.

There are various reasons for these errors; the first is the “Polish reality”. Of course, it should be stressed that the contemporary employee has changed. Currently, he is already more educated, has better competences and is certainly much more informed than those of previous generations. Therefore, he cannot be poorly motivated, limited to the implementation of simple, routine actions. It builds a sense of lack of recognition and limits faith in the sense of the tasks performed, and ultimately their usefulness for the organization.

Conclusions

The activities of modern enterprises, which function in changing and turbulent economic conditions, where the only constant is change, is determined by building relationships with different groups of stakeholders and actions aimed at social utility. Entrepreneurs who plan to achieve a lasting competitive advantage must build their strategies based on social connections – internal and external. In order to achieve this, they need to identify the key stakeholders who have an impact on the operation of a given economic entity in the market.

In the 21st century, these groups undoubtedly include employees. Therefore, an important feature of a company that wants to achieve market success is social sensitivity, which is manifested primarily by voluntary and long-term building of positive relations with its employees and creating optimal working conditions for them. Entrepreneurs should respond to the expectations of employees and provide them with job satisfaction and development opportunities. All this occurs because it is the employees who contribute to building and implementing a company’s business strategy.

As the research and analysis of the results have shown, building proper relations with employees depends on many factors. The most important is the recognition and reaction to the expectations of employees by using a systematic dialogue. Any form of communication is the simplest tool for greater involvement of this group of stakeholders. It is also important to conduct consultations, which help to get to know the opinion of the employees in every important matter for the company. Of course, this process cannot lack the form of a partnership, which requires the greatest amount of work, but it will certainly result in the formation of a common development strategy, in which each of the parties – employer and employee – will be equally satisfied.

Overall, entrepreneurs strive to generate profits, and employees – their key stakeholders – want their interests and expectations to be taken into account. Good practices and exemplary actions described in this article should be used to increase the effectiveness of employee work.

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The role of smart specializations in regional innovation policy – an analysis based on blue-economy sectors

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Abstract

This paper explores the role of regional policy in strengthening the EU's research and innovation policy paradigm, with a particular focus on smart specializations. These specializations play a major role in stimulating R&I at the regional level in less-developed regions of the EU. Smart specialization is the EU's new concept for the regions; it assumes improvement in both innovation and competitiveness, based on endogenic potential; in particular, in already existing branches of the economy. Smart specializations should, by definition, concentrate economic resources on chosen priorities; one of these priorities is the growth of the blue economy. Smart specializations need to be clearly defined, only then can they contribute to economic growth when combined with proper management of public financial means. The objective of this paper is to introduce and characterize the assumptions for smart specializations and to assess the progress of their implementation and the necessary conditions required in Polish regions; particularly when referring to sectors of the blue economy.

Introduction

The concept of smart specialization introduces a general outlook on the issue of specialization in science, technology and the economy in the European Union. Being a new idea in the European Union's Cohesion Policies, its assumptions refer to theories which have been presented in the literature for many years, especially those covering regional development, i.e.: the theories of: economic base, basic product, industrial district, territorial production systems, cluster, "the learning region" and the new geography of the economy.

Smart specializations have become a new philosophy for innovative policies that are shaping the European Union and therefore they have been a focus for many analyses and references in the European Union's programmes. The following papers are of particular importance for understanding and implementing the concept (Nowakowska, 2015, p. 59):

- Regional Policy Contributing to Smart Growth in Europe 2020: the document describes the role of regional policy in the implementation of the Europe 2020 Strategy within the intelligent growth concept, and, in particular, the implementation of the lead project: "The Union of Innovation" (European Commission, 2010, p. 553).
- Connecting Smart and Sustainable Growth through Smart Specializations: the document indicates the ways to connect smart specializations with stable and well – balanced economic development (European Commission, 2012).
- Guide to Research and Innovation Strategies for Smart Specialization RIS 3 which looks at the ways of designing smart specializations and the instruments for their implementation (Foray et al., 2012).

The documents present how the concept converges with the policies of the European Union and they give practical recommendations for constructing

regional policy aimed at the creation of smart specializations.

Purpose and research methods

The basic idea of the smart specialization concept is to enhance the innovativeness and competitiveness of regions by taking advantage of their assets and developing the most promising areas of specialization, with the aim of building a competitive advantage at the international level (Gralak, 2015).

The objective of this paper is to introduce and characterize the assumptions for smart specializations and indicate the progress of their implementation and the necessary conditions required in the Polish regions located along the Baltic Sea coast. Moreover, this paper reviews and analyses major documents exposing the question of smart specializations. The empirical part deals with the identification and assessment of the progress in the implementation of the concept in Polish regions, with particular focus on the blue-economy regions. The main findings outline the principles of innovation policies and position regional policy in that context, they also evaluate the novelty of smart specialization in the context of blue-economy development in the Polish regions stretching along the Baltic Sea.

The research performed on the matter in question includes various analyses of the literature, development projects and innovation strategies, both European and national. The research applies the method of induction (at the stage of the literature studies) as well as analysis and synthesis (the empirical stage), and finally the method of deduction (the conceptual stage).

The idea of smart specialization

The difference between the concept of smart specializations and the traditional concepts of innovation management, is the notion which can be defined as entrepreneurial discovery – an interactive process in which the forces that influence the market and the private sector of the economy search for information on new fields of activity, and government agencies assess the influence of selected areas on regional development and they support the regions which possess the greatest potential for achieving a competitive advantage (Wolniak & Hąbek, 2016, p. 133).

Smart specialization is based on the conviction that no country or region can be a leader in all areas of science and innovation, and that each of them has a certain potential which enables them to only

achieve a competitive edge in some areas. According to the European Commission, in knowledge based economies, each region has its own role to play, under the condition that they are able to find their competitive advantage as well as their potential and ambition to excel in selected market sectors or niches.

The notion of “smart specialization” does not have a standard definition. For the needs of strategic planning, it is defined as a new or evolving economic specialization which bases its competitiveness and development on specific and unique regional resources as well as their innovative combinations and applications (Gralak, 2015).

The concept supports the development of smart specialization in an attempt to improve the effectiveness of the innovative process, particularly in the context of public sector expenditure (Foray, David & Hall, 2011). It takes into consideration the assumption that regions should not and cannot develop activities in all areas at the same time. Regional authorities should choose such domains in which they have adequately developed resources, within which they should concentrate their research and development activities (McCann & Ortega-Agiles, 2015).

The necessary conditions for the implementation of smart specialization (UMWZ, 2015; 2016a; 2016b) are as follows:

- changing the traditional behavioral patterns in society (fear of the unknown);
- assurances of the efficiency and quality of the educational system and the ability to adjust that system to the market's needs and readiness to adequately respond to changes in the situation of the region;
- shaping of pro-innovation views and actions among entrepreneurs, giving incentives for implementation of innovations, especially those developed in co-operation with the research and development sector;
- implementation of innovative ideas in the market through actions aimed at lowering the risks connected with the process;
- support for research and development activities in research centers and companies;
- increasing the number and quality of innovative implementations, especially those based on research and development projects and with the participation of the institutions involved;
- support for innovative applications and new communication technologies which meet the needs of modern society;

- facilitation of access to the financial instruments that are necessary for innovative projects, including the newest solutions in this respect worldwide;
- effective allocation of financial means for research and development projects aimed at bringing innovative projects to the market;
- assistance for international cooperation and internationalization of companies in order to reinforce their competitive edge and to enhance their importance in international or global commercial supply chains;
- assistance given for cooperation between the scientific research sector and the economy through legal regulations that encourage the participants of the process to act more effectively;
- advancement and broadening of offers from institutions to support implementation of innovations and technology transfer as well as assurance of easier access to such services.

When analyzing the conditions required for the implementation of smart specialization in regional innovation policy it needs to be stressed that promotion of pro-innovative solutions, as well as openness towards new elements, are necessary for the development of the modern economy. The changes should be accompanied by initiatives supporting innovations in many aspects of life, relating to social, environmental and economic issues. The authorities need to focus on the human factor by creating opportunities for people to obtain better job qualifications that are indispensable for research and development activity. Programmes supporting all levels of education are helpful, especially those aimed at creativity and innovation development.

It should be remembered that one of the key factors that contribute to the creation of innovative markets is the possibility of obtaining financial means for realization of ground-breaking projects. Such projects are perceived to be risky by commercial financial institutions; therefore they must be supported by access to other sources of financing. In the long run, effective allocation of financial means for research and development projects will enable the creation of well-balanced financial instruments that will support the stable growth of innovative economies and create new added value to companies introducing new ideas to the market.

Innovative potential in Poland in the context of smart specializations

Having analyzed the potential for innovation in Poland, there appears to be a plethora of social,

economic and urbanization factors that influence the level of innovativeness. On one hand, the innovation process is strongly determined by the wealth factor and abundance of human capital which reinforce the search for new ideas, services or products. On the other, the ground breaking process depends on the preexisting technological capacities of the economy and also on the existing level of scientific research.

Taking into consideration some more important factors, particularly the ones connected with technological strength, it needs to be indicated that the regions of northern and western Poland feature a relatively low level in the R&D sector, when compared with, for example, Małopolskie or Mazowieckie; which are the national leaders in this respect. Internal outlays on the R&D to GDP ratio (the GERD) have been maintained considerably below the Polish average. The Lubuskie and Zachodniopomorskie regions occupy the last two places among all the regions in Poland with ratios of 0.20 and 0.27 respectively. Furthermore, the total internal outlays of the industrial sector on R&D (the BERD) in relation to GDP in 2017 were only 0.25% in the “microregion” (the Lubuskie and Zachodniopomorskie regions combined) and the outlay per head was lower than the average in Poland. The tendencies concerning the innovative activity of companies in Poland have been similar in recent years. The latest period has featured a drop in the number of companies actively innovating when compared with their overall number, in both the industrial and service sectors.

The above analysis, based on some important ratios, indicates that the existing innovation potential has not been applied at a satisfactory level. This has been happening despite the presence of academic centres and the intersectoral co-operation which has been attempted.

A solution for this situation can be well constructed policies that are pursued with the aim of establishing a proper system to create effective connections between science, technology, administration and the market. Such links will provide opportunities for the fast introduction of innovation which will improve competitiveness in the markets and will contribute to the enhancement of living standards.

The blue economy sector in Poland in the context of smart specializations

The improvement in the competitive advantage of some regions makes it possible to implement innovative solutions in transport and maritime industries. Such potential in the so-called blue economy is

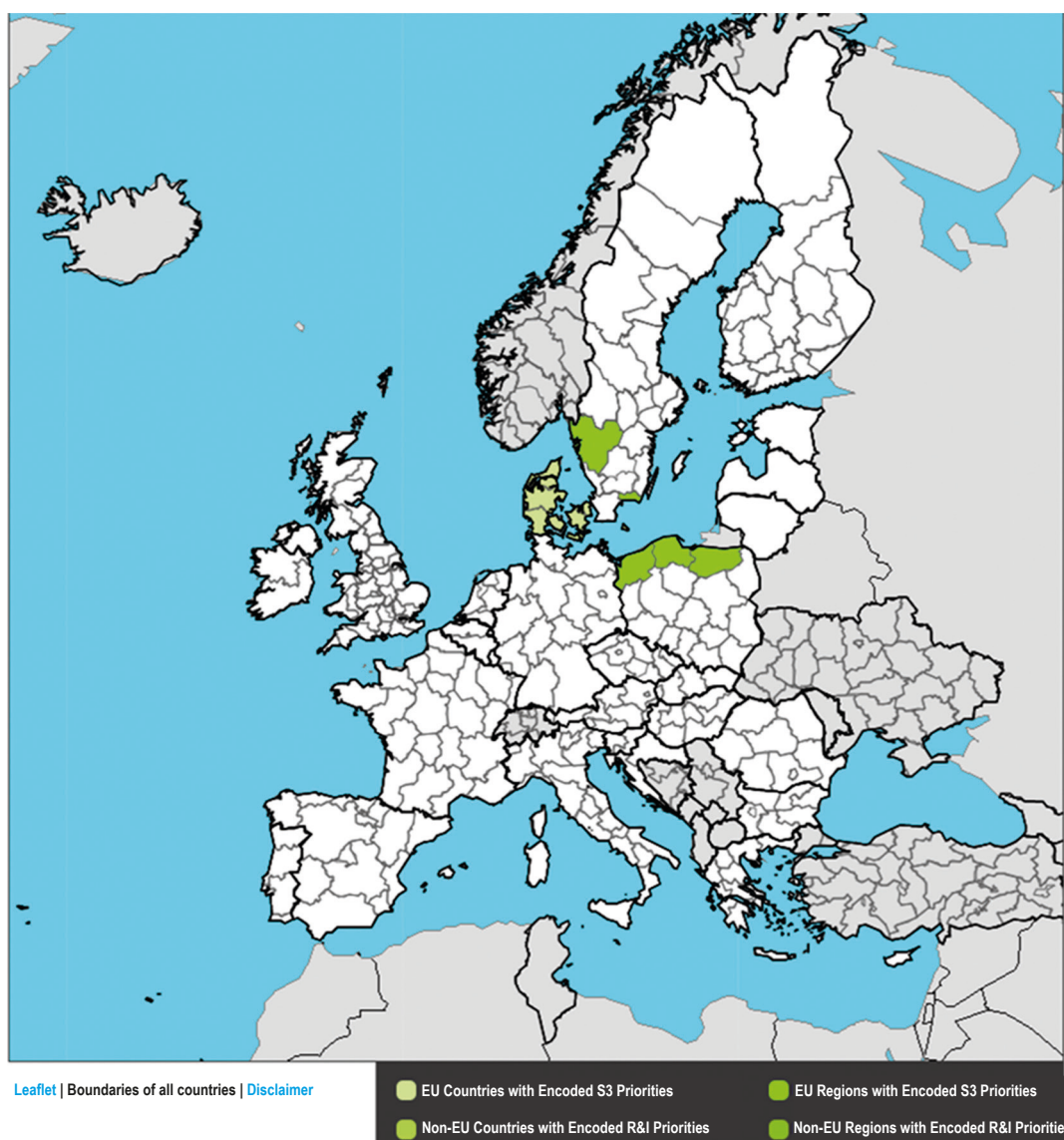


Figure 1. EU regions which have incorporated “blue growth” (The Smart Specialization Platform, 2019)

particularly visible in the northern regions of Poland; especially the Pomorskie, Zachodniopomorskie and Warmińsko-Mazurskie regions (see Figure 1).

As the authors of the report indicate, Poland’s blue economy employs 162,000 people and generates over 3.3 billion Euros in GVA. Poland’s blue economy is dominated by the coastal tourism sector, which contributed 27% of jobs and 20% to GVA in 2017. The ports, warehousing and the shipbuilding sectors are also important contributors to the blue economy; providing 18%, 23% and 14% of the jobs and 20%, 16% and 17% of the GVA in 2017 respectively. Even though Poland’s national GDP growth has been rising by 47%, growth in the blue economy GVA has been sluggish (8%). At 0.71% in 2017, the share of the blue economy GVA to national GDP fell 27% compared to 2009; blue economy employment also decreased. While national employment grew by

almost 3%, blue economy jobs fell 7% compared to 2009 (cit. (European Commission, 2019)).

Blue economy specializations as smart specializations of Polish regions

The choice of smart specialization in Polish regions features similar characteristics. Identification of a specialization is mainly based on statistical data: mainly on the GDP level generated by a particular branch of the economy, on the employment level and on the percentage of the workforce that is educated and prepared for the branch. Another important element are comparative analyses that are made in order to show the potential of key branches. In parallel, consultations are performed in all the regions, involving entrepreneurs, business environment institutions and non-governmental organizations.

It needs to be stressed that the level of diversification of smart specialization is different in particular regions of Poland; this causes significant difficulty when making comparisons between them. According to the methodology of comparative research, specializations are selected by referring to branch standardization. Specializations are put into groups and the groups are shown in sectors. The aim of such a rating system is to specify a direction for the development of a particular branch, based on a broader description in the strategic document. The research has taken into account the level of importance of each branch for the smart branch specialization strategy of a particular region as a whole. Unfortunately, the level of detail for each region (“voivodship”), and the number of specializations selected did not adhere to standardized rules.

The analysis of the selected smart specializations in the regions shows that the most popular Polish specializations do not belong to a specialization related to the maritime economy. The majority of Polish intelligent specializations remain beyond the sectors of “blue-growth”. The particular selection of regional choices concerning specializations are as follows: telecommunications, IT and multimedia have been chosen by Dolnośląskie and Wielkopolskie regions. Medicine and health-promoting tourism are supported by Dolnośląskie, Lubuskie and Zachodniopomorskie; within their innovative regional policies. Health food production and promotion is a feature of Dolnośląskie, Lubuskie and Opolskie. Bioeconomy will be supported in Dolnośląskie, Lubuskie and Zachodniopomorskie. The Opolskie region wants to focus its regional policy on energy production; including renewable sources of energy. Machine building and metal industries is another popular specialization which is supported in Dolnośląskie, Lubuskie, Opolskie and Zachodniopomorskie.

The table below presents the smart specializations which are divided into groups and branch sectors (see Table 1).

The above analysis shows that the blue economy specialization only appears in the group of intelligent specializations in the three voivodships (regions) located on the Baltic coast: Pomorskie, Zachodniopomorskie and Warmińsko-Mazurskie. The priorities of blue growth mainly refer to the following activities: port management, shipbuilding, transport, logistics and construction of sea infrastructure. The coastal locations of the three regions are crucial for the development of the sea-based economy. However, the smart specialization generated there belongs to a group of traditional sectors which feature a lower level of innovation. Therefore it should be concluded that the smart specializations of Pomorskie, Zachodniopomorskie, and Warmińsko-Mazurskie regions have to work on more promising prospects of future development in order to fulfil their functions and support interregional competitiveness.

This is particularly important in the context of the data shown earlier in this paper which mirror the deeper and deeper decreases in the blue economy evaluation indicators of the Polish coastal regions in comparison with other regions in the European Union.

In summary, it must be concluded that smart specializations pose quite a challenge for many regions in Poland. Inadequate levels of experience and know-how were a feature of the early stages of setting priorities and resulted in differences in the abilities of various regions to implement strategies for research and innovation within the smart specialization policy. In case of the blue economy regions, the new instrument of progress is not only the innovation strategies, but the very concept of the blue economy as such. It should be stressed that the traditional

Table 1. Smart specializations in the chosen regions in Poland (author’s own compilation based on the RIS, 2019)

Region	Smart specialization
Pomorskie	Off-shore, port and logistics technologies Interactive technologies in a high level IT environment Eco-effective technologies in production, transport, distribution and consumption of energy and fuels Medical technologies for the diseases of civilization and for anti-ongoing cures
Zachodniopomorskie	Bioeconomic (based on the natural resources of the region and its economic and scientific potential) Maritime industries and logistics (including ship building and off shore technologies) Machine building and metal industries. Extensive experience in ship-building is a precious asset here. The region features fast growth in this line of business. Services of the future (dynamic development of ICT, IT and KPO branches), as well as creative industries.
Warmińsko-Mazurskie	Water areas as an economic asset (including yacht and boat production, water sports, transport and construction of water infrastructure) Woodworking, timber and furniture industries High quality food production

maritime industries (i.e. shipping and fishing) have been the subject of European, national and regional policies for decades. On the other hand, the “blue branches” within such industries either lack adequate support, or the support is given at a very limited extent. The following conclusion indicates that, at the European level, particular guidelines on the strategies for research and innovation within the “blue regions” have not yet been highlighted.

“Blue growth” requires intensive action in order to enhance the potential for balanced innovation, which, in turn, requires streamlining of the means of support. Implementation of the smart specialization project in the regions around the Baltic Sea needs a high level of operational abilities and a system of common monitoring. The program of implementation of the project is part of a broader management, focused on smart development of the “blue regions”. The system of monitoring and assessment of smart specialization in the “blue growth” regions can be helpful in overhauling the strategies for research and innovation, and also to intensify the necessary actions to make the “blue regions” more visible.

Conclusions

Smart specialization strategies differ from typical innovation strategies through their references to the reality, i.e., not only taking into consideration research methodology, terminology or statistics, but also various conditions and features like geographical location or historical, social, economic and political background as well. It must be stressed that smart specializations should not be perceived as an inflexible element of economic development. On the contrary, the research should assume the evolution of smart specialization strategies and their modifications according to the changing needs or conditions.

The three regions analyzed in this paper, i.e., Pomorskie, Zachodniopomorskie and Warmińsko-Mazurskie have declared blue growth in their package of specializations. By definition, blue growth should lead to intelligent, socially inclusive and steady economic growth, aimed at innovation and also at the enhancement of the blue economy.

However, as mentioned above, the traditional economy sectors prevail within blue growth in Poland; predominately transport and harbor operations. These activities, enhancing and improving Polish ports, are necessary for the future development of the regions in question. At the same time, more emphasis should be put on diversification and

the support given to other aspects of the blue economy. One of the most important elements will be a well-qualified and flexible workforce that is prepared for the implementation of advanced solutions. Blue economy innovations will maintain the commercial utilization of the traditional maritime industries and will ensure well – balanced exploration of the sea’s resources, placing significant emphasis on protecting the natural environment.

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Tales from the Silk Road – a snapshot of trade with China in the Polish press during the second half of the 19th century

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Key words: history of trade, Silk Road, Polish press, 19th century, China, colonialism

Abstract

This paper presents trade between China and Europe along the historical Silk Road, based on the materials from the Warsaw press published in the second half of the 19th century. The 19th century was a period of intense military actions led by the European empires in the Far East. The defeat of the Qing Dynasty during the Opium Wars marked the so-called cutting of the “Chinese cake” and the gradual fall of the empire. The events of this period caused an increased interest in the subject of the Middle Kingdom among Europeans and also in the Polish press.

Introduction

The world paid little attention to the events in the Far East until the 19th century, and although Europe had observed these areas with interest since the Middle Ages, only the Opium Wars involving Great Britain and France caused the Chinese Empire to attract the attention of the rest of the world. During the period of geographical discoveries, a sea route to Asia was sought to shorten trade times, while expeditions in the 19th century were motivated by profits from military operations and land exploitation. For centuries, the isolation of China from the international arena was a key element of the colonial policy of European powers.

The Middle Kingdom in the 19th century was seen as a backward empire ruled by the Qing dynasty and Chinese officials. Compared with the Western European countries that went through the Industrial Revolution, China could only boast of a vast territory and an impressive population. It was the technological, economic, and social changes in the West that caused it to exceed the Middle Kingdom in a civilizational way (Frankopan, 2015). Even in 1820, China as a lone giant ranked first in terms of gross

domestic product. The empire accounted for 32% of global production, and 36% of the world's total population. In 1911, the ratio of the above values was only 9-to-25, and it was rapidly decreasing (Weggel, 2006). The press noted that the size of China's territory and its population ceased to dazzle Europeans, and the country remained merely a “colossus with feet of clay” (N.T., 1895, p. 89).

The noticeable interest of European countries in the Far East caused China to become one of the most popular topics of discussion in the European press. The Opium Wars from 1839–1842 and 1856–1860 and the outbreak of the Boxer Rebellion in 1898 attracted the greatest interest. With the development of political events, the number of articles describing armed operations increased, as did the number of texts on Chinese culture, history, and economy.

This work will present an image of trade relations between China and Europe, with a particular emphasis on the popularity of Chinese goods such as tea, porcelain, or silk in Polish lands. The aim is to broaden the reader's knowledge about earlier inaccessible areas and contribute to the growing interest in the Far East at the end of the 19th century among Polish readers.

The methodology used in this work was based on a critical review of English and Polish historical literature devoted to the Silk Road and materials from the Warsaw press from the second half of the 19th century. These valuable sources included reviews of political events, geographical descriptions, and travel relations.

Due to the limited volume of the paper, articles from two Warsaw periodicals from the second half of the 19th century were used. These were chosen based on the number of issues and the status of readership in the Congress Poland (The Kingdom of Poland, Congress Poland, a country created in 1815 by the decision of the Congress of Vienna from the lands of the Duchy of Warsaw – excluding Poznań – as a monarchy connected by a personal union with Russia). “Wędrowiec”, which was the first source, was a weekly periodical on travel and geography, and then socio-cultural issues, published in the capital from 1863 to 1906. It was one of the longest-running titles from that period. The second source material was “Ateneum – a scientific and literary magazine,” issued monthly from 1876–1901. Its editorial office was recognized as the center of academic life in Warsaw (Kmicik, 1970).

The historical Silk Road

China isolated itself during the period of antiquity and the Middle Ages and was not widely known to the rest of the world. The lack of official diplomatic contacts, geographic distance, and ignorance of the language meant that the ignorance of the West about the East and vice versa was maintained for many years. It should be emphasized, however, that the Middle Kingdom did not express excessive interest in the culture and political situation in Europe. The same cannot be said about the countries of the Old Continent, which from the 13th century regularly sent priests to China in an attempt to spread Christianity into unknown areas.

Another form of contact between Europe and the Chinese Empire was trade exchange, which occurred through the historical Silk Road. Goods had been transported by land transport since the 3rd century BC, until the period of geographical discoveries in the 15th century, after which they were replaced by sea transport. When examining its route, it should be noted that it never played the role of a single trade route with several arms, and was rather a network of land connections between East and West.

Researchers emphasize that despite the complexity of the system, the operation of the Silk Road is

one of the longest-functioning international mechanisms in history (Hübner, 2016). Historical studies indicate that the route originated in the former capitals of China, Xi'an, or Luoyang. The passage then diverged into the northern part which ran through Pamir to the Black Sea and a southern route through Central Asia, northern India, into the Middle East. From there, the goods reached the areas of the Mediterranean Sea.

New research suggests that the Silk Road should be perceived as “a complex arrangement of longer and shorter land roads, thanks to which goods, ideas, and people participated in the broadly understood commodity exchange and exchange of intangible assets between European, Asian and African countries” (Christian, 2000). In turn, Christopher Beckwith (Beckwith, 2009) goes a step further and compares the trail to a holistic system encompassing the culture, policy, and economy of Central Eurasia, in which local and international trade was an important element of civilization.

The name of the route was attributed to the German geographer and traveler Ferdinand von Richthofen, who tried to prove the existence of an international trade route connecting East and West in antiquity and the Middle Ages. Richthofen named the route *Seidenstrasse* (English Silk Road) in 1877, after the most valuable object of trade with China, i.e. silk (Wood, 2002).

The land route was covered with caravans using camels, mules, and horses (Boulnois, 1968). Silk, ceramic products, leather, furs, decorative bronze weapons, mirrors, tea, spices, and cosmetics were mainly transported towards Europe, while merchants returned to the Far East with gold and silver, textiles, precious stones, and amber. The proportions of the commodities varied depending on the period and demand. It should be noted, however, that the Chinese market was much more attractive to Europeans throughout the duration of the exchange.

The previously-mentioned geographic discoveries and the development of the maritime commercial fleet made water transport from around the 15th century more economical and safer. The sea route from the Persian Gulf to China took about 150 days, while the land road from Tana (present Azov) to Beijing lasted twice as long. In favor of shipping, it is worth mentioning that one ship could carry the same cargo as a caravan with a thousand pack animals (Latow, 2010).

Another breakthrough was the introduction of rail connections between Europe and Asia. In an extraordinarily extensive article in the *Ateneum*, Polish

readers can acquaint themselves with the plans of European powers regarding the routes of the iron railway, for example through Siberia to China or from Paris via Central Asia to India (Warnke, 1876; 1877a). The part about the planned Siberian railway, which was supposed to shorten commercial road to 18–20 days, should be particularly interesting for Polish customers. Its shorter duration was why it became more attractive than transport through the Suez Canal, although it was more expensive (P. St., 1893).

Wars for trade

Despite the change in the nature of trade between East and West, the trade balance with China continued to be negative for Europe, especially for the United Kingdom, which was looking for ways to stop the outflow of silver from the country to balance its interests. The solution was the illegal opium trade, whose scale grew rapidly at the beginning of the 18th century. In one of the articles introducing the problem of drug addiction, the author emphasized that “a Chinese without opium would not be a Chinese man” (Plain Truth, 1901a, p. 494). The illegal opium trade and an aggressive colonial policy led by Western powers (in particular Portugal and Spain) meant that in 1757, Emperor Qianlong issued a writ against foreign trade in China, excluding the port of Guangzhou.

The exception was the turnover of goods with Russia, which due to the political situation in Congress Poland, was the most widely reported in the Warsaw press. The exchange between the two empires had already been settled at the beginning of the 17th century. As a result of disputes over the border over the river Amur, the Treaty of Nerchinsk (1689) and the Treaty of Kyakhta (1727) were signed to regulate the territories and maintain trade relations. Under their terms, all trade and travels were to be conducted through Kyakhta, the last Russian city near the border with China. In the Middle Kingdom, it was the city of Maimaicheng, where a representative of the government in Beijing resided (Timkowskij, 1928).

Until the end of the 18th century, China pursued an isolationist policy, defending itself against foreign influences and Western goods. Unofficially, however, the opium trade was growing rapidly thanks to Chinese officials and traders living off regular bribes from foreign merchants. It was mentioned several times in the Warsaw press that “the sickness of bribes in China, because a Chinese man who considers something to deal with, strongly believes to take

advantage of his situation” (T. J-Ch., 1900). In 1800 alone, 200 tons of the drug were imported into the Empire, which increased 7 times over the next three decades (Greenberg, 1970).

The vision of reducing profits and limiting the activities of European buyers in China caused the powers to adopt a more aggressive policy. The primary British position in economic relations with the Chinese Empire resulted in concentrating two-thirds of the market. When the United Kingdom took the initiative to break the Qing state isolation, the rest of the Western countries quickly stepped in. The activities of foreign powers in China were perceived in the press as “a modern economic and political invasion” or “the desire for expansion, a feverish search for a capital investment” (Marchlewski, 1900, p. 454). The commentators also doubted that visions of profits due to the opening of ports would not be more attractive to Chinese officials than an open armed conflict. Perhaps “the buyers will be recommended to do what soldiers could not do – conquest of China and wining them for industry and European trade” (Plain Truth, 1900f, p. 1034).

In addition, attempts to limit imperial edicts concerning the opium trade, the most valuable commodity imported to the Empire, led to two armed conflicts in 1839–1842 and 1856–1860. During the Opium Wars, modern armies of the Western powers defeated the Chinese troops, leading to the signing of unequal treaties. The agreements guaranteed the opening of other Chinese ports to international trade, extraterritoriality of selected lands, and payment of high war contributions (Fairbank, 1996). Although only the British and French troops participated in the military operations, thanks to the most favored nation clauses, all benefits were also given to Russia and the United States, which had the largest shares in trade with China. This is a definition of the treaty obligation that is used in international trade relations. A country granting this clause to another country provides it with the same powers and facilities as any other country it trades with (Budnikowski, 2006). The provisions of the Beijing Convention ending the Second Opium War constituted the next step to transforming the Empire into a joint semi-circle of powers (Rodziński, 1974). In the Warsaw press, the following words began to appear: “Europe is digging deeper into Chinese estates and looking for goods there” (Plain Truth, 1900a, p. 110) or “Chinese expedition was undertaken not for ideas, but for interests” (Plain Truth, 1900e, p. 773).

The next step to the loss of independence of the Middle Kingdom was the Boxers Rebellion, referred

to in the Polish press as “the rebellion of the Great Kulak sect” (Wędrowiec, 1900, p. 435). The armed intervention of peasants in secret groups took place in 1899–1901 and was directed mainly against foreigners, which were gaining increasing influence in China. The actions of “white devils” (Plain Truth, 1900d, p. 713), as foreign citizens were labeled in China, were perceived as the cause of universal poverty and numerous natural disasters. The culmination of the uprising was the capture of Beijing and the siege of the diplomatic quarter in August 1900. Chinese forces were broken up by the united intervention of 8 countries (the intervention troops included soldiers from Great Britain, Germany, Japan, Russia, France, the United States, Italy, and Austria-Hungary), which resulted in the signing of the final agreement known as “The Boxer Protocol.” The agreement was signed with 8 countries participating in military operations as well as Belgium, the Netherlands, and Spain. According to this, China had to pay a compensation of 333 million dollars with interest within 40 years and could not import arms, ammunition, or materials used to produce them for two years (Boxer Protocol, 1901). The provisions of the protocol were widely commented in the press. The statement of British diplomat Robert Hart, who was the second Inspector-General of China’s Imperial Maritime Custom Service, regarding the insolvency of the Empire in the context of repayment of war damages was quoted (Marchlewski, 1901, p. 145).

As a result of the Opium Wars, unequal peace treaties, the weakening position of the Qing dynasty, and many internal rebellions allowed Western powers to gain considerable political influence in China (Schell & Delury, 2013). In Polish historiography, the process of dividing the Empire into areas of influence is referred to as “cutting a Chinese pie or watermelon” (Marchlewski, 1900, p. 455). The countries which mainly involved in this action were Great Britain, France, Germany, Japan, and Russia. Belgium, Spain, the Netherlands, Austria-Hungary as well as Italy also made other, less successful attempts.

The Manchurian Qing dynasty, which ruled the country for over two hundred years, had to deal with an economic crisis and strong social tensions. However, it soon turned out that the remains of an inept old regime were deeply rooted in society (Fenby, 2009). The press often emphasized the reasons why China did not keep up with the modernization of the Western world: “deep in stagnation, they allow themselves to waste, to decay the economic wealth in which they abound. The government and national

character seems to exclude any similarity of transubstantiation” (N.T., 1895, p. 90).

In 1912, the world witnessed the actual fall of the empire and the dethronement of the last Chinese dynasty. Over the next few decades, the country became a place of civil wars and Japanese occupation. In the 20th century, China was to undergo a rapid historical change, while similar processes in the West lasted for centuries. In one generation, the Chinese were faced with a transition that they had not experienced in the two thousand years of the duration of the Empire.

Poles in China

The tense political situation and the establishment of official diplomatic contacts with Far East countries made the Chinese culture, considered so far exotic and inaccessible, a topic of interest to politicians, travelers, researchers, and journalists around the world. Due to the involvement of Polish invaders in events in the Far East, the growing interest was also visible in Congress Poland. A journalist writing for *Ateneum* in the article “In the East Asia” highlighted the importance of the situation: “[...] in this state of affairs, first-hand information about the Asian East is very desirable for us, and a person who disregards them cannot consider themselves as educated. It was never more needed.” (N.T., 1895 p. 79).

However, this was not the beginning of Polish-Chinese meetings which extended knowledge about this Asian country. Polish exploration of the Middle Kingdom (also called *Kitaj Kitaj* (Russian) – from the name of one of the nations (10th–11th century) – *Kitans* (Liao country)) was a long-term process, and its beginnings date back to the 13th century (Konior, 2013). The Battle of Legnica in 1241 marked the first time that it was possible to watch the Chinese war inventions used by the Tatars. A few years later, the Franciscan Benedykt Polak set off with a papal mission to the capital of the Mongol Empire, Karakorum, to form an alliance in the fight against Islam. He is considered by historians the first Pole to reach East Asia (Kadulska & Włodarski, 2008). Many researchers emphasize that this was also the first European long-distance journey into Asia (Kałuski, 2001). His travel report, entitled “History of Tartarorum”, describes customs and foreign policy as one of the most valuable historical sources discovered in the 20th century (Kajdański, 2005). In the following centuries, other Polish missionaries set out into unfamiliar areas, the most famous of which

was Michał Boym, a Jesuit from Lviv, who reached China around 1646. He is called the Polish “Marco Polo” (Kajdański, 2005) and the author of many works on the Empire in the fields of geography, ethnography history, and medicine.

Among Poles who involved in the history of Polish-Chinese relations, it is worth mentioning the prisoners sent to the Russian Empire for illegal activities during the partitions, because their escape routes often led to China. The Polish engineers and builders of the Chinese Eastern Railway in Manchuria also marked their presence in the Far East. In China, there were also officials and diplomats serving in Russian diplomatic missions, clerics, and scientific expeditions. There were also soldiers appointed to German or Russian military service conducting military operations within Asia, many of which left valuable diaries, scientific works, or works devoted to the culture, nature, or history of China. More information about Poles who contributed to the popularization of knowledge about China from the 13th to the 20th century may be found in the literature (Kajdański, 2005). Some were published as articles in the Polish press. Nikolai Przewalski, conducted extensive natural studies in Asia beginning in the 1870s (Warnke, 1877b) or Maurycy Beniowski, whose memoirs describe his escape from captivity in Kamchatka (Jaroszevska, 1894), should also be mentioned.

Chinese products in Poland

Until the 16th century, Chinese products entered Polish territory by land, but after the popularization of commercial shipping, their transport routes changed. However, the method of acquiring goods, which intermediaries of many nationalities – Persian, Armenian, or Italian (Odyniec & Włodarski, 2001) – participated for centuries, did not change. The complexity of the trade process and the lack of direct contact with Chinese buyers caused products from China to not always be perceived as typically Chinese, e.g. as Turkish or Persian. Among the most popular available in Polish territory were luxury products such as silk, porcelain, tea, and fine art crafts. Their recipients were, therefore, only wealthy noblemen or collectors. During this period, it was not profitable for merchants to import cheap consumer goods from such distant regions.

The advantageous, but not used, geographical location of Warsaw in the context of international trade was noticed by Leon Iwanicki (Iwanicki, 1894) in an article on the importance of Siberian

railways. The capital of the Congress Kingdom was to become a link connecting the West with the Far East thanks to the construction of the Warsaw–Terespol and Brest–Moscow railways. The dependence of domestic trade on Russia and the overcrowding of the market with foreign commodities meant that Warsaw held a weak position and was described as “a vole pole looking at the great route” (Iwanicki, 1894).

Among the imported luxury goods, the exception was tea, which gained popularity even among middle-class townspeople and peasants. From the middle of the 18th century, the number of mentions of herbal decoction increased significantly. In Polish literature, it initially appeared under the name of “thee” or “herba” from the Latin coat of arms – herb (Tarasiewicz, 2009). As for the properties of the exotic drink, the researchers were divided. Benedykt Chmielowski in the first Polish encyclopedia of the popular “Nowe Ateny” mentioned that the drink is a great way to relieve pain, heal ulcers, and even to brighten someone’s mood. Less enthusiastic was the botanist Krzysztof Kluk in “Dykcyonarz Roślinny”, in which he emphasizes the negative impact of tea on the nervous and digestive systems. In his opinion, if China sent all poisons to Europe, they could not harm more than drinking tea (Kluk, 1805). Interestingly, the decoction was originally treated as a medicine, then as a refreshing drink (Odyniec & Włodarski, 2001). It seems that the reluctance to brew tea arose from the inability to prepare and store it (Tarasiewicz, 2009).

Estimating the amount of imported tea to Polish lands during the 19th century is not an easy task due to the lack of reliable numerical data. Its presence was closely related to the Russian trade and the great popularity of the drink in those lands. The process of intensively importing tea to the Kingdom of Poland dates back to the 1830s. Historical studies show that in 1825, around 10.2 pounds of Chinese tea was brought to Warsaw, and in 1838, it was 52.1 pounds. In general, throughout the quarter-century until 1850, there was an 815% increase in tea imports (Tarasiewicz, 2009). English-type tea was also imported to Polish territory. The British, after establishing their colony in India, introduced popular varieties from the Assam region into the market. However, its cultivation outside the territories, which depended on the Empire, significantly reduced the quality of the plant leaves (Iwanicki 1894). In many sources, we can find information about its bitter taste and popularity among the poorer sections of society (Gliszczyński, 1859).

There are also data on tea consumption in Polish lands which shows an increase of 54.5% from 1894 to 1911 (Tarasiewicz, 2009). Despite growing interest in this drink, the population of Congress Poland consumed two-times less tea than the population of Russia, and four times less than the Netherlands during the same period. Although the press did not provide accurate data on consumption or transport of tea on national lands, it thoroughly analyzed statistics on international drink trade. Tea was included in the list of the most important export products from China in 1899 in one of the *Ateneum* issues, the exported value of which amounted to 1174 tons of silver (Marchlewski, 1900, p. 445).

The most widely discussed product in the Warsaw press imported from the Middle Kingdom was silk, often called the noblest fiber in the world. Archaeological research dates its production in China in 3600 BC (Wood, 2002). In the article, there are descriptions of the fate of silkworms' arrival to Europe "only in the 6th century after the birth of Christ, Greek monks brought eggs of these insects from China, hidden with the greatest foresight in the hollows of their clubs, because the jealous Chinese did not want to release silkworms from their homeland" (Wędrawiec, 1863, p. 255). The studies show that silk production was already known in the 6th century AD in Persia, Syria, and Greece, and it was brought to Italy in the 12th century.

One of the largest centers of the silk industry in the Old Continent was the Lyons Factory in France. In spite of the dynamic manufactories and improvements in weaving technology, the Chinese production methods far exceeded the European ones. The problem was mainly the cultivation of silkworms, which was a very complex and tedious process. While China lost only one silkworm per one hundred, in France their mortality exceeded fifty percent (Boulnois, 1968).

The Poles undoubtedly knew about the Chinese origin of the material, since silk fabrics were also called "kitajka". The first manufacture of silk fabrics on Polish territory occurred in 1643 in Brody (Kajdański & Kajdańska, 2007) (Brdo is currently located in the Lviv region in Ukraine). However, most of the goods were imported from France or Italy. Due to high silk prices, materials with an admixture of silk threads, such as damask, velvet, or satin, were often imported. Extremely fashionable in Polish lands in the 18th century were chiné fabrics decorated with delicate floral motifs (Gutowska-Rychlewska, 1968). In those days, silk was highly desired by the sophisticated ladies living by the Vistula River,

and the author of an article emphasized that taking out millions of money abroad in exchange for silk matrices could significantly increase the country's prosperity (Wędrawiec, 1863b, p. 255).

Despite the advanced silk industry in Europe, China was exporting larger quantities of the material to the West. Due to its small volume and lightweight nature, it was extremely easy to transport. Land transport of silk was more economical, despite higher tariffs for railways (Iwanicki 1894).

Even before 1838, the East India Company which had the largest share of trade with the Middle Kingdom was unable to purchase more than 5,400 rolls of silk per year. In 1900, the global export of raw silk from China reached 4,800 tons (Boulnois, 1968). Along with tea, silk accounted for as much as 3/5 of all exported goods at the turn of the 19th and 20th centuries (Iwanicki, 1894, p. 247).

Chinese porcelain entered Europe through Palestine because crusades were organized in the 12th and 13th centuries, but it was rather rare in Polish lands. Sources contain few references to the presence of pledges or individual items, e.g., a pitcher lined with porcelain, found on a list of wedding gifts of Zygmunt August from 1543, or porcelain dishes in the residence of Jan Zamoyski (Kałuski, 2001). It is difficult for researchers to name dishes in Polish sources, since faience products, mainly from the Netherlands, are not always distinguished from porcelain.

Elegant dishes inspired by Asian designs were found in many affluent Polish homes. The widespread production of ceramics in Europe also meant that many articles in the Warsaw press were devoted to it. In one of them, it was emphasized that for centuries, the secret to the production of the material was closely guarded by the Chinese and only the German alchemist Johann Friedrich Böttger, in the 1710s, broke this monopoly (today it is believed that Böttger's master, Ehrenfried Walther von Tschirnhaus, was a European porcelain inventor). Despite the rapid development of factories in Europe, the quality of porcelain (in particular, lightness and hardness) did not match Chinese products (Wędrawiec, 1863a). The growing demand for "authentic" ceramics is also apparent in the statistics of imported goods from China. The "other" category in statistics (Kański, 1979), which included porcelain, constituted 4% of items in 1864 and 34% in 1894.

The popularity of porcelain initiated an interest in Asian art. The passion for Chinese design found its expression in the 17th century. The style inspired by the art of the Far East, called chinoiserie, was visible in gardens, functional interiors, and porcelain.

The intensification of these tendencies, especially in the second half of the 18th century, was associated with the intensification of trade relations and an increase in missionary activity in Asia (Kąkol & Reglińska-Jemioł, 2008).

Inspirations by Chinese landscape art influenced garden designs in Congress Poland and architecture of the Łazienki Park in Warsaw as well as elements of the palace park in Wilanów (Zasławska, 2009). Separate Chinese rooms referred to as oriental cabinets were arranged in many castles, e.g., in Łańcut and Białystok. Chinese calligraphy instruments, porcelain tableware, and valuable travel manuscripts were found in the collections of many wealthy Polish collectors. In the inventory of the Zhovkva treasury of Jan III Sobieski from the 1640s, a set of Mahjong (Chinese social game) tiles was even found (Gębarowicz, 1973). Sobieski is often mentioned as an expert on Chinese affairs in Poland, as well as one of the most zealous lovers of oriental products among Polish kings (Zasławska, 2009).

Conclusions

History has shown that events from the turn of the century in China heralded the process of regaining its full sovereignty. In this context, the contemporary recipient will be interested in another aspect mentioned by the European and Polish press. Many articles devoted to the situation in the Far East have a vision of the Middle Kingdom, in which it will be strong enough to resist its former oppressors. It was written: "If one day the wake of China from eternal lethargy results in a struggle between Asia and Europe, it will probably be in the economic and mental field" (Plain Truth, 1901b, p. 733). There were also more poetic phrases: "China is like a dormant volcano: Who can predict the moment of the explosion?" (Plain Truth, 1900b, p. 469) Or "[war] is an irritation of a hundred-armed dragon. It will lose a few arms, close itself in to ease the momentary pain, but with time, regaining strength, it will attack the enemy and smother it inevitably!" (Plain Truth, 1900c, p. 510). The considerable anxiety over the growing power of the Far East appears extremely interesting in the context of the current political and economic situation in which China remains the main focus.

Searching for traces of knowledge of Chinese civilization in the history of Polish lands is an extremely labor-intensive task. Despite significant difficulties in dealing with the Far East, resulting from distance as well as cultural and language barriers, the desire

to learn about oriental subjects was assessed. The importance of Far East issues for Poles is demonstrated by the multitude and quality of historical sources, including the wide variety of subjects related to the Empire in Warsaw newspapers. It is worth noting that this is only a fragment of content, based on two titles, which reached readers in the second half of the 19th century in Congress Poland.

The notable interest in economic topics was due to three factors. The first is the background to the political conflict in China, which, as the article has shown, was due to the colonial powers looking for a market and war profit. The European audience was perfectly aware that the war was being waged in the name of economic benefits. In view of a similar political situation, the partitioning of China and the actions of Western powers in foreign territories were particularly noted in the Polish press.

The second factor is the slow development of capitalism and the view of Polish lands as an important link connecting the West with the Far East. The future of international trade was shown as a profitable and private state activity. One of the suggestions to stimulate the Polish economy was the creation of a joint-stock company in Warsaw for trade with China, which would have agents in Kyakhta, Shanghai, and Canton, as well as warehouses in Irkutsk, Tomsk, and Kyakhta (Iwanicki, 1894).

The last factor is the development of economics as a scientific field. A breakthrough in the approach to "economic affairs" was the publication of the work "Research on the nature and causes of the wealth of nations" by Adam Smith in 1776. Its bold theories concerning the development of the free market formed the basis of modern economic theories and were an attempt to systemize knowledge of the history of industrial and commercial development in Europe. The Scottish philosopher's activities also contributed to an increase in the number of press titles devoted to economic issues (Bizon & Lubińska, 2018).

It would seem that in the second half of the 19th century, the Polish press did not discuss topics devoted to political events on the other side of the world; however, studies showed that this was a particularly popular topic. The published texts often referred to the travels of diplomats or missionaries, and the economic news included information about the condition of the Chinese economy, and articles wholly devoted to the description of society or customs were also published. Topics related to trade between Europe and the Empire, referring to the tradition of the historic Silk Road, were readily discussed.

Most texts published in the Warsaw press from this period are reprints from foreign magazines or were based on foreign language articles. However, there were works that were not reproducible that presented a Polish view on the social or political situation in the 19th century in China and are the most valuable for the conducted research. Nevertheless, there is no doubt that the publication of articles, both reprints and original, devoted to the subject of the Far East demonstrates the need for a change in the perception of the Middle Kingdom as merely an exotic destination.

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Significance of selected modes of transport used in services facilitating Polish foreign trade

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Key words: Polish foreign trade, international trade in commodities, modes of transport, branches of transport, transport development, trade development

Abstract

The aim of this paper is to assess the utilization of selected transportation modes in services facilitating Polish foreign trade between 2010 and 2017. Poland's foreign trade in commodities is characterized generally herein. The contribution of individual transport modes (i.e. road, rail, inland waterways, sea, or air) to facilitating Polish exports and imports is analyzed in terms of quantity and value. As research material, data from the Customs Administration Analytical Centre are used. Simple statistical and graphic methods (e.g., structural and dynamics indicators) are applied. Polish foreign trade in commodities grew between 2010 and 2017. At the same time, the shares of individual transport modes in facilitating exports and imports shifted, with transport by road remaining the largest contributor. Quantitatively, the share of road transport increased, in both exports and imports; however, a reverse trend was observed for its value.

Introduction

The dynamic development of international trade is one of the most important processes characterizing the contemporary global economy. This development is justified by the benefits it brings, which may have an economic aspect, as well as a competitive/complementary, technological/technical, or simply resource/climate-related side to them (Bernaś, 2002). The development and effectiveness of international trade in commodities is determined by, among other things, logistics and transport processes. Transport has multiple functions, one of which to serve as an instrument of commodity and service exchange, which determines how traded goods are moved (Grzywacz & Burniewicz, 1989).

The objective of this paper is to analyze and assess the utilization of selected modes of transport in services facilitating Polish foreign trade in commodities. Moreover, the work describes the structure of exports and imports according to different transport modes. The following hypothesis is assumed for the

purposes of this paper: The dynamic development of Polish foreign trade in commodities is accompanied by transformations in the modes of transport used to facilitate exports and imports.

This publication discusses practical problems arising from statistical treatments of the Polish commodities trade. These issues focus on analyzing foreign commodity turnover and the significance of selected modes of transport in services that facilitate exports and imports. This analysis is complemented by assessing them in the context of current circumstances characterizing selected transport markets.

Literature review

Problems with international trade have been at the center of many researchers' interest as far back as the early modern period. The resulting international exchange theories have proven to be successful at explaining and assessing the development of international flows of commodities. The literature concerning this subject is rich and effective at describing

both traditional and contemporary international trade theories (Dixit & Norman, 1980; Krugman, 1994; Feenstra, 2015). Contemporary research on international exchange has mainly focused on the problems of globalization (Eaton et al., 2016), economic integration (Ohlin, 1935; Baier & Bergstrand, 2007), the development of international flows of services (Kimura & Lee, 2006; Jones & Kierzkowski, 2018; Malkowska, 2018), innovation (Grossman & Helpman, 1990; Santacreu, 2015), and their effects on the development of economies (Krugman, Obsfeld & Melitz, 2014).

The functioning and development of trade would not be possible without transport, which affects other sectors of the national economy, including trade. Transport plays a significant role in ensuring the functioning of the national economy (Hoyle, 1973; MacKinnon, Pirie & Gather, 2008). The relationship between transport and economic growth is not a direct one but is rather related to the influence it exerts on production and distribution structures and processes, the location and sizes of enterprises, and other production organization characteristics (Nistor & Popa, 2014).

In the literature focusing on transport and logistics problems, foreign trade analyses are typically the only complementary element studied (Grzelakowski, 2012; Pluciński, 2016; Mańkowska, 2019). There are no papers concerning how foreign trade tendencies affect the utilization of particular branches of transport that focus on foreign trade and only treat transport-related issues as a complementary element (Komornicki, 2000).

Various forms of transport are used in services facilitating foreign trade, and the basic modes of transport are sea, road, rail, inland waterways, or air. Each of these modes has its respective advantages, as well as its own limitations. Moreover, transport activity generates costs, both internal and external (Urbanyi-Popiołek, 2013). The latter type of costs, which are linked to negative consequences for the natural environment and human life, have been the subject of many literature analyses (Bickel & Friedrich, 2013; Kotowska & Kubowicz, 2019). This is related to the ongoing promotion of and frequent assistance provided (e.g. by the EU) to those branches of transport that are environmentally friendly.

Methodology

This article discusses Poland's foreign trade, which is treated here in a narrow sense by including only trade in commodities. The starting point

for the study is to create a general profile of Polish foreign trade in commodities, presented quantitatively (taking into account the volume of trade) and in terms of value (shown in USD). Categories such as the exports of commodities, the imports of commodities, and the balance of trade are discussed here. By way of addition, Poland's most important trade partners, commodity structure, and the ratio of the value of exports and imports to Poland's GDP are shown. Data from the Customs Administration's Analysis Center and from the public statistics database of the Chief Statistical Office are used.

Later on, the article analyzes the degree to which the five main branches of transport were used, i.e. sea, road, rail, air, and inland waterways, in services facilitating Polish exports and imports in the period of interest. These branches were chosen by the availability of cohesive statistical data. Exports and imports of commodities according to the individual types of transport from 2010–2017 are profiled in the paper. Also, commodities trade is examined from the point of view of its quantity and value. Additionally, the share of each type of transport in general exports and imports is shown. The indicators calculated for 2010 and 2017 are compared to observe and assess the changes that occurred over time.

The time scope of the study is from 2010 to 2017 and was selected due to the availability of homogeneous and current statistical data. To analyze Polish exports and imports of commodities and the shares of individual branches of transport in facilitating the country's foreign trade, the time series methodology was applied in order to depict the tendencies observed over a longer period. In some justified cases, the analysis is limited to a comparison between the base year 2010 and the target year 2017 to provide a more transparent analysis.

Polish and international literature sources that discuss this subject matter were used. Desk research, simple statistical methods (structural and dynamics indicators), and the descriptive method with elements of deduction were utilized. Drawings and a table were used to present the results.

A general profile of Poland's foreign trade in commodities between 2010 and 2017

Poland's foreign trade developed between 2010 and 2017, with exports of commodities growing by 44.6% from USD 157 bn in 2010 to USD 227.1 bn in 2017. The value of commodity imports grew by 31% from USD 170.3 bn in 2010 to USD 223.2 bn in 2017, indicating that the growth rate of foreign

sales was higher than that of foreign purchases. Consequently, the balance of trade became positive, and although it was negative between 2010 and 2014, it demonstrated a trade surplus since 2015. The balance grew more than four times, i.e. from USD -13.3 bn in 2010 to USD 3.9 bn in 2017 (Figure 1).

A value-based analysis of Poland's foreign trade is complemented by a quantitative examination. In 2010, the export of commodities amounted to 80.1 m tons and reached 109.3 m tons in 2017, representing an increase of 36.5%. Commodity imports grew from 120.8 m tons in 2010 to 144 m tons in 2017, i.e. by 19.2%. Notably, the balance of trade in commodities over the entire period was negative, and the largest deficit was observed in 2011 (-51.8 m tons) and the lowest in 2013 (-20.6 m tons) (Figure 2).

The ratio of the value of exports to the GDP is an indirect indicator of how export-oriented an economy is, and can illustrate the degree of the economy's

“openness”. For Poland, the ratio grew from 33.3% in 2010 to 39.8% in 2017, suggesting that the openness of the Polish economy improved. At the same time, the share of imports in the Polish GDP increased from 37.2% in 2010 to 39.1% in 2017, which indicated a continually growing dependence of the economy on the commodity imports.

Over the eight years of interest, Poland's five most important trade partners remained constant. For exports, in order of importance, they were Germany, the United Kingdom, the Czech Republic, France, and Italy. Among them, neighboring Germany had the largest share in Poland's international sale of its products (26.1% in 2010 and 27.5% in 2017). The share of each of the remaining countries did not exceed 6.5%. As for imports, Poland's most crucial importers in 2017 were Germany (23%), China (12%), Russia (6.4%), Italy (5.3%), and France (3.9%). Over the same period, the highest drop in its share in Poland's imports was observed for Russia

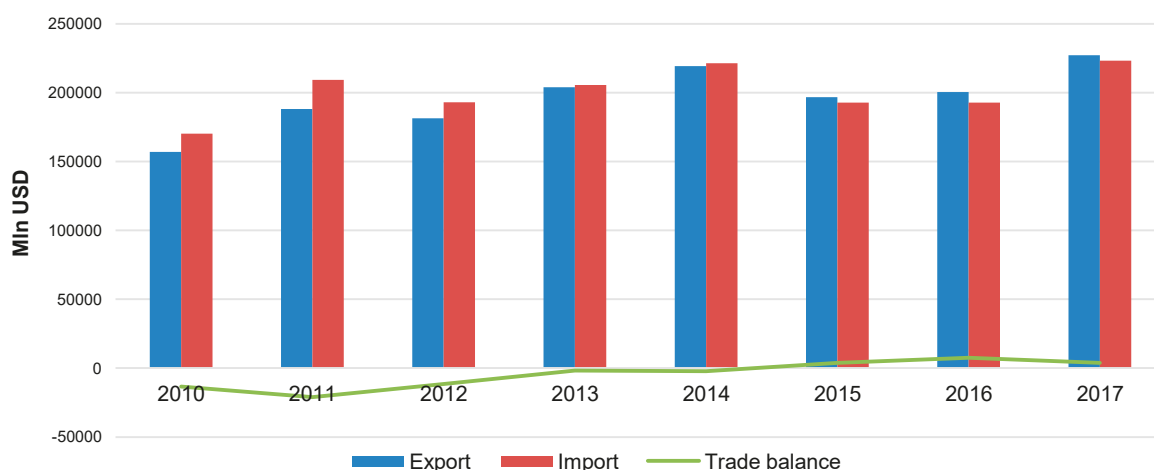


Figure 1. Poland's foreign trade in commodities between 2010 and 2017 in millions of USD (based on data from the Customs Administration's Analysis Center, 2011–2018)

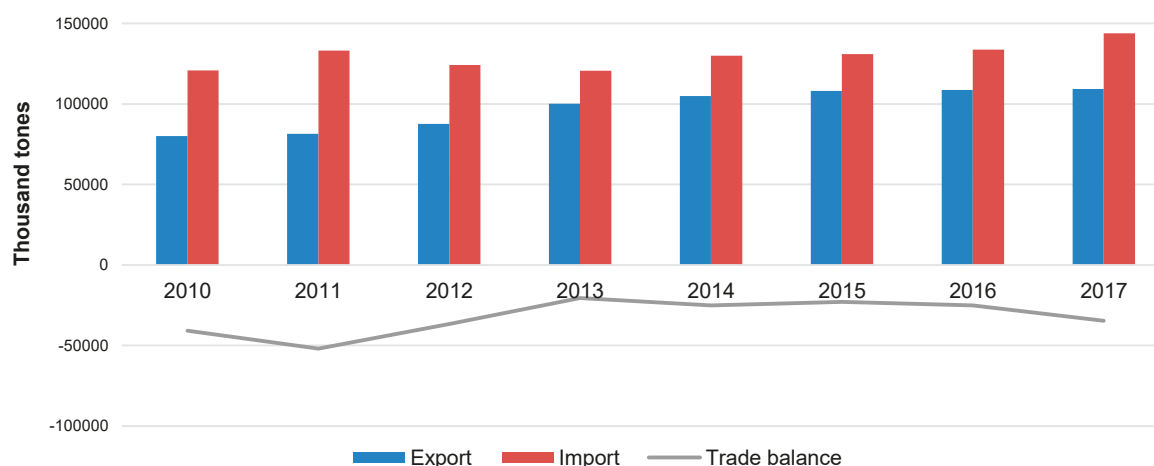


Figure 2. Poland's foreign trade in commodities between 2010 and 2017 in thousands of tons (based on data from the Customs Administration's Analysis Center, 2011–2018)

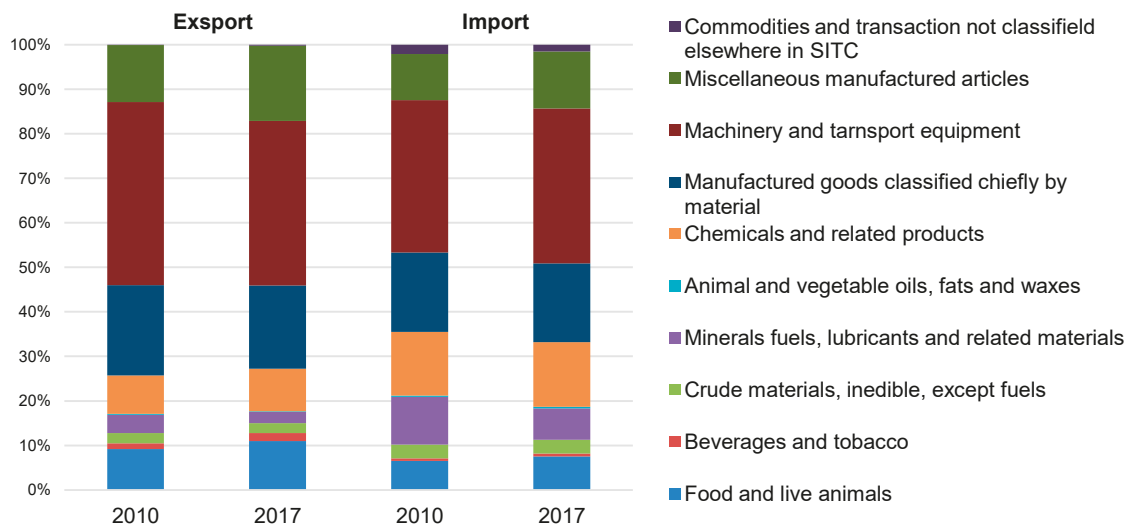


Figure 3. Commodity structure of Poland's exports and imports in 2010 and 2017 by sectors, according to the SITC Nomenclature (based on Statistic Poland, 2011; 2018)

(10.2% in 2010) and China (9.2% in 2010). Between 2010 and 2017, there were also changes to the commodity structure of Poland's foreign trade, as shown in Figure 3.

As for exports, the largest share increase was observed for the "Miscellaneous manufactured articles" (by 4.1 p.p.) and "Food and live animals" (by 1.8 p.p.) groups of commodities. The most notable drop was observed for the "Machinery and transport equipment" (by 4.1 p.p.), "Minerals fuels, lubricants, and related materials" and "Manufactured goods classified chiefly by material" (by 1.6 p.p.) categories. As for imports, the largest share increase was observed for the "Miscellaneous manufactured articles" (by 2.5 p.p.) and "Food and live animals" (by 1 p.p.) groups, with the most remarkable decrease observed for the "Minerals fuels, lubricants and related materials" (by 3.7 p.p.) group.

Utilization of individual branches of transport in services facilitating Poland's foreign trade

Commodity exports

From 2010–2017, the utilization of individual transport branches tended to change. The largest volume of exported commodities was carried by road, and the least by air. From 2010 to 2017, the volume of goods transported by road, rail, and sea increased (by 51.8%, 9.5%, and 0.05%, respectively), while at the same time, a decrease was observed for transport by inland waterways (by 49%) and air (by 69%) (Figure 4). In terms of the value of Polish exports of commodities, transport by road was dominant, with inland waterways transport coming in last. The value of exported goods grew for transport by air

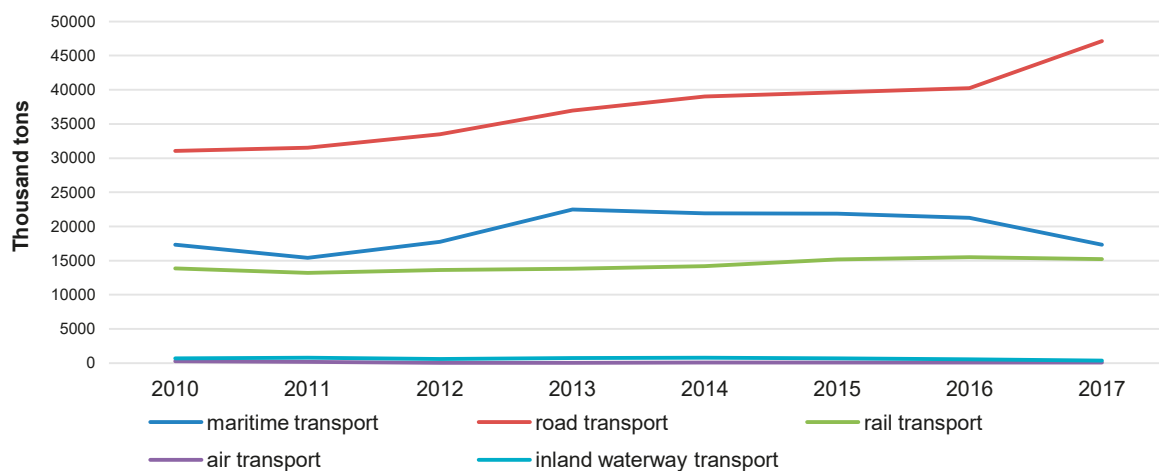


Figure 4. Poland's commodities exports by branch of transport between 2010 and 2017 in thousand tons (based on data from the Customs Administration's Analysis Center, 2011–2018)

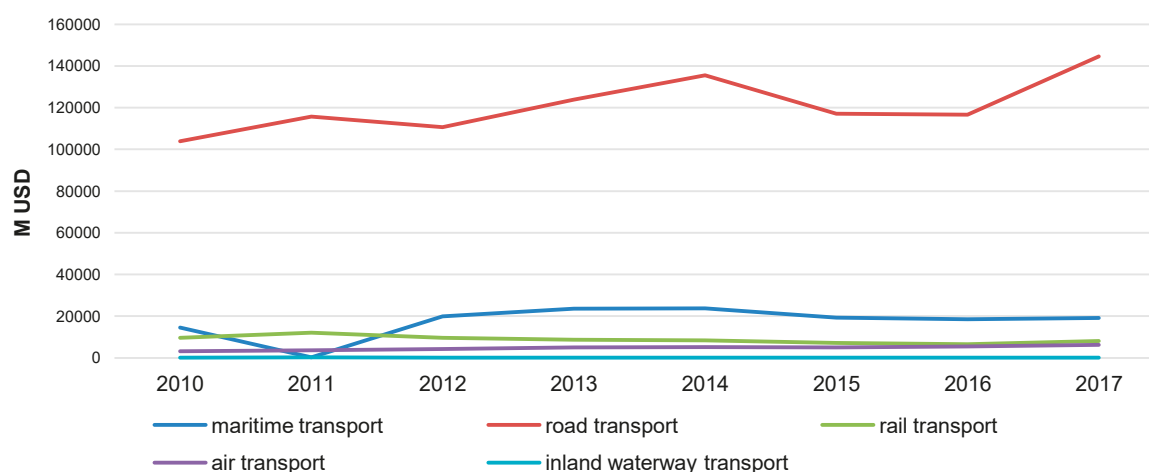


Figure 5. Poland's exports of commodities by branch of transport between 2010 and 2017 in millions of USD (based on data from the Customs Administration's Analysis Center, 2011–2018)

(by 98.4%), road (by 39.1%), and sea (by 31.7%) and decreased for transport by rail (by 15.9%) and air (by 70.5%) (Figure 5).

An analysis of Poland's commodity exports by individual transport branches shows a clear dominance of transport by road, both in terms of volume and value. Examining the dynamics of the year-by-year figures shows an annual growth in the transported volume. In 2010, foreign sales using road transport amounted to almost 31.1 m tons and reached over 47.1 m tons in 2017, which was a growth of more than half (Figure 4). The value of commodities transported by road increased by 39.1%, i.e. from USD 103.9 bn in 2010 to USD 144.6 bn in 2017 (Figure 5). For road transport, the performance of the exports of commodities was higher in terms of volume than it was in terms of value.

Polish commodity exports via maritime transport grew between 2010 and 2017, despite fluctuations in some of the years. The volume of goods grew only slightly, i.e. by 0.05%, and was approx. 173.1 m tons both in 2010 and 2017. The largest volume transported by sea was observed in 2013 with almost 22.5 m tons and the smallest in 2011 with 15.4 m tons (Figure 4). A much greater increase in the value of Poland's commodity exports via maritime transport was observed. In 2010, the value of goods sold internationally was almost USD 14.7 bn and reached USD 19.2 bn in 2017, which constituted an impressive growth of 37.7% (Figure 5). Thus, the value of exports was much higher than the volume. It should be noted that although nearly identical volumes of goods were transported by sea in both the base year and the target year, the value of the goods grew significantly. This could be explained by the sale of more expensive or more processed products than before.

There were also fluctuations in commodity exports via rail, as well as a growth in the volume of goods by 9.5% (Figure 4), accompanied by a decrease in their value by 15.9% (Figure 5). In 2010, Poland exported 13.9 m tons of commodities worth over USD 9.6 bn by rail. In 2017, this figure rose to 15.2 m tons worth USD 8.1 bn.

An opposite situation was observed for air transport, in which the volume of exported commodities decreased from 247 k tons in 2010 to almost 77 k tons in 2017, which constituted a drop of 69.0% (Figure 4). Despite this, the value of commodities exported using this mode of transport grew by as much as 98.4%, i.e. from USD 3.2 bn in 2010 to USD 6.3 bn in 2017. Notably, in this case, the value of exports grew systematically year-by-year, except for 2015 (Figure 5).

The largest decreases in Poland's commodity exports were seen in the case of transport by inland waterways, both in terms of volume and value. Poland's commodity exports using this transport mode amounted to 678.3 k tons in 2010 and merely 345.9 k tons in 2017, which was a 49% decrease (Figure 4). The value of international sales of goods decreased by 70.5% from USD 136 m to USD 40 m (Figure 5). The commodity exports by inland waterways continued to systematically decrease both in terms of the volume of goods (since 2014) and their value (since 2013).

The imports of commodities

Substantial changes were observed when analyzing Poland's commodity imports by taking into account the main branches of transport. Between 2010 and 2017, imports by all transport modes,

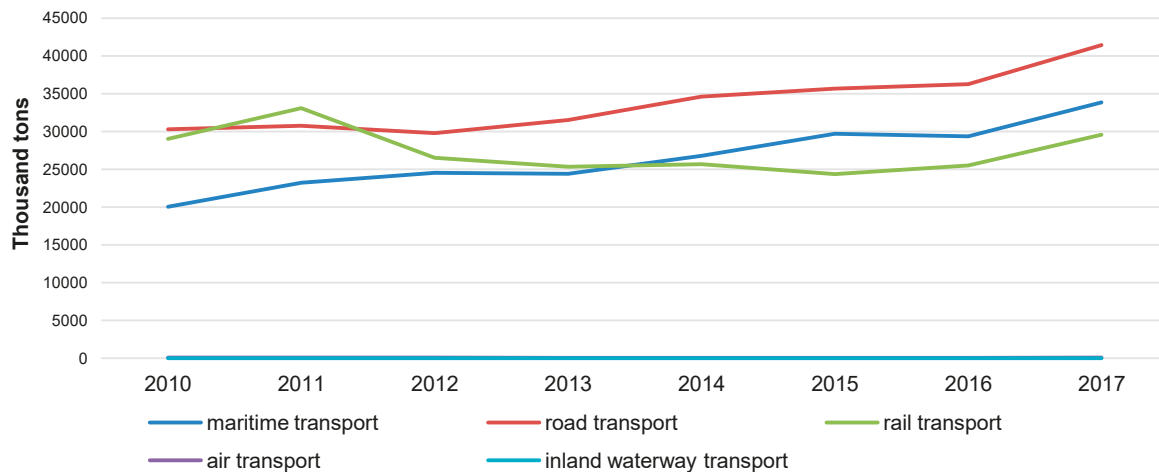


Figure 6. Poland's commodity imports by branch of transport between 2010 and 2017 in thousands of tons (based on data from the Customs Administration's Analysis Center, 2011–2018)

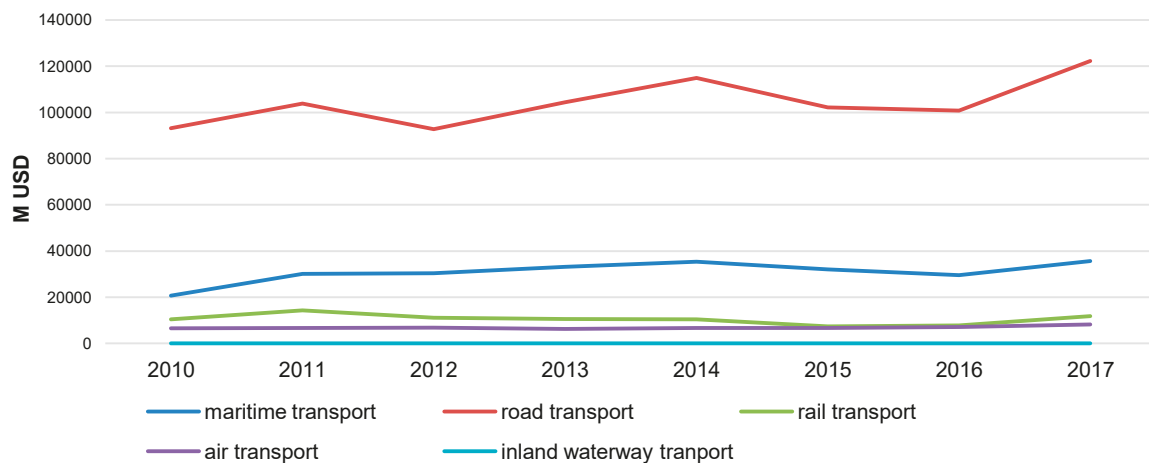


Figure 7. Poland's commodity imports by branch of transport between 2010 and 2017 in millions of USD (based on data from the Customs Administration's Analysis Center, 2011–2018)

except for inland waterways, grew. The largest increase in commodity imports was observed for transport by sea, both in terms of quantity (Figure 6) and value (Figure 7).

Poland's import activity is mostly based on transport by road. In 2010, this mode of transport was used to import 30.3 m tons and reached 41.4 m tons in 2017, an increase of 36.7% (Figure 6). The value of imported commodities increased here by 31.3%, with USD 93.1 bn in the base year and USD 122.3 bn in the target year. The latter figure was simultaneously the highest value reached during the period of interest (Figure 7).

Transport by sea came second in terms of the volume of imported commodities. This figure grew systematically, except for 2013 and 2016 which displayed small decreases. Maritime transport was used to import over 20 m tons in 2010 and 33.8 m tons in 2017, which amounted to an impressive 68.8% increase (Figure 6). A similar tendency was observed

in terms of value, where the growth was even larger and amounted to 71.9%. The value of Poland's imported commodities by sea rose from USD 20.7 bn in 2010 to USD 35.6 bn in 2017.

In the same period, rail transport was used to import over 29.0 m tons of commodities in 2010 and 29.6 m tons in 2017, which was a growth of 1.9%. However, it should be noted that the highest value was observed in 2011, with 33.1 m tons (i.e. more than in the case of road transport in the same year), and the lowest in 2015, with 24.4 m tons (Figure 6). Generally, the value of commodities imported to Poland by rail declined, except for some larger increases in 2011 (USD 14.4 bn) and 2017 (USD 11.8 bn). Hence, an overall increase of 13.5% was achieved from 2010 to 2017 (Figure 7).

Poland's imported commodities by air amounted to 97.6 k tons in 2010 and 100.7 k tons in 2017, which constituted a 3.2% increase in terms of volume. It must be added here that the highest value

of imports by this mode of transport was observed in 2012 with 102.8 k tons and the lowest in 2014 with 69.8 k tons (Figure 6). The value of the imports of commodities by air amounted to USD 6.5 bn in 2010 and USD 8.2 bn in 2017, which was a 25.3% increase (Figure 7).

Inland waterway transport had a much smaller share in Poland's imported commodities than the other modes. In 2010, it was used to import 10.1 k tons of goods, with only 5.1 k tons imported in 2017, a decline of 49.2% (Figure 6); however, it should be noted that the lowest value (0.01 k tons) was observed in 2013. The value of goods imported by inland waterways amounted to USD 2.6 m in 2010 and USD 1.02 m in 2017, which was a decrease of 60.2%.

Assessing the significance of utilizing the main transport branches in services facilitating Poland's foreign trade

The significance of individual branches of transport in services which facilitate Polish foreign trade in commodities was diverse and continually changed from 2010-2017. In terms of quantity, the dominant transport mode was road, the share of which grew from 38.8% in 2010 to 43.1% in 2017. The share of the remaining transport branches decreased. For transport by sea, the drop amounted to 5.8 p.p. (from 21.6% in 2010 to 15.8% in 2017), and for transport by rail, it amounted to 3.4 p.p. (from 17.3% in 2010 to 13.9% in 2017). The share of the other branches was minimal and did their combined total not exceed 1.2% in 2010 and 0.4% in 2017. In terms of the value of exported goods, the share of all branches of transport, except for transport by air, declined. Here, the advantage of road transport over the other modes was even larger than in the case of the quantity of

exported goods. In 2017, it amounted to almost 63.7% (Table 1).

As for imported commodities, the share of transport by road and sea rose between 2010 and 2017, both in terms of quantity and value, while the remaining transport modes decreased (Table 1). Road transport was the dominant mode among all used in services facilitating Polish foreign trade. Its significance rose over the period of interest despite the fact that the national and provincial roads, which are the most important in the country's entire road system, account for less than 12%. The forecast for the coming years suggests that the road market will continue to develop; therefore, it appears likely that it will remain unrivaled, especially when it comes to services facilitating Polish foreign trade.

Maritime transport plays a significant role in Poland. Since joining the EU, Poland has carried out numerous strategic investments in its largest ports (e.g., in the Central Port in Gdańsk, or the construction of the external harbor in Gdynia, or the construction of the LNG terminal in Świnoujście). The growth in significance of maritime transport in services facilitating the Polish foreign trade was also assisted by investments planned for the years to come, e.g., the modernization of the Świnoujście-Szczecin fairway, or the construction of a new LNG redistribution station in Świnoujście.

Transport of freight by rail is an element of Poland's integrated transport system, although it does not play a dominant role in the carriage of goods by land. The main problems encountered by this branch of transport are the decreasing length of railway lines, the insufficient technical condition of railway lines, and the exceedingly slow process of rolling stock replacement, all of which limit any expansion. Recently, the carriage of freight by rail has been unstable due to growing competition

Table 1. The share of branches of transport in Poland's exports and imports of commodities in 2010 and 2017 expressed in % (based on data from the Customs Administration's Analysis Center, 2011–2018)

Year	Maritime transport		Road Transport		Rail transport		Air transport		Inland waterway transport	
	volume in thous. tons	value in millions of USD	volume in thous. tons	value in millions of USD	volume in thous. tons	value in millions of USD	volume in thous. tons	value in millions of USD	volume in thous. tons	value in millions of USD
Exports										
2010	21.614	9.282	38.801	66.207	17.330	6.146	0.309	2.017	0.847	0.087
2017	15.840	8.453	43.128	63.682	13.903	3.573	0.070	2.767	0.316	0.018
Imports										
2010	16.596	12.171	25.083	54.663	24.021	6.114	0.081	3.849	0.008	0.002
2017	23.502	15.967	28.777	54.780	20.531	5.298	0.070	3.681	0.004	0.000

from road transport (Fechner & Szyszka, 2018). An opportunity for improving rail transport, also in respect of facilitating foreign trade, has been seen in investments co-financed under EU funds from 2014–2020.

Air transport is not important to Poland's international trade in commodities, and 90% of the Polish freight market is accounted for by two airports, one in Warsaw and one in Katowice. That lack of modern freight handling infrastructure is perceived as the major obstacle to the development of the freight market at Polish airports. Apart from this, there is enormous competition from German hubs, such as those in Frankfurt and Leipzig. It has been suggested that Poland is merely a freight supply region to be benefited from by other airports, and not a venue where carriage business is expected to develop.

The level of utilization of inland waterway transport in Poland is very poor, and thus this mode has the smallest significance in facilitating Polish foreign trade, primarily due to infrastructural limitations. Only 5.9% of domestic waterways meet the requirements of waterways of international importance. Moreover, Poland only has one port, in Gliwice, that is adapted to handle containers and is itself an element of a logistics center. It has been indicated that one of the inland waterway development priorities should be to modernize the Odra and Wisła waterways between Warsaw and Gdańsk (Fechner & Szyszka, 2018).

Individual main transport modes offer different means to facilitate Polish foreign trade, and their contribution may be subject to significant changes in the future. For example, (1) the EU transport policy indicates that by 2030, 30% of road freight transport over 300 km should shift to other means of transport, such as rail or waterways. By 2050, this rate should reach 50% (European Commission, 2011); (2) an increase or decrease in importance other than the main modes of transport, e.g., intermodal or multimodal transport. Studies suggest that the share of the main transport branches in facilitating Polish exports has decreased (from 78.9% to 73.3% in terms of quantity, and from 83.7% to 78.5% in terms of value), but their share in facilitating Polish imports has risen (from 65.8% to 72.9% in terms of quantity, and from 76.8% to 79.7% in terms of value); (3) changes with respect to the commodity structure and the destinations of the Polish foreign trade. As an example, EU Member States are the main recipients of Polish exports, but not all of them have access to sea waters, hence any increase in the share of maritime transport will be limited.

Conclusions

Between 2010 and 2017, the Polish foreign trade in commodities grew both in terms of value and quantity. Higher export and import value growth rates were observed than in terms of volume, possibly because more expensive and more processed or more technologically advanced products were being sold internationally. In terms of value, a trade surplus has been observed since 2015, while in terms of volume there was always a trade deficit.

Not all branches of transport experienced a growth in Polish export and import commodities. In the case of the exports, the largest growth was observed for road transport, and the smallest for air transport (in terms of volume) and inland waterway transport (in terms of value). In the case of imports, road transport was also the dominant mode, although the largest growth was enjoyed by maritime transport, both in terms of volume and value.

The changes within Poland's foreign trade were accompanied by changes to the structure of transport modes used to facilitate it. During the period of interest, changes with respect to its structure turned out to be unfavorable from the point of view of environmental protection and sustainable development. Moreover, research has shown that the share of the main transport branches in services facilitating exports fell, but their share in facilitating imports grew between 2010 and 2017. Hence, the role of intermodal/multimodal transport in services facilitating the Polish foreign trade is also changing.

Over the coming decade, the structures of the individual transport branches used to facilitate trade are expected to change. The share of transport by road should decrease in favor of more environmentally friendly modes, such as transport by rail or waterways. Any increase in the significance of rail transport in services facilitating Poland's foreign trade will largely depend on the results of investments using EU funds. As for inland waterway transport, any increase of its currently marginal share appears to be the biggest challenge due to the enormity of the required investments to modernize waterways and mostly, river harbor infrastructure; however, this calls for government-level commitment.

Nevertheless, it should be remembered that the choice of the means of transport for the carriage of commodities, including into foreign markets, is determined by multiple factors. In the case of international trade, of significance are issues such as the development directions of Polish exports and imports and the commodity structure of trade.

The specifics of foreign trade should be taken into account when planning the development of transport infrastructure.

Acknowledgments

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The e-commerce logistics models of Polish clothing companies and their impacts on sustainable development

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Key words: e-commerce, sustainable development, clothing industry, logistics, distribution, B2C, natural environment, society

Abstract

This paper discusses logistics models of e-commerce implemented by Polish clothing companies. The author has conducted research on Polish clothing companies and logistics operators serving e-commerce branches, and here presents and compares these models. There are various logistics models of e-commerce, which differ from each other in organisation of deliveries, level of outsourcing, location for keeping stocks, level of logistics in customer service, and organisation of returns (goods returned by customers). The impact of the different e-commerce models on ecological, economic, and social priorities is then discussed.

Introduction

E-commerce is growing dynamically in Poland, especially in the clothing industry. However, if goods ordered over the internet are to be delivered in a timely manner, proper conditions, and without errors, appropriate organisation of logistical processes is needed, especially in the area of distribution. Distribution can be organised in various ways, which affect both the costs and the levels of customer service. This is therefore very important for the competitiveness of a company. However, looking more broadly, it also has an impact on sustainable development.

The aim of this paper is to present the impact of various elements of e-commerce logistics models used by Polish clothing companies on sustainable development. The processes of clothing distribution in e-commerce, various models developed by the author, and the impacts of the elements of e-commerce logistical models on sustainable development have been analysed by the author based on original research.

The author conducted observations and interviews with management staff, during visits to

clothing enterprises and logistics operators cooperating with them, supplemented by telephone interviews. The research was carried out from July 2017 to July 2019.

Review of the literature

Sustainable development is defined in the literature in different ways. This concept can be considered from the macroeconomic (whole economy) and microeconomic (enterprise) perspective. In a narrow sense, it focuses on the natural environment. In the broadest sense it is understood as the ability to achieve various goals – economic, social, ecological, spatial, technical, etc. – in harmonious manners (Tundys, 2018, pp. 39–43). The aim of sustainable development is to ensure the quality of life for present and future generations by appropriately balancing the use of economic, social, and natural capital (Piontek, 2001, p. 17). The concept of sustainable development is understood in this paper as a balance between economic, social, and environmental priorities.

The internet can be used at various stages of the purchasing process, such as for identifying needs,

looking for information, and evaluating alternatives, but first of all, for placing orders by customers. E-commerce is technologically linked with m-commerce, i.e. mobile commerce, using smartphones or tablets (Grabiwoda, 2018, p. 138). In both cases, there is a need for properly organised logistics. Online sales may be the only distribution channel used by a company or may merely support traditional sales (Chodak, 2014, p. 22). Traditional sales in a shop and online sales can be combined in multi-distribution channels (Smyk, 2016, p. 18). There are various types of online stores, e.g. mono-brand (under the license of a producer), and multi-brand (Dziegieć, 2014, p. 231) and various types of e-commerce: B2B, B2C, C2C, C2B. The focus of this paper is on B2C, cases in which online sales only support traditional sales, and thus various distribution channels are used (multi-channel).

There are similarities between retail sales via the internet and retail sales in stores. For example, many logistics activities, such as transport and storage are performed in both cases. On the other hand, there are also differences; for example, orders over the internet are more diverse and placed in much smaller quantities than those in traditional stores (Murphy & Wood, 2011, p. 68). Also there are different regulations concerning the return of goods (Szołtysek & Twaróg, 2017, p. 201–202).

In the literature, e-commerce models are usually presented from the point of view of an e-store. For example, according to Marut (Marut, 2018), three e-commerce logistical models can be distinguished among Polish e-stores: the warehouse model (an e-seller has its own warehouse), drop-shipping (an e-store does not store goods but only mediates between a customer and a producer or a distributor), and fulfillment (an e-store purchases goods but stores them in the warehouse of an external company, which handles transactions and supervises the shipment of goods). Łapko and Wagner (Łapko & Wagner, 2019, p. 122–129), describe, in addition to these three models, the pseudo-just-in-time model (goods are ordered by an e-store only when a customer places an order), extended shopping (a supplier is fully responsible for the realization of an order, including warehousing, customer service, and the handling of returns), and commodity brokering (an e-shop, after receiving an order, finds the products at a supplier). Smużniak presents logistical models of online stores both in supply (own warehouse, drop-shipping, fulfillment, just-in-time, mixed method, and electronic deliveries) and distribution of goods (courier parcels, parcels and mailing lists,

parcel lockers, own transport, urban couriers, and distribution of intangible goods) (Smużniak, 2016, p. 1027–1030). Other models, focusing on the place from which goods are sent to online customers, are presented by Pluta-Zaremba and Rutkowski: deliveries from local stores, deliveries from a warehouse serving traditional stores, and from a warehouse directly to an on-line customer (Pluta-Zaremba & Rutkowski, 2005, pp. 226–227).

This paper presents e-commerce logistical models in which, apart from storage, other criteria are also considered relevant. These models are presented not from the point of view of an e-store, but from the point of view of a clothing company (a clothing manufacturer or distributor ordering products under its own brand), for which the Internet is one of its distribution channels.

Clothing and accessories are the most popular categories of products ordered in Poland via the Internet. In 2018, they were ordered by 64% of people from the online buyers group (Gemius, 2018, p. 142). At the same time, according to the same research, long waiting times for deliveries of products were indicated as the biggest problem associated with e-commerce (indicated by 40% of respondents) (Gemius, 2018, p. 120). The research also shows that the cost of delivery is not the most important assessment criterion used by online customers. Timely deliveries, lack of damage to goods, and guarantee of a delivery date are much more important (Kawa, 2014, p. 7). That means, that properly organised distribution of goods to online customers largely determines the success of e-commerce.

In the following sections of this paper, the distribution processes of clothing in e-commerce are discussed, on the basis of the author's research in the field, followed by the e-commerce logistical models and their impacts on sustainable development.

The clothing distribution processes in e-commerce

The processes of clothing distribution described below for online customers are presented from the point of view of a clothing company. The discussion concentrates on logistics, ignoring marketing and financial aspects, such as payment for shipping. The processes of distribution for clothing in e-commerce are as follows:

- Clothes are delivered to the warehouse of a company that organises online sales – either directly from a sewing facility or from a warehouse, from which deliveries to shops are performed. In online

shopping, short delivery time is important (customers are not willing to wait long for deliveries), so the clothes ordered by customers are usually already produced and kept in stock. Of course, it may happen that stocks run out without being replenished, therefore information about the availability of goods needs to be updated on a regular basis. Sewing clothes, after accepting an order from an individual online customer, takes place very rarely.

- An online customer places an order on the online store's website. Online purchases of clothes are developing very dynamically at the present. In the opinions of many customers, the advantages of online shopping compared to traditional stores (convenience, low price, and a large selection), compensate for disadvantages – the waiting time for delivery and the inability to try on purchased clothes before placing an order.
- Orders are sent to a firm that distributes clothes for online customers. It can be the same company that organises traditional distribution, but not necessarily. Orders are prepared – clothing is completed, packaged, addressed, and delivered – from a warehouse.
- A shipment of clothing is transported from a warehouse to an online customer. Transport can be dealt with, for example, by a courier company. A parcel is delivered to a customer or, for example, left in a parcel locker. The distribution process ends, unless a customer resigns from the purchase.
- Resignation from the purchase of clothing ordered online often happens because customers cannot try on clothing before placing an order. It is therefore a common practice online to order several designs, colours, and sizes of clothing and to return some of them after trying-on. A customer sends goods back to a firm handling returns from online customers. It may be to the same place whence the goods arrived to the customer or to another place. The sending of clothes and receiving of returns from online customers is not always performed by the same company.

Returned clothes are checked for compliance with the conditions of returns – e.g. due date and state of the clothing (damaged, dirty, etc.). Then clothes are prepared for re-sale – cleaned, pressed, packaged, and handed over to a warehouse, where they wait for another customer.

From the logistics point of view, the main differences in the distribution of clothing to online customers versus in traditional distribution are as follows:

- fewer nodes in the distribution channel (there are no shops and showrooms);
- greater centralisation of inventories (in traditional distribution, part of the inventory of clothes is kept in stores);
- less predictability of orders for online customers;
- smaller sizes of delivery, to many different locations;
- more returns than from customers of traditional stores.

The first two features mentioned above are beneficial from the point of view of costs (lower costs of maintaining inventories and showrooms). The following ones are challenges for companies. Apart from the above mentioned features, adaptation to the dynamic growth of purchases via the internet, as well as the need for high precision in the preparation of orders, are also challenges. One risk for mistakes results from the range of products offered (many variants, sizes, colours, and clothing fashions).

Elements of the e-commerce logistical models

As mentioned before, the models of e-commerce clothing distribution are presented here not from the point of view of e-stores, but of clothing companies for whom online sales only supplement traditional sales.

Models of e-commerce distribution for clothing consist of many elements. When creating them, one should find answers to the following questions:

- What firm deals with deliveries of clothing for online customers? From the point of view of a clothing company, we can distinguish between own or external distribution here. In own distribution, the organisation of e-commerce deliveries is handled by the clothing company (a clothing manufacturer or a company for which clothing is produced), while in external distribution a clothing company outsources this function.
- Where are inventories of clothing for online sale maintained? Deliveries to online customers can be made from the same warehouse as deliveries to traditional shops or from another warehouse.
- Whether goods are delivered to a warehouse by a push or pull system. Deliveries in a push system are based on pushing clothes from a previous node – e.g. from a production plant; therefore, inventories are usually held for a long time. On the other hand, deliveries to a warehouse in a pull system are frequent, in small quantities, on the basis of

actual demand; therefore, inventories of clothes are maintained for a short time.

- By means of what kind of transport and of what capacity, are clothes delivered?
- What are the standards for online customer service, the time required to complete an order placed over the internet, and the percentage of errors?
- What firm prepares returned goods for resale and where are the returned goods sent?

There can be many combinations of these elements, therefore various e-commerce logistic models.

Selected e-commerce logistical models in the Polish clothing industry

Below are identified three models of clothing distribution for online customers used in the clothing companies studied by the author:

- Model 1 – own e-commerce logistics service: deliveries to online customers and showrooms from the same warehouse,
- Model 2 – e-commerce logistics service: outsourced deliveries to online customers and showrooms from the same warehouse,
- Model 3 – e-commerce logistics service: outsourced deliveries to online customers and showrooms from separate warehouses.

Model 1 is the simplest model, often functioning in small and medium-sized clothing companies. It will be presented using the example of the company Unikat from Szczecin – a lingerie manufacturer. Unikat organises deliveries to online customers from the same warehouse in which clothing for its shops are kept. In this model, there is no transportation of clothing between different warehouses, as in some other models. What's more, there is also no external transportation between production and the warehouse, because they are located next to each other. Clothes ordered by online customers prepared by the employees of the company are delivered to customers by one of four courier companies with which Unikat cooperates. These are the same companies that also transport goods to shops. Therefore the same resources are used for serving online customers and the shops. Clothes returned from online customers are sent back to the same warehouse. In this warehouse the goods are checked and prepared for re-sale. This model is presented in Figure 1.

The next two models are presented using examples of large clothing companies. These companies have outsourced customer service of online customers, as well as production, focusing on what is the

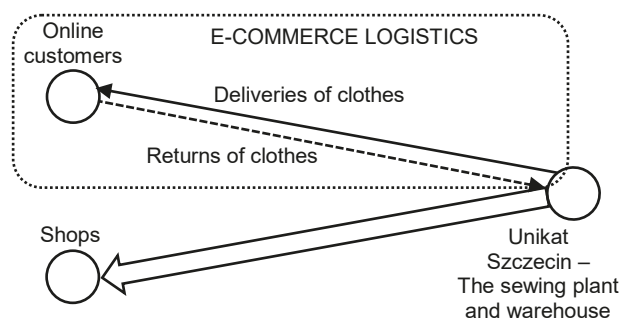


Figure 1. The e-commerce logistics model on the example of Unikat (author, based on this research)

most profitable in the clothing industry – the sale of custom-branded clothing, in their own showrooms.

Model 2 will be presented with the example of online distribution by the clothing brand Vistula (Vistula Group S.A. after the recent merger with the company Bytom S.A., adopted the name VRG S.A.). Deliveries for online customers are organised by the logistics operator – Spedimex Company. Vistula outsourced to Spedimex all distribution of goods – not only deliveries to online customers, but also to its own shops. Clothing sent to the Distribution Center of Spedimex in Stryków is transported from the sewing facility immediately after production (push flow; the goods are “pushed” and not delivered according to actual demand). The Spedimex Distribution Center holds stocks both for the needs of showrooms and for the needs of online customers. Inventories are often stored for longer terms. On the other hand, goods returned from online customers are sent not to a Spedimex warehouse, but to the sewing plant, because it can better prepare the goods for re-sale than the logistics operator. In the sewing plant, the returned clothing is checked and, if necessary, cleaned, ironed, folded, and transported back to the Spedimex Distribution Center. This model is presented in Figure 2.

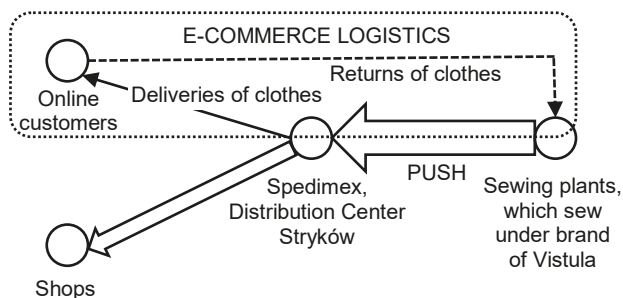


Figure 2. The e-commerce logistics model on the example of the Vistula's brand (author, based on this research)

Model 3 will be presented using the example of the largest Polish clothing company, LPP S.A.,

owner of the Reserved, Cropp, House, Mohito and Sinsay brands. This company, unlike with the previous models, shares the organisation of distribution. It hands over the service of online customers to Arvato, while it deals itself with traditional distribution – through its own Logistics Center and a network of over 1,700 showrooms. The outsourcing of their e-commerce logistical services, despite having their own Logistics Center, was caused by not only a significant increase in online sales, but also by its specificity. It is a process different from traditional distribution and LPP decided to entrust it to a specialist. Deliveries of clothing from the LPP Logistics Center in Pruszcz Gdański to the Arvato warehouse come on a daily basis, in amounts resulting from current levels of inventories. It is therefore a “pull flow.” When an order arrives from an online customer, clothing is ready for shipment and forwarded to

a courier company. Arvato serves both delivery to online customers and returns from them. This model is shown in Figure 3.

In addition to LPP S.A., Arvato also serves online customers for other well-known clothing companies. For example in the case of Inditex (Zara), Arvato maintains inventories and sends clothes to online customers in Poland and a dozen other European countries. For Inditex, however, Arvato does not deal with returns. Arvato offers a short time in preparing orders for shipment due to a good IT system and a properly prepared, trained staff. The company serves, apart from the clothing industry, the cosmetics, electronics, toys, and even pharmaceuticals industries. It enters markets where there is a big share of online sales.

A comparison of individual elements of e-commerce logistical models in the clothing industry is presented in Table 1.

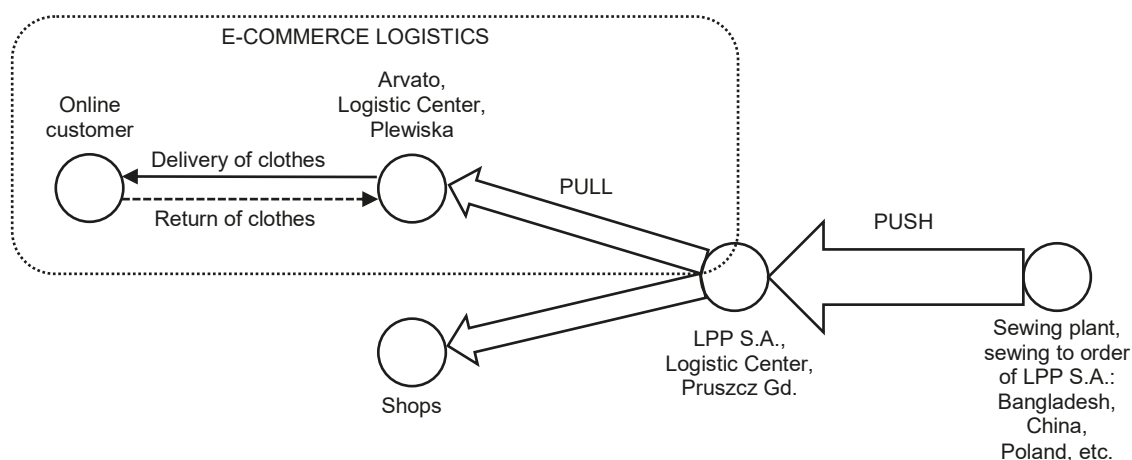


Figure 3. The e-commerce logistics model on the example of LPP S.A. (author, based on this research)

Table 1. Similarities and differences between e-commerce logistics models in the clothing industry

Elements of the model	Model 1	Model 2	Model 3
A firm delivering clothes to online customers	A clothing company	A logistics operator	A logistics operator specializing in e-commerce
A location holding stocks for online sale	Own warehouse; deliveries to online customers and showrooms from the same warehouse	The warehouse of a logistics operator; deliveries to online customers and showrooms from the same warehouse	The warehouse of a logistics operator; deliveries to online customers and showrooms from separated warehouses
Deliveries to a warehouse in which inventories for online customers are maintained	Deliveries from a sewing facility; a warehouse located at a sewing facility	Deliveries from a sewing facility; the “push flow”	Deliveries from a logistics center, in which inventories for shops are maintained; the “pull flow”
Transport to an online customer	A courier	A courier	A courier
A place to which returns are sent	The same from which the goods are shipped (own warehouse)	Other than the one from which the goods are shipped (sewing plant)	The same from which the goods are shipped (a warehouse of a logistics operator specializing in e-commerce)

Clothing distribution in e-commerce versus shops, and sustainable development

Sustainable development means a balance in achieving economic, social, and ecological goals.

From the financial point of view, the development of online sales is a necessity for clothing companies. In this way, a company can win new customers and also retain existing customers who increasingly prefer this way of shopping. Increasing the share of sales online versus in stores allows one to reduce:

- inventory maintenance costs – due to greater centralization of inventories and shifting from shops to a Distribution Center, which reduces total levels of inventories and, consequently, costs related to their maintenance, e.g. costs of capital tied up in inventories;
- costs of operating shops.

However, in online sales the costs of returns increase (checking the goods and preparing for re-sale, transport). Transport costs can also increase due to deliveries to the final consumer, however, they are largely transferred to online customers, who do not pay for transport except in cases of larger purchases.

In terms of social goals, two groups should be considered: online customers and employees.

From the customer's point of view, online shopping is convenient and in many cases, better than traditional shopping, which eliminates the spatial and assortment gap. A customer is offered delivery to a chosen place, and a range of product selection in an online store wider than in a traditional shop. When it comes to the time gap, the situation is a bit more complicated. On the one hand, there are no restrictions related to shops' operating hours; orders can be placed around the clock. On the other hand, customers have to wait for delivery – the time between choosing clothes and receiving them. However it should also be taken into account that, due to internet shopping, a customer saves time related to traveling to and from a store. However, a customer has unlimited time to choose and compare products, so can spend more time shopping online than they would in a traditional shop.

Preparing deliveries for online customers is connected with greater requirements for employees than in cases of traditional distribution. Skills and experience are also required for checking returned clothes. Therefore, companies try to reduce staff turnover and offer higher salaries and additional benefits, such as social packages or free transportation to work from

nearby towns. From this point of view, increasing the share of online sales is beneficial for employees. However, on the other hand, the demand for employees from traditional shops may decrease.

From the point of view of ecology, the impact of online distribution compared to traditional is not completely clear.

For the natural environment, road transport is particularly harmful, especially when the loading capacity of the means of transport is underutilised. Such situations often happen with deliveries to online customers. Deliveries to stores are more predictable, because they are usually planned for specific days of the week. On the other hand, the consequence of traditional shopping is individual transport from a store to a customer's home. Of course, it is difficult to calculate which method brings greater environmental costs; a lot more information is needed.

Impacts of individual elements of e-commerce logistical models on sustainable development

The impacts of the e-commerce models described earlier on sustainable development are ambiguous, because in each of them are elements more or less friendly to the natural environment. These elements also influence the economic and social aspects of the models in various ways.

In general, the following solutions may be more environmentally friendly:

- Outsourcing of e-commerce logistics to a logistics operator who specializes in providing these services to various customers. This allows the operator to achieve economies of scale (and therefore to lower costs), due to the greater possibility of consolidation of shipments and better use of a vehicle loading capacities, allowing a reduction in the number of transports, which is more beneficial for the natural environment (models 2 and 3).
- Stocks of clothing for online sales are kept in the same warehouse as stocks of clothing for traditional distribution. If the stocks for showrooms and online customers are in the same place, they do not have to be transported between warehouses, which is beneficial for the natural environment (models 1 and 2).
- Warehouses supplied by push instead of pull systems. The "push" flow means generally less frequent deliveries in greater quantities, and therefore lower external costs (model 2). On the other hand, from the economical point of view, the costs of maintaining inventories increase.

- Longer order times via the internet. It is beneficial from the point of view of the environment and transport costs, as it allows the consolidation of shipments transported in the same direction, and thus increases the use of loading capacities and reduces the frequency of trips. There is, however, a trade-off between ecological and economic, versus social goals – the expectations of a customer who would like to receive a parcel as soon as possible.
- Transport of goods returned by online customers to the same warehouse from which the goods will be sent again to a next customer (and not for example to a sewing plant). As a result, the goods will not have to be transported between a sewing plant and a warehouse, in which stocks are stored, which is beneficial both for the environment and the economy (models 1 and 3).

Conclusions

Clothing companies use various e-commerce logistical models. The differences pertain to: who deals with deliveries to online customers (own or outsourced logistics services), the location holding inventories for online sale (own warehouse of a clothing company or a warehouse of a logistics operator; the same warehouse, from which traditional stores are served or another warehouse), the supply system of a warehouse (push or pull) and the place to which returns are delivered (warehouse or sewing facility). In each of the models, there are elements more and less friendly to the natural environment, which also influence the economic and social aspects in various ways.

Models, that require fewer movements of goods between warehouses or between a warehouse and a sewing facility are environment-friendly (e.g. keeping stocks for online sales in the same warehouse, which also serves traditional shops; returning goods to a warehouse, from which the goods will be sent to a next customer, not to a sewing plant). These solutions also reduce transportation costs.

Models that reduce the frequency of transport and improve the utilization of means of transport are also environmentally friendly. These solutions also reduce transport costs, but at the same time they can lead to increased costs for maintaining inventories (push flow) or may be disadvantageous from the point of view of satisfying customer needs (longer delivery time to online customers).

On the other hand, from the point of view of the natural environment, economy, and society,

outsourcing of distribution to online customers is usually beneficial; it allows achieving economies of scale, reducing transportation traffic, and often also reducing failures of delivery due to the employment of better trained and better paid employees.

In summary, some elements of logistical e-commerce models allow achieving, at the same time, ecological, economical, and social goals. In some cases there is a trade-off between these goals. In order to investigate more closely the impact of e-commerce in the clothing industry on sustainable development, further research should be carried out.

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Impact of e-commerce on external transport costs

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Key words: efficiency of logistics processes, models of economic efficiency of transport, simulation, sustainable supply chain, e-commerce, costs of transport processes, external costs of transport

Abstract

The problem presented in this paper concerns the impact of e-commerce on transport costs, including external transport costs, compared with traditional shopping. E-commerce is a phenomenon of the modern economy that can significantly impact both the efficiency of the distribution of goods and on external transport costs. Although such a distribution system can increase the costs of freight transport to final consumers, it can also reduce traffic in cities and thus total external transport costs. In order to assess this impact, the author developed a simulation model and used it to conduct analyses. The analyses were based on available statistical data, data from the literature, and from the transportation market in Poland.

Introduction

It is unlikely that the concept of Corporate Social Responsibility will be implemented if there is a conflict between the business goals of enterprises and social (e.g., environmental) goals. Therefore, solutions should be sought that will increase the efficiency of logistics processes and productively use resources, which also indirectly reduces external costs. The key word here is “compromise”, or perhaps even abandoning ambitious pro-ecological goals for real solutions that will be acceptable for the business side.

The main purpose of this article is to estimate the impact of e-commerce in the B2C segment on external transport costs. Analyses were carried out based on available statistical data and the subject literature. In order to estimate the impact of e-commerce on external costs, simulations were conducted using a model developed by the author.

Literature review

The e-commerce market impacts the efficiency of logistics processes, including transport processes.

There is no consensus in the literature about the effects of e-commerce on the demand for transport services. According to some authors, e-commerce will increase freight transport (Schöder, Ding & Campos, 2016), while other authors think e-commerce may contribute to the growth of consumption (e.g. thanks to lower costs), and thus indirectly to increasing demand for transport services (Ferreira, Smith & Mead 2001). Digitization refers not only to the method of placing orders for products but some products may also have an electronic form (books, music, films) (Sznajder, 2006, s. 27; Staniszevska & Gordon, 2015, s. 92; Antonowicz, 2016). In Greece, for example, products susceptible to digitization account for around half of e-commerce sales (Basbas, 2006). This phenomenon is driven by the fact that young people have a large share of purchases made electronically and can also collect the goods themselves (Kozerska, 2014). The positive impact on external costs will be even greater if the documents are also sent electronically because the demand for paper will decrease (Dobosz, 2012).

However, even if the total volume of sales does not change significantly, the specificity of e-commerce distribution may reduce the efficiency of

transport processes, which may increase the costs of these processes, as well as external transport costs.

An important issue here is in which distribution channels these goods are transported. Distribution can take place in two main ways:

- Through existing distribution channels;
- In dedicated e-commerce channels, which may also require the use of a separate fleet (perhaps even technologically adapted to the specifics of e-commerce).

The specificity of e-commerce can also have an impact on the efficiency of transport processes if deliveries to customers are performed quickly (Nemoto, Visser & Yoshimoto, 2001). As a result, more expensive transport solutions may be used e.g., air transport, but the load capacity may be lower due to different shipment dimensions. Processes of decentralization and sub-urbanization may cause more remote and less densely populated areas to be served by smaller, underutilized vans. However, there are different views on this subject, (Hassall, 2001), and statistics do not seem to confirm such forecasts. According to Eustat data, vehicles below 3.7 tons ("light commercial vehicles") have had a constant share (82–86%) in road transport for many years in the European Union (EUSTAT) despite the fact that the e-commerce market is dynamically developing.

Another issue specific to e-commerce are returns, which according to some authors generate the largest costs (Żurek, 2015). Returns can be made as part of the return transport but can also generate additional journeys, which may also result from ineffective deliveries to customers (customer absence at home).

However, there are solutions aimed at increasing the efficiency of goods delivery processes – creating a network of transshipment points, where goods are transshipped from smaller to larger locations, using so-called secure storage boxes to enable optimization of vehicle routes. Research carried out in Germany in France confirms that such solutions can greatly benefit society and help reduce congestion and environmental pollution. In addition, it can also benefit companies by increasing the number of successful first-time deliveries, optimizing delivery rounds, and lowering operational costs (Morganti et al., 2014).

The experience is positive, and the implementation of e-commerce shopping can result in up to 30% reduction in transport performance, which means less congestion in urban areas. According to research conducted in 6% of Polish companies, e-commerce has a positive impact on costs (Wiśniewski, 2017). However, there are different views on this subject, and no consensus has been reached in the literature

about the impact of e-commerce on energy consumption, and its positive environmental impact is being questioned (Basbas, 2006; Dost & Maie, 2017). Environmental effects depend on previous transport behaviors, and e-commerce can be a substitution for both individual and collective transport. In the UK, NERA (Dodgson, Pacey & Begg, 2000) have estimated that home shopping will reduce car-based shopping travel by 5% by 2005 and 10% by 2010 (European Parliament, 2002).

In the literature, the importance of Logistic Customer Service in the e-commerce industry is widely acknowledged (Esper et al., 2003; Agatz, Fleischmann & Van Nunen, 2008; Ramanathan, 2010). According to M. Szyda, logistics processes are becoming increasingly effective, which results in not only lower logistics processes costs but also better customer service (Szyda, 2014). However, according to other studies, factors such as the reliability, completeness, price, and time of deliveries, and the selection of a courier company do not affect the frequency of shopping, at least for some social groups (Gajewska, 2017).

The logistics capacity of a company significantly impacts its e-commerce logistics performance, and this potential can be increased by outsourcing logistics functions (Wilding & Juriado, 2004; Joong-Kun Cho, Ozment & Sink, 2008). However, a company performing its own distribution also has its advantages. For example, cargo space can be better utilized, especially if the load dimensions are standardized, as it is the case of manufacturers such as IKEA.

In order to achieve business goals (increase sales), enterprises may accept increased transport costs; however, reducing transport costs is also in their interest. Reducing these costs can be achieved by increasing the efficiency of transport processes – primarily by optimizing vehicle routes, increasing their tonnage and increasing their use. Thus, it can be said that in e-commerce, there can be a convergence of business and social goals, including environmental ones.

This problem will be discussed in the further, analytical part of the article.

Model of e-commerce distribution transport costs

In a traditional system, goods from suppliers are transported to a distribution center, and then to shops, from where consumers deliver the goods themselves to their own homes. In e-commerce, goods from

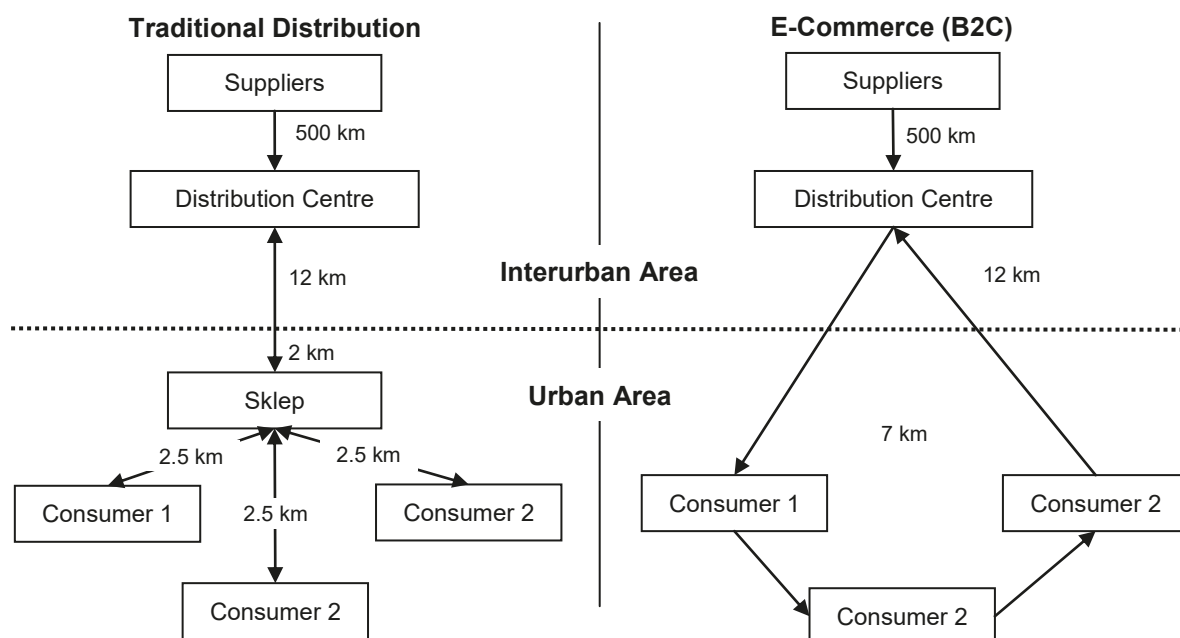


Figure 1. Distribution process of goods in a traditional distribution channel and in e-commerce

Table 1. Capacity and external costs of road vehicles (data from Polish transportation market and Maibach et al., 2008)

Efficiency of vehicles	Passenger Car Petrol 1.4–2L	< 7.5 t	7.5–16 t	16–32 t	> 32 t
Permissible gross weight [tons/vehicle]		3.5	8	16	40
Net weight [tons/vehicle]		1.6	3.7	9	25
Volume [m ³]	0.5	8	40	55	90
Freight rates [€/vkm]		0.59	0.88	0.75	1.00
External unit costs – Interurban [€/vkm]		0.16	0.18	0.18	0.20
External unit costs – Urban [€/vkm]	0.36	0.92	0.94	0.94	0.99

a distribution center are transported to consumers by vans (Figure 1).

To calculate the economic efficiency of both systems, the author has developed a mathematical model to perform the following simulations:

1. The impact of delivery parameters in e-commerce distribution on external costs;
2. Impact of e-commerce distribution on the profitability of a company;
3. Level of reduction of external costs in the case of e-commerce distribution;
4. Identification of distances on which e-commerce distribution is more effective than traditional distribution.

The input data for all four simulations are shown in Figure 1 (distances at each stage of the distribution) and in Tables 1 and 2. External unit costs

are based on the literature. Freight rates are based on information from the transportation market in Poland. Since the quality of e-commerce transport services is important in Poland, and the efficiency of transport processes is relatively lower, rates for smaller vehicles (< 7.5 t, 7.5–16 t) are 30% higher than average market rates.

To ensure comparability of calculations, it was assumed in the initial variant that distances from suppliers to a distribution center, and from a distribution center to the boundaries of a given locality, are the same in both systems. The differences concern the length of routes covered by traditional distribution consumers and by delivery vehicles in e-commerce.

The impact of delivery parameters in the e-commerce distribution on external costs

In the first step, the impact of 4 parameters were calculated – distances of the final distribution to customers, distances from suppliers to a distribution center, the utilization of the capacity of vehicles from the final distribution, and the level of returns.

Table 2. Commodity parameters

Tonnage [tons]	Volume [m ³]	Weight of a commodity [kg/pcs.]	Retail price [€/pcs.]
56 000	381 818	0.40	15

In order to ensure comparability, it was assumed that these parameters changed proportionally (10% and 20%).

Based on the assumptions, the total external transport costs were calculated. The results in Table 3 and Figures 2 and 3 vary depending on which vehicle is used. For vehicles with a lower payload (< 7.5 t), the degree of capacity utilization has the greatest impact. For larger vehicles (7.5–16 t), the most important is distance from the supplier. The distance of the final distribution to the final consumer is of average importance for both vehicle types. It may be surprising that the share of returns (which is considered significant in the literature) is of little importance, although in the last variant, the amount of returns represents 30% of sales. In the model, it was assumed that returns will generate additional transports. In fact, they can be transported together with other goods, so the returns could have an even smaller impact on costs. In the subsequent simulations, this parameter will not be considered.

Table 3. Impact of different parameters on external costs in e-commerce distribution (thous. EUR)

Capacity of a vehicle	< 7.5 t		7.5–16 t	
Changes of parameters	10%	20%	10%	20%
Longer distance in final distribution	1834	1906	1207	1233
	4.1%	8.2%	2.3%	4.5%
Increase of a distance from a supplier	1845	1929	1263	1346
	4.7%	9.4%	7.0%	14.1%
The decrease in capacity utilization	1866	1995	1219	1268
	5.9%	13.2%	3.3%	7.4%
The increase in product returns	1784	1786	1187	1194
	1.2%	1.3%	0.6%	1.2%

Impact of e-commerce distribution on the profitability of a company

The second simulation concerns the impact of e-commerce distribution on a company's profitability compared with a traditional one. With assumed margins (based on the margins of large listed companies),

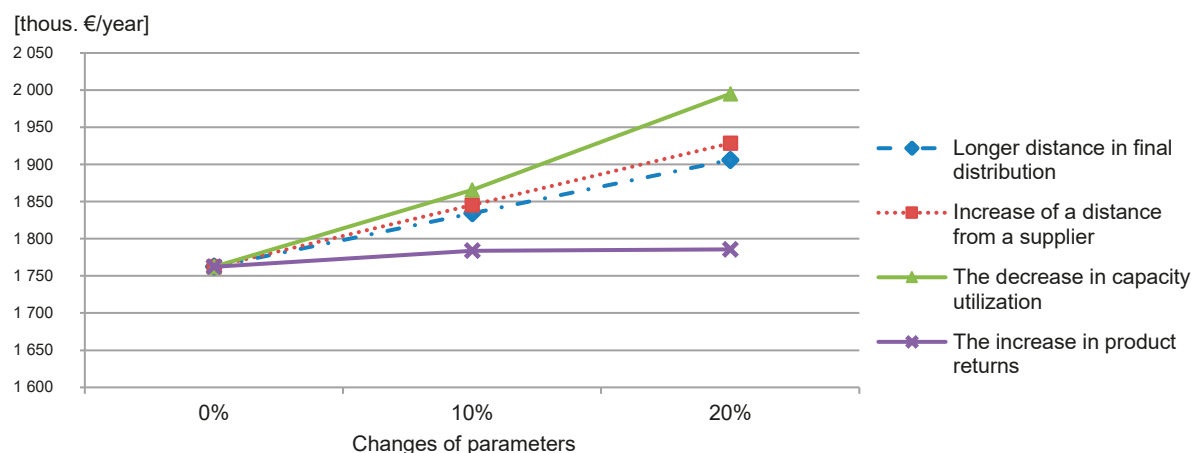


Figure 2. Factors of external transport costs in e-commerce distribution (< 7.5 t)

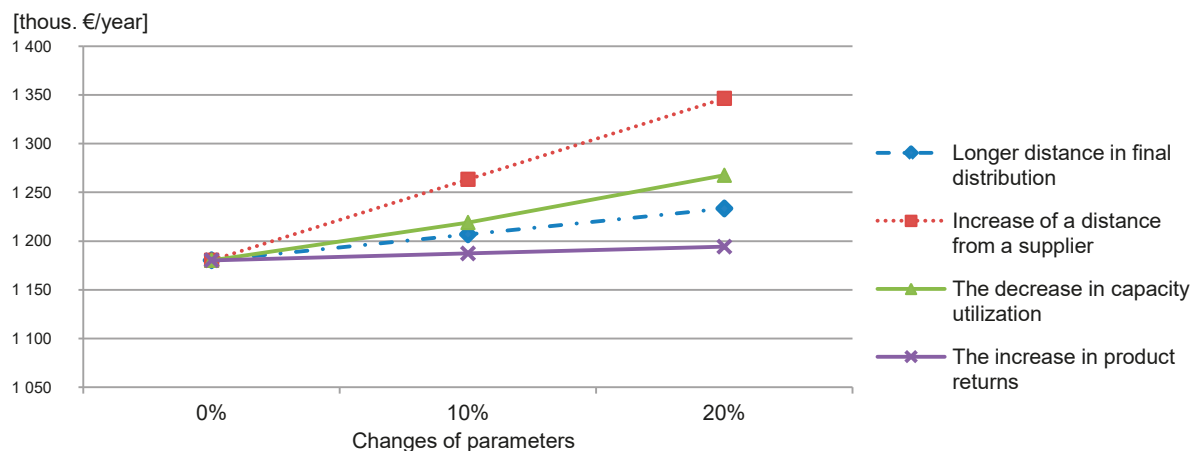


Figure 3. Factors of external transport costs in e-commerce distribution (7.5–16 t)

changes in profitability were calculated depending on the capacity of a vehicle and distances (50 and 150 km). The results are presented in Table 4.

Table 4. Impact of transport costs on profitability

Profitability of traditional distribution		5.00%	
A vehicle	Distance [km]	Utilization of vehicles	
		70%	90%
< 7.5 t	50	4.91%	4.93%
	150	4.72%	4.78%
7.5–16 t	50	4.97%	4.98%
	150	4.91%	4.93%
16–32 t	50	4.98%	4.99%
	150	4.95%	4.96%

The influence of the analyzed factors – the type of vehicle and the utilization of its load capacity and the distance of transport – is quite visible. With the assumed turnover level (Table 2), e.g., in variant 1 (using vehicles < 7.5 t, at distances up to 50 km, using 70% of their payload), the profits in the e-commerce distribution decreased compared with traditional distribution by 2 million € due to increased transport costs. Additional and comparable cost increases were caused by increased distances from suppliers, which may also be the consequence of e-commerce distribution; thus, efficient transport utilization is important, and the use of a vehicle with a capacity of 7.5–16 t, increases profits between 1.5 and over 4 million €.

However, an increase in the transport costs of e-commerce distribution can likely be compensated for by reducing the distribution costs of products (stores, employees, and warehouses) and higher revenues. For example, if sales increase by 5%, then profits would increase by over 3 million € in variant 1, with a 70% capacity utilization and almost 4 million € at 90%. This may explain the popularity of this distribution strategy.

Level of reduction of external costs in e-commerce distribution

The purpose of the third simulation was to compare the external costs of e-commerce and traditional distribution. Three variants of distances were assumed, on which consumers travel to shop: 2.5, 5, and 7.5 km. The distances travelled by e-commerce vehicles were 25%, 50%, and 100% longer. The external costs of public transport were omitted because they were very low. It was also assumed that half of consumers use cars and that 50% of these

used their car's trunk. As in the previous simulations, calculations were carried out for smaller and medium-sized delivery vehicles with a 70% capacity utilization. The results of these simulations are presented in Tables 5 and 6.

Table 5. Changes in the external costs of e-commerce compared with traditional shopping

Vehicle capacity	< 7.5 t	Capacity utilization	70%
The distance of the customer from the market [km]	2.5	5	7.5
Distance in distribution: e-commerce/individual transport	Change of costs		
25%	–30.8%	–45.0%	–51.4%
50%	–27.0%	–40.2%	–46.2%
100%	–19.5%	–30.8%	–35.9%

Table 6. Changes in the external costs of e-commerce compared with traditional shopping

Vehicle capacity	7.5–16 t	Capacity utilization	70%
The distance of the customer from the market [km]	2.5	5	7.5
Distance in distribution: e-commerce/individual transport	Change of costs		
25%	–50.9%	–65.0%	–71.4%
50%	–49.5%	–63.2%	–69.5%
100%	–46.7%	–59.7%	–65.6%

External e-commerce costs are much lower compared with traditional ones, as are the distances on which the consumer moves by car. Savings are significant, even when using smaller delivery vehicles (Table 5).

Identification of limit distances on economic efficiency of e-commerce distribution

The purpose of the last – fourth simulation was to examine the maximum possible delivery distance to a customer's home without increasing external transport costs compared with traditional distribution. These distances are a measure of the effectiveness of the e-commerce distribution system. Two factors were considered in the simulation – the loading rate of delivery vehicles (70% and 90%) and distance. It was assumed that in traditional distribution, the distance from suppliers is 500 km. The results are shown in Figures 4 and 5.

Even if goods were purchased from suppliers 1000 km from the distribution center, e-commerce

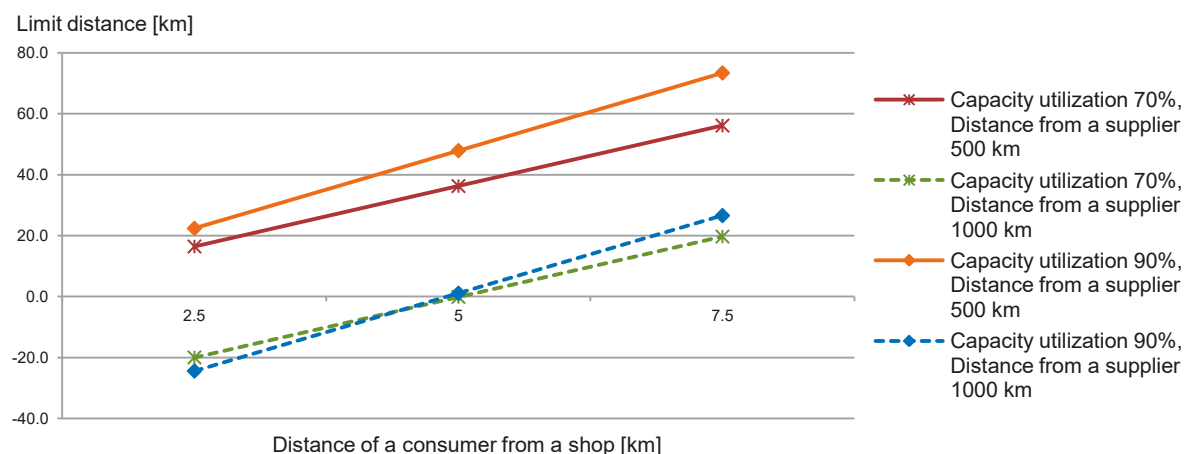


Figure 4. Limit distances in the final distribution in e-commerce (vehicles < 7.5 t)

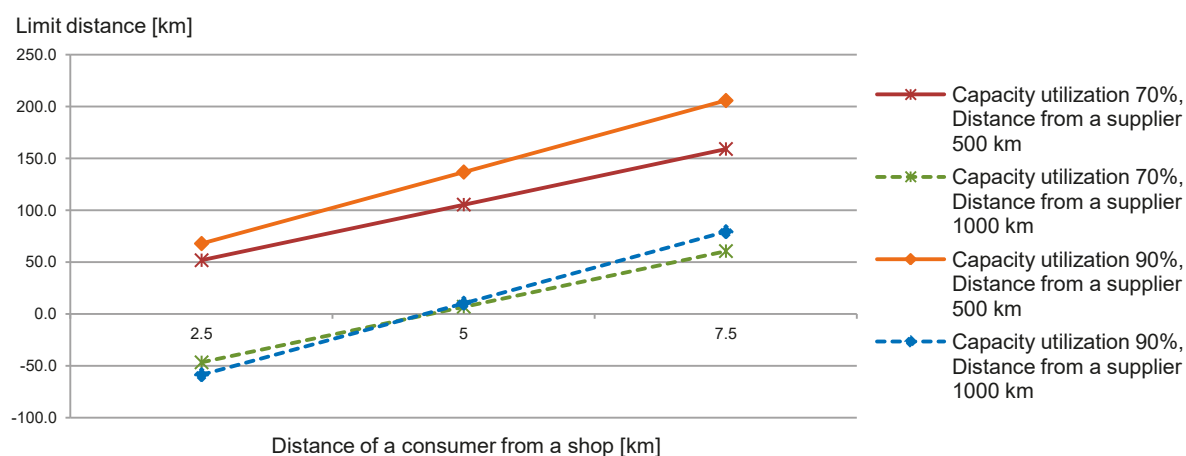


Figure 5. Limit distances in the final distribution in e-commerce (vehicles < 7.5–16 t)

still generated lower external costs, even if consumers took short car trips to stores. For example, e-commerce still generated lower external costs than traditional distribution in a variant in which vehicles up to 7.5 tons are used at 90% capacity, suppliers were located 1000 km or more (suppliers located in Europe), consumers 2.5 km from stores, and delivery vehicles were used to transport goods to consumers for distances less than 6.8 km. Additionally, if consumers were located 7.5 km from stores, delivery routes can extend up to 57 km. The use of larger vehicles provided even greater opportunities, and the border routes for the above assumptions are respectively 25 km and 163 km. The use of larger vehicles becomes possible when consumers are located outside urbanized areas (e.g., on the outskirts of cities) due to lower tonnage restrictions outside agglomerations. E-commerce can adversely affect the environment if the distances from suppliers are higher, e.g., 2000 km. If air transport becomes involved (suppliers from outside Europe) external costs would further increase.

Summary and Conclusions

E-commerce distribution can be beneficial both from microeconomic and macroeconomic points of view. If deliveries to consumers' homes in the e-commerce system contributed to reducing their car trips, this would significantly reduce external costs. The level of reduction will be greater as the efficiency of transport processes increases, which is also beneficial for e-commerce companies. Therefore, there does not have to be a "conflict of goals" between business and social goals; however, the benefits of increasing the efficiency of transport processes may be greater for society than for companies. This problem will arise if, despite a decrease in the efficiency of transport processes, companies will achieve satisfactory financial results not because of lowering their transport costs, but by increasing sales. Compared with the traditional method, this distribution method will generate higher external costs when delivery routes to customers and the distances from suppliers become significantly longer. Such

a variant, however, is quite real in the e-commerce industry for reasons independent from it. It is necessary to take into account demographic phenomena ("urban sprawl") and factors characteristic for the e-commerce industry – the possibility for consumers to search for suppliers around the world.

The results of the simulation were based on the assumptions made by the author, who tried to take into account the actual conditions as much as possible. However, in order to correctly estimate the costs and benefits for both companies and society, it is necessary to conduct research aimed at collecting data on parameters such as transport distances, utilization rates, transport costs, and rates, and also the transport and shopping behavior of inhabitants. Also, not all variants were calculated e.g., digitalization of products and its impact on transport costs.

In the end, although this was not the subject of consideration in this paper, the author would like to formulate the following hypothesis based on many years of research carried out: e-commerce distribution will be all the more cost-effective if large logistics operators are involved, who, thanks to economies of scale, are able to deliver goods to customers at lower costs without lowering the level of customer service. This can indirectly reduce the negative impacts on the environment.

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Global trends in maritime cruise fleet development

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Key words: maritime tourism, cruise shipping, shipping, cruisers, cruise fleet, trends

Abstract

The exercise of the economic and social functions of maritime tourism has undergone significant changes in recent years. A case in point is the development of the maritime cruise fleet, in both quantitative and qualitative terms, across various regions. This is a result of, among other things, the changing needs of international tourists in particular regions. The worldwide expansion of globalization has also marked a turnaround in preferences, with customers now willing to visit regions formerly unattractive or rarely considered by tourists. These changes are also visible in the variety of transport modalities available to passengers for both domestic and international voyages. To a large extent, these changes stem from technological developments. New possibilities for quick and efficient passenger transport have contributed to transforming maritime tourism in many countries. This, in turn, has led to increasing volumes of tourist traffic, generating economic growth for such nations. This article discusses contemporary trends in the world's cruise ship fleets in the context of the technical parameters of global cruise shipping. The authors have attempted to determine the basic quantitative parameters and metrics expected for characterizing the global cruise ship fleet. To accomplish this, the method of linear regression has been used, with the input data being the sizes of cruise ship fleets and some other characteristic parameters, during particular time periods, carrying capacities, registered tonnages, numbers of passenger cabins, main and auxiliary engine powers, and levels of fuel consumption. The econometric model of linear regression has allowed calculating the projected values for the nearest future.

Introduction

The development of the global economy at the beginning of the 21st century was dominated by new trends inextricably connected with the growing importance of the service sector within the global economic system. A special place there is held by tourist services, whose development is driven mainly by growing social mobility and wealth. The growth of tourism has been accompanied by new trends pushing entities who provide tourist services to create new products.

Tourism is a sector of national economies which has developed rapidly worldwide of late. Within the last 10 years, the number of passengers serviced annually by the CLIA (Cruise Lines International Association Inc.) fleet alone rose from 17.8 to

30 million (CLIA, 2019). In some regions, tourism is the primary sector of business, even sustaining some local economies (mainly in the Caribbean area (CLIA, 2019)). It also represents a most important sphere of both economic and social activity for nations in general. Indeed, the volume of tourism is a yardstick of the living standard and civilizational development of a society. According to the World Travel & Tourism Council (WTTC), the tourist economy across the world accounts for more than a 10.4% slice of the gross global product (WTTC, 2019). This indicator shows the economic position of tourism in today's world while also highlighting the strong connections between what is happening in the tourist sector, in other sectors of the economy, and in the world economy as a whole.

Factors in the development of world maritime tourism

The literature defines maritime tourism as tourism comprised of travel along fixed sea routes, cruises to attractive destinations, and individual yachting trips over maritime or inland waterways, as well as many other recreational activities pursued on or by the water. Cruises are self-contained tourist products featuring short-distance (local) and long-distance (domestic and international) voyages by sail- or motor-powered vessels, maritime and inland passenger shipping, canoeing, and rafting (Kaup, Łozowicka & Chmielewska-Przybysz, 2013). Miotke-Dzięgiel emphasizes that “The contemporary market for maritime tourism includes a wide range of voyages by different means of maritime transport” (Miotke-Dzięgiel, 2002). Therefore, the concept of maritime tourism covers all its multiple forms, such as cruising, maritime sailing, passenger coastal shipping (‘the white fleet’), ferry services, canoeing, underwater tourism, and travel services operated by cargo and passenger-and-cargo vessels. In a narrow understanding of maritime tourism, it is assumed that spending time in or on the water is the main reason for undertaking this form of travel. A broader understanding of the term takes into account water-related tourism as a possible, though not usually the main, motivation for tourists to choose a specific cruise / travel destination (Mańkowska & Mańkowski, 2010).

The conditions of maritime tourism and its developmental trends are shaped largely by changes in the world economy, such as (Urbanyi-Popiołek, 2013, p. 84; Program of development, 2015):

- financial factors related to the increasing wealth of societies;
- political factors related to the security and stability of regions where maritime tourism is present and also from growing international integration as exemplified by, among other things, conveniences related to the freedom of travel, e.g. the opening of internal state borders within the European Union, visa-free entry, and convenience in cross-border traffic. It should be remembered that local and regional conflicts in many areas adversely affect the amounts and routes of maritime tourism;
- economic factors: economic crises in many developed economies will reduce tourist traffic from and to these countries and divert the same traffic to quickly-developing countries;
- social factors: economic growth, improved education levels, and generally greater access to

wealth in a country influences the supply of and demand for tourist services which become more attentive to the needs of tourists with exacting requirements; these factors are related to the motivations for travel by sea and a direct result of growing social and economic mobility in Europe, the USA, Canada, and Asia, as well as increasing leisure time, urban fatigue, occupational burnout, and longer life expectancies; sea travel is seen as a remedy to tiredness and psychological strain;

- environmental factors: growing social awareness of environmental protection and climate change will spur tourist services towards compliance with the highest standards of environmental protection, including cruise services;
- technological factors: advances in information and communication technology have enormous impacts on providing methods of access to tourist services, including the adjustment of methods and services to diverse customers’ needs.

These factors contribute to new trends in world tourism whereby trips are becoming shorter but more frequent, with travelers increasingly expecting services tailored to their needs and offering a more ‘genuine’ travel experience. In addition to these demands, supply factors play a large role in creating demand as maritime tourism services, carriers, and tour operators offer diverse choices of vessels and itineraries. These changes are also driven by developments in tourist infrastructure, such as hotels and land-based transport infrastructure (Urbanyi-Popiołek, 2013). World trends in demand for tourist services include more customers with discerning tastes who are vocal about their needs, rising levels of education, lifestyle changes in Western societies characterized by the increasing importance of individual needs, superior awareness with respect to environmental protection and sustainable development, and growing interest in and use of new IT technologies, including the internet (Markiewicz, 2013).

The factors discussed above have led to the rise of luxury passenger cruises as increasingly popular options for tourists from Western Europe and the USA. Luxury tourism is designed for customers willing to pay a premium for experiences that satisfy their high expectations. A particular example of luxury tourism is cruising, understood as touring the world on board a passenger ship travelling between destinations hosting tourist attractions (Taraszkiewicz, 2008). According to Swoboda-Rydz, a passenger ship is designed for pleasure cruising, in which the voyage itself, the associated modern

conveniences, and the destination all contribute to the desired positive travelling experience (Swoboda-Rydz, 2012). Transport is not the main goal here because cruises usually end at the point of departure. According to the federal US register, a cruise ship is defined as a passenger ship with capacity to carry over 400 passengers and more than 200 feet (60.96 metres) in length. This definition also covers ferries conforming to these rules and regulations (Rules and regulations, 2011). Certainly, this represents a form of tourism that does not place any demands on the tourist. The passenger may spend the entire voyage on the ship, taking advantage of a wide range of recreational activities. This means that he/she may be unlikely to visit the port cities, but this does not detract from the role of cruising in the development of modern tourism (Mańkowski, 2008). The most famous passenger carriers include the “Queen Mary 2,” “Queen Elizabeth II,” and “Queen Victoria,” while the “Symphony of the Seas” operated by the Royal Caribbean International, was commissioned into service in April 2018 and is now the largest and most expensive such vessel (EUR 1.3 billion).

Selected classification criteria in the world cruise fleet

Cruise Lines International Association (CLIA) is an umbrella body with a worldwide membership of over 30 shipping associations operating more than 300 cruise ships. The increasing size of newly built vessels is one of the characteristic developments in

maritime tourism nowadays. The tendency is most prominent in the North American maritime cruising market, especially in the Caribbean. The enlargement of passenger ships has economic motives. In the face of growing competition, many shipping associations believe that long-term survival on the market is impossible without a reduction in operating costs (Gaworecki, 2000, pp. 42–43). This means that a ship able to accommodate more passengers at a time makes better business sense. According to Kizielewicz, the long-time hotbeds for cruising are in the Americas, in particular the Caribbean Sea area, and in Europe, led by the Mediterranean area (Kizielewicz, 2015). Other regions command a much smaller share of the market. One can see there is a strong demand in these regions, as they are home to the largest maritime cruising corporations, such as the Carnival Cruise Line, Royal Caribbean International, Norwegian Cruise Line, and Costa Crociere (Table 1). Also, these regions contain leading destinations such as Miami and the Everglades in Florida, and Barcelona and Rome in (Civitavecchia) in the Mediterranean area. The largest cruise ships are operated by Royal Caribbean International, a Norwegian-American company headquartered in Miami and responsible for a 25% market share of luxury cruises. All of this company's ships have, since 1991, had the words “of the Seas” added to their names. Their largest ship is Symphony of the Seas, a 1.4 billion-dollar project built, like most of these ships, by Finnish shipyards (Rettinger & Urbańska, 2012).

Table 1. The 15 top-ranking cruise shipping companies (end of 2016) (ISL, 2018)

Owner/operator	Country	No.	1000gt	Berths	Average 1000gt	gt-% share	Average age
Carnival	USA	102	8 754	224 115	86	44.3	12.9
RCCL	USA	40	4 480	109 615	112	22.7	13.6
NCL Group	USA	24	1 909	46 592	80	9.7	11.0
MSC	Switzerland	12	1 189	31 756	99	6.0	9.1
TUI Group	Germany	15	784	19 930	52	4.0	19.1
Genting Group	Malaysia	8	530	13 075	66	2.7	19.0
Disney Cruise Line	USA	4	426	8 520	107	2.2	11.3
Silversea Cruises	Italy	8	142	2 268	18	0.7	20.1
Fred Olsen Cruise Lines	Norway	4	125	3 785	31	0.6	34.5
Phoenix Reisen	Germany	4	124	3 154	31	0.6	29.5
Louis Group	Cyprus	4	98	3 940	25	0.5	32.5
Viking Ocean Cruises	Norway	2	96	1 874	48	0.5	0.5
Cruise & Maritime Voyage	UK	3	84	2 650	28	0.4	50.0
SkySea Cruise Line	China	1	72	1 778	72	0.4	21.0
Windstar Cruises	UK	6	56	1 234	9	0.3	27.2
Others		64	889	24 766	14	4.5	26.3
TOTAL		301	19 759	499 052	66	100.0	17.5

Maritime tourism, due to the number of participants, can be divided into (Ward, 2006):

- Individual cruises (1–9 passengers), which are organized on the smallest crafts;
- Group cruises (10–500 passengers), on small ships;
- Mass cruises (501–2000 passengers), on medium size vessels;
- Large resort ship cruising, (2001–4000 passengers), on the largest ships.

Considering tourism in terms of purpose travel, the following classification can be described: (Kizielewicz, 2012):

- cultural tourism: sightseeing excursions to coastal towns and cities, national parks, fishing villages, natural reserves, and places of worship;
- adventure tourism: fishing and diving cruises (e.g., SCUBA, cave diving, and snorkelling);
- topical tourism: Valentine's Day cruises, Christmas cruises, golfing cruises, gambling cruises, cruises for seniors, photographers, women, singles and others;
- educational tourism: cooking cruises, dance cruises, and language cruises;
- business tourism: company cruises, motivational cruises, business meetings, seminars, conferences, symposiums, and congresses;
- entertainment tourism: dance events on the sea;
- health tourism: SPA & Wellness cruises, surgery cruises, and fitness cruises;
- eco-tourism: cruises to ecologically intact areas.

In closing, it should be emphasized that the development of new generations of cruise craft will increasingly rely on economies of scale (i.e. the mass tourism market), at the cutting edge of design

and technical innovation and offer a multifaceted recreational shipboard experience (Johnson, 2002).

An analysis of quantitative and qualitative aspects of the world cruise fleet – the authors' own research

As of August 31, 2019, the database at maritime.lhs.com put the number of cruise ships at 585 worldwide, of which only 7 are ice-classed and therefore fit to provide services associated with arctic tourism. The combined register tonnage within that group stands at 23,162,737 and net capacity at 14,207,466. The total carrying capacity was 2,293,761 dwt with a total of 705,740 berths. The changes in the basic parameters of the fleet from 2010–2018 are illustrated in Table 2.

The average weighted per-ship register tonnage within the cruise group was 39,574 gross and 24,286 net. The average values for linear parameters are as follows:

- LOA (length over all) – 154.1 m,
- Width – 21.06 m,
- Water line – 9.7 m.

With these figures, the average number of decks on a cruise ship is 7, each of which houses on average of 507 cabins with 1221 berths. The average size of ship crews is 478. The total number of berths available to passengers within that fleet is 693,748.

The above data refer to the entire existing fleet. For ships commissioned into service between the years 2010–2018, the average values of the fleet's main parameters have been shown in Table 2 in order to illustrate how the calculations have changed in both quantitative and qualitative terms. These

Table 2. Basic quantitative and qualitative parameters of world cruiser fleet (based on (HIS, 2019))

Year	No. of ships	Average main engine power	Total fleet engine power	Average LOA	Average No. of cabins	Average No. of decks	Average No. of pax. places	Total fleet No. of pax. places
[unit]	[pcs]	[kW]	[kW]	[m]	[pcs]	[pcs]	[pcs]	[pcs]
till 2009	451	20 660	9 069 709	142.0	438	6	1 069	482 090
2010	17	42 063	715 068	221.5	579	9	1 520	25 837
2011	12	26 373	316 474	154.0	664	7	1 483	17 794
2012	9	49 322	443 894	248.3	796	9	1 880	16 916
2013	7	37 254	260 780	234.5	1 244	14	2 584	18 086
2014	7	43 956	307 692	246.9	757	9	1 688	11 813
2015	9	31 632	284 684	205.2	1 161	12	2 587	23 283
2016	12	41 789	501 462	249.2	1 053	13	2 596	31 150
2017	17	29 341	498 800	195.9	1 500	14	3 513	59 724
2018*	24	23 479	563 490	163.0	119	3	24	6 793
2010–2018	117	34 382	4 022 664	206.5	774	9	1 809	211 658

* only a single large vessel was delivered in that year; the other 23 vessels were very small units, of which 8 with space to accommodate 36 passengers and 4–16 passengers.

additional figures are much higher than the averages for all ships, which means that the following have taken place in the last 9 years:

- the world cruise fleet has increased its size by over 25.9%;
- average power of a cruise ship has grown by over 66.4%;
- total engine power in the cruise fleet has grown by 44.4%;
- the average length of new ships is over 45% greater than the average overall figure for the world fleet;
- the average number of passenger cabins on new ships is higher by 76.7% than the overall figure;
- the average number of berths on new ships has grown by close to 70%;
- the combined number of berths on new ships equals 43.9% of the overall available number of berths pre-2010, amounting to an almost two-fold increase in that figure.

As for engine power, a total figure of 13,272,894 kW was recorded for main engines and 797,884 kW for generators. On average, each ship is powered by three engines with the combined output of 23,547 kW and three generators with 4030 kW each. The average daily fuel consumption hovers at 103 tons, of which 93.6 tons are used for propulsion and the other 9.4 tons for utility purposes. The stated figures refer to HFO and MGO drives and do not include the seven ships powered by LPG/NPG.

Prospects for development of the world cruise fleet

The growth values stated above for the period between 2010 and 2018 with reference to the basic

quantitative and qualitative parameters of the world cruise fleet provided the inspiration to survey the prospects for these parameters up to the year 2030.

This has been done using linear regression with the input data being the size of the world cruise fleet and its associated parameters such as average craft length, average main engine power, and combined engine power of all fleet members. Also consideration has been given to other parameters impacting the fleet's capacity, such as the average number of cabins per ship, the average number of passenger berths and the combined number of berths offered to passengers in all ships in the fleet. Thanks to the econometric linear regression model, it has been possible to determine the parameter values for the period from 2019 to 2030. Regression means that when the value of an independent variable changes by a unit, the dependent variable rises or drops (depending on the sign) by a parameter value b . The angular coefficients of straight lines $b(y)$ and $b(x)$ are referred to as regression coefficients (Aczel, 2000; Kleinbaum et al., 1998).

These methods yielded some interesting values for the parameters under discussion, as presented in Table 3.

The linear regression model is somewhat inadequate for extremely long strings of input data, as seen in the above calculations, particularly where the forecast number of berths is concerned. The figure forecast for the years 2019–2020 proved to be lower than the actual figure for 2018, calling for a cautious treatment of values calculated for subsequent years, especially because the estimated percentages of growth for other parameters are inconsistent with the calculated growth of the overall number of berths.

Table 3. Estimation of chosen parameters of world cruiser fleet

Year	No. of ships	Average LOA	Average main engine power	Total fleet engine power	Average No. of cabins	Total pax. places	Average No. of pax. places
Unit	[pcs]	[m]	[kW]	[kW]	[pcs]	[pcs]	[pcs]
2019	573	233.2	38 997	13 754 924	1 022		2 286
2020	583	238.7	40 113	14 157 606	1 059		2 366
2021	594	244.2	41 229	14 560 288	1 096		2 446
2022	604	249.6	42 344	14 962 652	1 132	698 351	2 526
2023	615	255.1	43 460	15 365 653	1 169	710 344	2 605
2024	625	260.6	44 576	15 768 335	1 205	722 337	2 685
2025	635	266.1	45 692	16 171 017	1 242	734 330	2 765
2026	645	271.6	46 807	16 573 699	1 278	746 323	2 845
2027	656	277.0	47 923	16 976 381	1 315	758 315	2 925
2028	666	282.5	49 039	17 379 063	1 351	770 308	3 004
2029	676	288.0	50 155	17 781 746	1 388	782 301	3 084
2030	686	293.5	51 270	18 184 428	1 425	794 294	3 164
$\Delta 30/18$	+20.8	+90.5%	+117.3%	+37.0%	+181.1%	+14.5%	+159.1%

According to the estimates, the fleet should grow by little more than 20% which represents 686 vessels. This should be mentioned in conjunction with the calculated lower limit of projection (LLP) – 682 and the upper limit of projection (ULP) – 691. This means a good match with the forecast and a narrow margin of error.

It is interesting to consider the forecast average length of cruise ships, with the figure expected to double (over 90% growth) and a very large spread between LLP and ULP: 265.3 metres and GGP 332.6 metres, respectively. It could be argued therefore that the world cruise fleet will increase not only in size but also in craft length.

This argument is borne out by the estimated average values for number of cabins per ship and number of berths available. The first parameter is expected to grow by 181%, while the second by 159%. We may therefore go further and say that cruise ships will not only become longer but will also grow in capacity to accommodate increasing passenger traffic. As we analyze the ranges of estimates for these two parameters, we see that the forecast is consistent. For an average of 1425 cabins, LLP is 1115 and ULP is 1734. For an average of 3164 berths, LLP stands at 2514, while ULP at 3975. In terms of carrying capacity, it can be seen that individual craft may vary considerably in size, which further supports the previous conclusion.

Estimates for the average engine power of cruise ships show a +117% growth. This means that energy demand will rise much more quickly than the fleet's size. LLP for this parameter was 42,980 kW, and ULP – 59,561 kW. The spread of estimated values is therefore wide.

The combined fleet power is estimated to reach 18.18 MW with narrowly spread LLP and ULP, standing at 18,017,083 kW and 18,351,773 kW, respectively. To conclude, while the average for an individual ship may differ with respect to other craft within the analysed fleet, the combined figure for power does not display considerable inconsistencies and therefore seems reliable.

Conclusions

In closing, it should be pointed out that tourism becomes increasingly popular worldwide year after year. At the same time, it is undergoing constant changes, creating new challenges related to aligning the modernization and adaptation processes with ever-changing demand. These tendencies affect product creation in that they determine products'

perceived attractiveness, quality, and innovativeness. One of the most characteristic features of maritime tourism development recently is the rapid increase of ship sizes, especially in North American waters, the largest maritime tourism market at present. The tendency to build increasingly larger ships makes economic sense. In the face of growing competition, many shipping associations believe that long-term survival on the market is impossible without reducing operating costs. A single large ship is more economical than two smaller craft, leading to lower costs, better passenger comfort and more attractive entertainment options.

In 2018, 28.5 million people, including two million Germans, took cruises, and the figure is rising. What used to be an impossible dream is now available to a larger clientele due to price cuts. Environmentalists criticize the trend, arguing that cheap holiday tours exact a high cost in terms of environmental damage. Most of the 300 craft are still powered by heavy fuel oil (mazut), classified as among the most toxic of fuels, with negative effects on the environment. Burning mazut releases high doses of CO₂, sulphur oxides, dust, and heavy metals. Ships need to run air conditioning, lighting, and heating also when moored at berth or in the harbor, leading to increases in complaints among seaside populations about air pollution. To remedy this, most ships are now switching to more expensive and more environmentally friendly diesel engines during stoppage times in port (Schlagwein, 2019).

A survey of the climatic impact of cruise shipping needs to consider that cruising makes up a mere 2% of worldwide tourism. For comparison, 60% of holiday makers in 2018 chose travelling by plane. In that regard, we also need to remember that the development of the tourist industry heavily affects nature and local communities, that is to say, exactly the things that attract tourists to a specific locality. The problems plaguing tourist areas include mounting road traffic, crowded venues and congested walking trails, storming of tourist attractions, landscape damage due to poor designs and layouts for buildings and other infrastructure, depletion of natural resources, shrinkage of wildlife areas, climate change, and undesirable social phenomena such as prostitution and begging, followed by displays of uncouth tourist behavior. These problems can even threaten the success and continuation of tourism in particular places.

Therefore, it is necessary to strive for the sustainable development of the tourist industry wherein our desires to travel will not prevent others or future

generations from enjoying the possibility. However, this cannot be achieved without taking action to preserve natural and wildlife resources, as well as to support local communities and their cultures and economies. Among current trends within the industry is so-called 'responsible tourism,' which means organizing and engaging in tourism in an economically, environmentally, and culturally responsible way.

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The impact of seaport development on the social environment: a case study of a port city with low unemployment and dominating tourism function

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Key words: seaports, port cities, socio-economic relations between seaports and port cities, investments in seaport infrastructure, container terminal, Świnoujście

Abstract

The issue of the impact of seaports on their direct vicinity has been repeatedly addressed in the academic literature. The developed merits of their impact is mainly related to employment in the port/port cluster, the seaport's share of the municipality's labour market, and the added value produced by the port/port cluster or the volume and structure of uncompensated flows into the municipality's budget on account of the port's operations. This article is aimed at providing an answer to the question of how to evaluate the impact of a new investment project in a seaport on its direct vicinity in a situation of low unemployment in the port's municipality and the dominating tourism function in its economy. The research methodology was based on a single case study of the city of Świnoujście and the seaport in Świnoujście; the dominating economic function of this municipality is tourism. Moreover, it is the location of one of the four seaports with primary significance for the national economy. The development plans for the Szczecin & Świnoujście Seaports Authority include the construction of a deepwater container hub terminal. The investment will have an impact on the local social environment. The results of the conducted research studies are presented in the article both in a traditional approach enumerating the benefits of such an investment project for the local environment, as well as proposing a new approach to the evaluation of its benefits (*inter alia*, providing employment opportunities for people who so far have been forced to look for jobs outside the municipality and the long-term unemployed, preventing young and educated people from moving out of the municipality, attracting new inhabitants, improving the employment-to-population ratio, and stopping the city's population ageing).

Introduction

The impact of seaports on their direct vicinity has often been the subject of research studies. The existing academic literature identifies various aspects of the seaports' impact. In addition, their merits have been put forward so as to assess their significance for port cities. The impact may also be viewed from the point of view of new investment projects being implemented in seaports. However, a certain research gap may be identified in the academic literature in relation to the impact of seaports on port cities in a situation of low unemployment and domination of the tourism function in the port

municipality's economy. The main purpose of this article is to provide an answer to the question of how to assess the impact of a new investment project in a seaport on its local environment.

The study focuses on Świnoujście, a port city located in the West Pomeranian voivodeship, Poland. Świnoujście is located on 44 islands, including three major ones: Uznam (Usedom), Wolin, and Karsibór. In terms of the national administrative classification, it is a city county. The economy of the Świnoujście municipality is dominated by tourism, which is due to the city's location on the sea coast as well as its official status as a spa resort. Moreover, it is the location of one of the four seaports

of primary significance for the national economy. The specific feature of the Świnoujście municipality is the domination of the tourism function in its economy, rather than the port function that played a major city-forming role in the second half of the 20th century. This article focuses in particular on the possible social impact of a planned investment project; namely a deepwater container terminal in Świnoujście (DCTS).

The outcome of the research study is a concept that allows for a broader view of the impact of the new investment in the seaport on the direct vicinity of the seaport (port city), which goes beyond the expected direct employment benefits.

Literature review

The issues that are related to the impact of seaports on their direct vicinity have been presented in various aspects, such as the influence of the seaports or investment projects implemented in seaports on port municipalities (Stevens, Treyz & Kindahl, 1981; Davis, 1983; Suykens, 1989; Ferrari, Percoco & Tedeschi, 2010; Shan, Yu & Lee, 2014; Song & van Geenhuizen, 2014); the benefits enjoyed by the seaport's stakeholders and the place of representatives of the local environment in the classification of port stakeholders (Benacchio et al., 2001; Notteboom & Winkelman, 2002), attracting new inhabitants through port agglomerations due to the large number of business entities operating on port premises and in its direct vicinity (Musso, Benacchio & Ferrari, 2000; Bottasso et al., 2013) as well as port cluster functioning or business activity clusters (Haezendock, 2001; De Langen, 2006). There have also been research studies related to the identification of potential conflicts between a city and a port, and the grounds for cooperation between a city and a port (Hoyle, 1989; Amato, 1999; Wiegman & Louw, 2011; Daamen & Vries, 2013; Parola & Maugeri, 2013). In the academic literature as well as in business practice, the merits have been established to measure the social impact of seaports on their local environment, which are mainly related to employment at the port/port cluster and its share in the municipality's labour market, and the added value produced by the port/port cluster.

In Poland, following its economic transformation, the growth-related benefits that have been enjoyed by the direct vicinity of seaports (Szwankowska & Szwankowski, 1997; Pluciński, 2013; Matczak, 2016; Nowaczyk, 2016) were studied along with the issues connected with the seaport-port city relations,

such as: port cities being the direct hinterland of seaports (Szwankowska & Szwankowski, 1997), organisational interconnections between port cities and ports (Waldziński, 1999), seaports within the areas of port cities (Szwankowska, Szwankowski & Tubielewicz, 1994; Krośnicka, 2005) as well as revitalisation of old port structures (Kochanowski, 1998).

Methodology

The research study applied the single case study method, one of the qualitative research methods (Yin, 2017). The conclusions obtained by applying the single-case study method may be generalised and projected onto other cases that are characterised by similar variables and conditions (Grzegorzczak, 2015).

In view of the principles of applying the method in research studies, the following research questions were formulated:

1. How does the existing domination of the tourism function in the municipal economy affect its social environment?
2. To what extent will the port city's social environment be affected by the construction of a modern container terminal in the situation of low unemployment and domination of the tourism function in the local economy?

This study focuses on the social impact of a new investment project i.e. a deepwater container terminal in Świnoujście (DCTS) on the local environment (the city of Świnoujście). The planned terminal is to serve the cargo category that has experienced the most rapid increase in its share in seaborne trade – containerised general cargo. It is expected to be a hub terminal that is able to handle transoceanic container ships. Implementation of the investment project would dramatically improve the position of the port of Świnoujście on the port services market in the area of containerised cargo handling.

In order to apply the single case study method, a number of techniques and tools for data gathering and analysis were used. The analysed materials included, *inter alia*, the available statistical data provided by the Central Statistical Office as well as the internal materials provided by the Szczecin and Świnoujście Seaports Authority, selected port operators and the city of Świnoujście.

Thus the source information that was gathered and analysed made it possible to obtain an answer to the research questions and formulate generalisations that may be used by other researchers.

The case study of Świnoujście

The co-existence of the tourism function and the traditional port functions in Świnoujście

Even though Świnoujście is a port city, tourism is the leading business sector in its economy, with substantial potential for future development. The tourism function has been predominantly developed in the part of the city that is located on the island of Uznam. The factors that are decisive for the development of the tourism function of Świnoujście include its natural conditions (its geographical location, in the vicinity of the German border, various natural resources, the wide and sandy beach, diverse water bodies that enable different forms of water tourism to be practiced, and its official spa status), its cultural heritage in the form of historic military facilities, the expanding range of services for tourists and the relatively well developed tourism infrastructure. The number of tourists coming to Świnoujście has been steadily growing; over the last decade, the number of overnight stays in the area of Świnoujście has doubled, reaching 2.1 million in 2018, which made Świnoujście the seventh most popular resort in Poland. Foreign tourists, predominantly from Germany, account for a significant share of that business. The decisive factor for the attractiveness of Świnoujście among foreign tourists is that Poland offers lower prices compared to other EU countries. Another factor contributing to the increased attractiveness for tourists is also the upgraded standard of hotels and catering services. The prevailing forms of tourism in Świnoujście are connected with leisure, spa treatments and active tourism (sailing, cycling). The highest occupancy rates in the hotels and other facilities that offer accommodation to tourists are observed from July to September. Even though there has been a trend in recent years showing a longer and longer tourist season, the insufficient development of all-season tourism and tourism-related infrastructure still affects the seasonality of the services offered by the city (Report, 2013).

The traditional port functions in Świnoujście are carried out mainly in the part of the city that is located on the island of Wolin. The port in Świnoujście is a seaport of primary significance for the national economy (Journal of Laws, 1996). The port is able to serve vessels with a draught of up to 13.5 m and a length of up to 270 m. The main areas of business of the Świnoujście port include:

- the area for handling bulk cargo such as coal, iron ore, or grain;
 - the sea ferry terminal, which is the most advanced on the Polish sea coast;
 - the LNG terminal.
- In terms of transshipment volumes, the port of Świnoujście is the third biggest in Poland (following Gdańsk and Gdynia). In the years 2016–2017, the transshipment volumes amounted to 12.6–14.7 million tonnes, the predominant part of which was general cargo carried by ferries. The only container terminal that operates in the port of Świnoujście is located in the bulk cargo handling area, at the Hutników & Górników wharf (the total length of the wharf is 660 m). It is able to handle post-panamax 4500 TEU container vessels (OT Port Świnoujście, 2019). Nevertheless, the port of Świnoujście's share in the containerised cargo transshipment in all Polish seaports is negligible. Over the past few years it amounted to ca. 0.2%, which corresponds to an annual turnover at the level of 4–5 k TEU (GUS, 2018). The port of Świnoujście is not equipped with a container hub terminal. However, „Strategia rozwoju portów morskich w Szczecinie i Świnoujściu do 2027 roku” (ZMPSiS, 2014) and „Program rozwoju polskich portów morskich do 2020 roku, z perspektywą do 2030 roku” (MGMiŻŚ, 2018) have proposed the construction of such a terminal in Świnoujście. According to the developed concept, a deepwater container terminal in Świnoujście is to be located in the outer port, east of the existing LNG terminal. The initial transshipment capacity of the terminal is planned to be 750 k TEU, and the target capacity is to be 1500 k TEU.

The social environment in Świnoujście

The social impact assessment related to the new investment project in the seaport should be preceded by an analysis of selected information on the social environment of the city of Świnoujście (Table 1).

The major conclusions from the analysis of the population data, presented in Table 1 and detailed in the databases of the Central Statistical Office (GUS, 2018), may be summarised as follows:

1. A population of over 41 k puts the city in fifth out of the eight population ranges applied in Poland (range: 20,000–49,999). Over the years 2002–2016, the population of Świnoujście dropped by 1%. Świnoujście showed a natural decrease of 157 inhabitants, whereas the average for the whole country is close to the level required for generational renewal.
2. Although the share of the working age population of Świnoujście is close to the average for Poland,

Table 1. Selected data regarding the social environment of Świnoujście (December 2016) (study based on data published by the Central Statistical Office for December 2016)

Selected categories of the social sphere		Świnoujście	Poland
Population		41,032	38,433
Rate of natural increase (per 1,000 population)		-3.6	-0.2
Inhabitants' age	working age population (%)	61.7	61.7
	young population (%)	14.2	17.9
	elderly population (%)	24.1	20.2
Average population age [years]		44.2	41.2
Employment-to-population ratio (per 1,000 population)		198	240
Unemployment rate %		5.6	8.3
Average monthly gross pay [PLN]		4,307	4,291

the share of the young population is lower than the national average by 21%, whereas the share of the elderly population is higher than the average for Poland by more than 16%. The population of Świnoujście is aging faster than the average rate in Poland (by 7.2%), and even the average rate in the West Pomeranian voivodeship (by 6.5%). The forecasts show that by 2050 the population of Świnoujście will fall from the present 41 thousand to 34 thousand.

3. As for the working population in Świnoujście, over the past decade there have been changes in the total numbers of working people and the shares of both sexes in the working population as a whole. Over that period, the total number of working people in Świnoujście fell by 38% (from 13.1 k to 8.1 k), and it was particularly severe in the case of men (the share of men in the total workforce fell from 60.3% at the end of 2006 to 44.7% at the end of 2016). Over that decade, the number of working men fell by as much as 53.9%. Over the same period, the share of women in the total workforce of Świnoujście rose to 55.3%, whereas the number of working women over the decade fell by a mere 13.3%. What is interesting is that, in the same period, the population of Świnoujście rose almost negligibly from 40.8 thousand to 41.1 thousand). However, the share of men in the overall population of Świnoujście hardly changed (from 48.5% to 48.2%).
4. At the end of 2016, the unemployment rate in Świnoujście was at the level of 5.6%. The unemployment rate in Świnoujście is much lower than either that for the whole West Pomeranian voivodeship (11%) or Poland (8.3%). Due to the domination of the tourism function in

Świnoujście's economy, the unemployment rate fluctuates on a seasonal basis within the range of 2.4 per cent (it fluctuates between 5.3% in July or September to 7.7% in February). This is connected with the seasonality of some of the jobs in Świnoujście. However, it should be noted that not all non-working people register themselves as unemployed. A significant number of men registered as residents of Świnoujście cannot find an attractive job in that municipality, so they take jobs outside Świnoujście, often abroad.

5. The average monthly gross pay in Świnoujście in 2016 amounted to PLN 4,307, which corresponded to 100.40% of the average monthly gross pay in Poland. In that year, the average pay in Świnoujście was markedly higher than the average for the West Pomeranian voivodeship (PLN 3,946).

The impact of the new investment project on the social environment of Świnoujście

As it has already been shown in the literature review, in a traditional approach, from the point of view of a port city, the functioning of the seaport and its development are mainly connected through the creation of new jobs, both in the areas that are directly connected with the port's function and management, and the complementary sectors. The recent studies on the impact of seaports on their vicinity (Mateczak, 2016) have shown that each job in a seaport results in two jobs in the port sector and subsequently four jobs in the direct environment.

Transposing the deliberations to the situation in Świnoujście and the impact of the planned DCTS on the direct environment, it should be assumed that people working in the port sector will mainly come from the city of Świnoujście. However, employment opportunities will also be offered to people from outside the city (such as, *inter alia*, people working in the educational and research spheres), so employment should be viewed as a benefit for the West Pomeranian voivodeship as a whole. The outcomes for the labour market, connected with the implementation of the contemplated investment project, may be summarised as follows (Employment size estimated on the basis of the experience of DCT Gdańsk) (ZMPSiŚ, 2017):

1. Employment directly at the container terminal – ca. 1000 employees, of which ca. 760 employees are directly involved in the provision of services and ca. 240 office workers.
2. Employment in the port sector, generated by each job at the container terminal – ca. 2000 people.

3. Employment in the state administration in connection with the sea and land trade of cargo at the container terminal – ca. 75 people.

Additionally, in the direct (regional) environment, ca. 4,000 people will be employed in connection with the functioning of the deepwater container terminal.

In view of the results presented above for the analysis of the social environment in Świnoujście, the author suggests a broader approach to the impact of the DCTS on its local environment (Figure 1).

The impact may be related to the following issues:

1. At the current employment level in Świnoujście, i.e. 8.1 k people (December 2016), the new investment will significantly increase the job supply on the local labour market (more non-seasonal jobs).
2. The new jobs would be offered to both qualified workers and people with tertiary education and would offer a much better chance for the male part of the population in Świnoujście to find a permanent job, compared to the current situation where the local labour market is dominated by the tourism sector.
3. In view of the increasingly difficult conditions for the functioning of the bulk cargo transshipment area in the port of Świnoujście, the deepwater container terminal should also be viewed in terms of permanent jobs for the stevedores who have been working in the bulk cargo transshipment sector. The terminal as such may contribute to changes that are beneficial to the tourism sector in terms of reducing the possibility of air pollution in the course of bulk load transshipment operations (an increase in the ratio of containerised bulk cargo transshipped in the seaport).
4. An extended job offer is also an opportunity to provide employment to long-term unemployed people. Additionally, more diverse job offers may also improve the employment-to-population ratio, which in Świnoujście (as at December 2016) was 17.5% lower than the national average.
5. A positive impact of the new investment in the seaport should be analysed in the context of halting, or at least slowing down, the process of the population decrease in Świnoujście. This pertains to both preventing young people from moving out of the municipality, and attracting new inhabitants who are of working age or younger. Another positive effect would be halting or at least slowing down the ageing of Świnoujście's population.
6. In addition to the beneficial effect on the migration ratio, good work prospects for young people will positively affect the natural population increase ratio in Świnoujście, which is of utmost

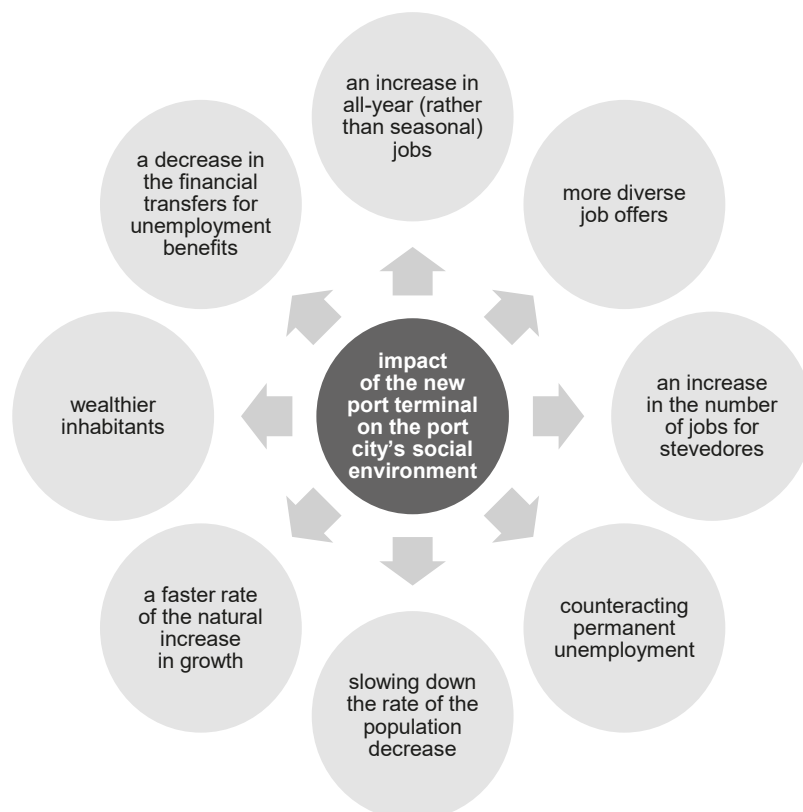


Figure 1. The proposed broader approach to the impact of a new investment project in the seaport on the local environment in the situation of a low unemployment level and domination of the tourism function in the port municipality's economy

importance in the context of the observed ageing process of the population in the city, and the forecasts for continuing population decrease.

7. Due to the fact that the port sector is the most dynamically developing sphere of the maritime economy in Poland, it can be assumed that the wages and salaries of people employed at the DCTS will have a positive effect on the financial standing of their families, as well as the firms cooperating with the terminal, and also on the demand for goods in the city.
8. Occupational inclusion of people who have so far been permanently unemployed should lead to a decrease in financial transfers for unemployment benefits. New employees will also contribute to increasing the proceeds of the city that will be obtained from personal income tax.

Conclusions

This research study has made it possible for a broader approach to be taken to the social impact assessment related to the new investment project in the seaport in Świnoujście. As a result, it was possible to contribute to the research findings in that regard. The application of the single case study method made it possible to focus on the specific example of a port city characterised by low unemployment and its dominating tourist function in the local economy. As a result of the social impact assessment related to constructing the deepwater container terminal in Świnoujście, the following factors were enumerated:

- an increase in job offers other than seasonal work;
- a more diverse job supply on the local labour market;
- the possibility of transferring the stevedores now operating in the bulk cargo transshipment area;
- the successful occupational inclusion of permanently unemployed people;
- the improved attractiveness of the local labour market for young people to counteract the population decrease and attract new inhabitants;
- the increased rate of the natural population increase;
- wealthier inhabitants as a result of increased earnings;
- a reduced need to pay unemployment benefits (the funds may be used for other needs of the municipality).

The proposed concept of the social impact assessment is not exhaustive. The author hopes that, as a result of ensuing academic discussions, the list will be added to by other researchers.

Acknowledgments

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Mechanical Engineering

Determination of the operating parameters of steam jet injectors for a main boiler's regenerative feedwater system

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Key words: steam jet injector, steam cycle, steam turbine, propulsion plant, thermal efficiency, determination

Abstract

Due to the development of alternative propulsion systems, there is a need for LNG tanker turbine propulsion plants to regain their competitiveness. Previous research revealed effective methods to increase the thermal efficiency of the steam cycle based on quality assessment, and it was proposed that the latent heat of the main turbine exhaust steam could be recovered. Research was carried out for the steam cycle using regenerative heat exchangers fed by steam jet injectors. In this paper, an algorithm to determine the operating parameters of steam jet injectors, and the calculation results for different drive steam parameters are presented. The obtained results will be used as input parameters for further heat balance calculations of the proposed regenerative steam cycles.

Introduction

An analysis of modern steam propulsion systems of LNG tankers (Dzida & Mucharski, 2009; Adamkiewicz & Grzesiak, 2017) indicates that they have insufficient thermal efficiencies. Despite the advantages of these propulsion plants such as their reliability, low maintenance costs (OPEX Operational EXpenditure), low emissions (NO_x, SO_x, HC), and the simplicity of energy conversion, they are being displaced from the market by highly efficient plants equipped with diesel engines (Grzesiak, 2018; IGU, 2018). At the same time, steam turbine manufacturers are pursuing research and development to increase their energy efficiency (Hirdaris et al., 2014; Kowalczyk, Głuch & Ziółkowski, 2016; Adamkiewicz & Grzesiak, 2017; Grzesiak, 2018).

In order to determine the possibility of increasing the efficiency of steam turbine plants, the identification of waste heat energy sources and a quality assessment were carried out for two of the main

waste heat energy fluxes: exhaust gas from main boilers and condensation heat released in the main condenser (Adamkiewicz & Grzesiak, 2019). The analysis showed (Adamkiewicz & Grzesiak, 2018; 2019; Grzesiak, 2018; Grzesiak & Adamkiewicz, 2018) an unsatisfactory efficiency of turbine propulsion plants compared with other systems, and the need to analyse waste heat energy fluxes in order to research feasible technologies for its effective use. This analysis showed that (Adamkiewicz & Grzesiak, 2019) the exhaust steam flux has a high energy potential, but its energy level is too low to be useful for regenerative feed water heating due to its low temperature and pressure. Additionally, there is a need to identify solutions to increase the energy level of exhaust steam so that it is useful.

The use of steam injectors in which the turbine exhaust steam mixes with the turbine bleed steam offers a possible solution. The results of calculations made for simple systems according to the Clausius-Rankine cycle, whose heat-flow diagrams are presented in Figure 1 (Adamkiewicz & Grzesiak,

Table 1. Determined functions of evaluation of the waste energy source quality

	Mass Flow	Energy flux	Press. Abs.	Temp.	Enthalpy	x	Exergy	ψ temp	ψ f(b,i)
	[kg/s]	[kJ/s]	[bar]	[°C]	[kJ/kg]	[-]	[kJ/kg]	[-]	[-]
MT condenser losses	22.61	48742.7	0.066	38	2294	0.888	1926.4	0.132	0.8936
TA condenser losses	1.587	3673.99	0.075	40	2452	0.95	2069.7	0.175	0.8945
Exhaust losses	43.84	12482.2	1.05	155	285	xx	139.2	0.806	0.5460

2018; Grzesiak & Adamkiewicz, 2018) indicate the validity of using a steam jet injector. Such a use proposes a modification while maintaining the same steam cycle parameters (superheated steam pressure and temperature). This increases the thermal efficiency of the plant due to a decrease in the bleed steam demand, which increases the available enthalpy drop in the turbine. At the same time, less heat is removed from the cycle in the condenser. Increasing the ejection level and using the bleed steam from the lowest possible energy level increases the regeneration degree of the plant (Adamkiewicz & Grzesiak, 2018; Grzesiak & Adamkiewicz, 2018). However,

using the injector to obtain the desired pressure at the device outlet requires a relatively high supply steam pressure.

This makes it necessary to determine the bleed steam parameters to effectively supply the regenerative steam injector, which is the aim of this article (Hirdaris et al., 2014). The bleed steam parameters were determined from an exemplary steam-powered system (CST – conventional steam turbine) of an LNG tanker with a capacity of 138,000 m³ from 2003.

For the calculations, the obtainable parameters of the state of the considered propulsion plant steam cycle (CST) were selected. For selected energy fluxes, the operating parameters of steam injectors in individual control planes were determined. The calculation results will serve as inputs for additional calculations of the heat balance of the cycles by applying steam jet injectors (in the regenerative main boiler feedwater systems of vessels).

Determination of parameters of driving steam for steam jet injectors

The parameters of the bleed steam supplying the regenerative steam jet injectors were determined. Table 2 shows the steam parameters of the cycle implemented by a conventional steam system of an LNG tanker. The last two fluxes in Table 2 are the steam parameters determined based on the expansion curve, which was based on the state parameters at the measuring points available for the UA-400 turbine (Figure 2).

Determination of operating parameters of steam jet injectors

The outlet stream parameters of the injectors were determined for the feed injector bleed steam at 19.5 bar, 10 bar, 6.6 bar, 3.1 bar, 3 bar, and 1.5 bar (Table 3). The outlet steam from steam jet injectors is a mixture of feed steam (bleed steam from the main propulsion turbine) and sucked steam (exhaust steam from the main propulsion turbine).

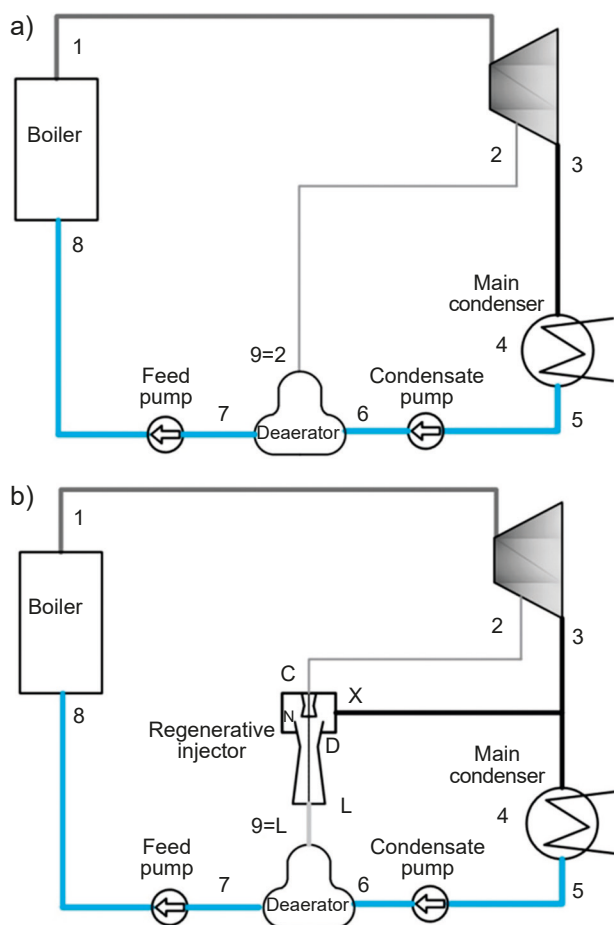
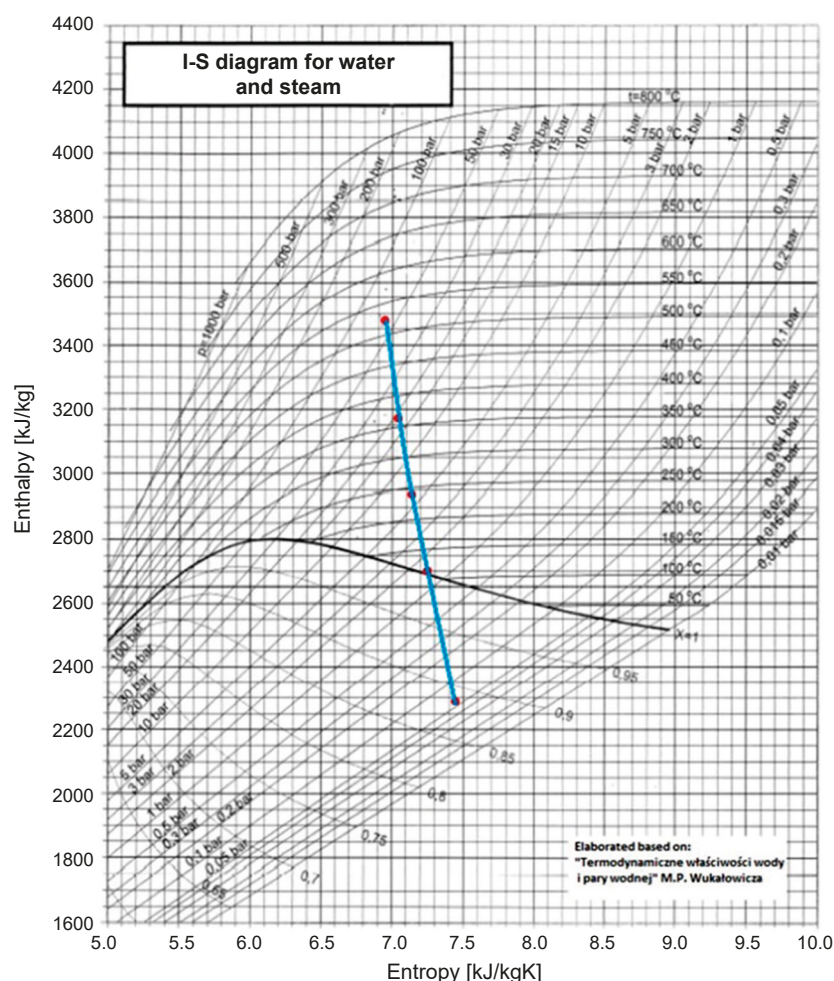


Figure 1. Thermal – flow diagram of proposed model a) Clausius-Rankine cycle with regenerative heater (deaerator) feed on steam bleed; b) Clausius-Rankine cycle with regenerative heater (deaerator) feed by regenerative injector

Table 2. Parameters of the steam for the CST plant of an LNG carrier

State	Pressure	Temp	Enthalpy		x
			[kcal/kg]	[kJ/kg]	
[–]	[bar]	[°C]			[–]
Superheated Steam after boilers	61	525	831.3	3481	1
Superheated Steam HP Turbine In	59.5	520	828.7	3470	1
HP Bleed	19.5	372	761	3186.2	1
HP Turbine Exhaust	6.6	245	703	2943	1
IP Bleed to HP Heater	6.6	245	703	2943	1
Feed Pumps Exhaust Steam	3.1	310	742	3100	1
LP Bleed	1.5	131	653	2734	1
TA Exhaust Steam	0.075	40	587	2452	0.95
Exhaust Steam from LP Turbine	0.06	38	551	2294	0.89
10 bar from expansion curve	10	287	722.5	3025	1
3 bar from expansion curve	3	170	669.5	2803	1

**Figure 2. Steam expansion curve in a Kawasaki UA-400 Turbine on an I-S diagram**

Calculations were made in accordance with the algorithm presented in Figure 3 (Gryboś, 1956; Goliński & Troskołański, 1979; Hegazy, 2007).

Figure 4 presents the correlation of steam pressure leaving the injector as a function of the degree of ejection (defined as the ratio of the steam sucked

in by the injector to the drive steam of the injector). The equation describing the steam pressure after the injector depending on the assumed degree of ejection was also determined.

The calculated exhaust steam pressures for a steam injector fed by 19.5 and 10 bar allow the

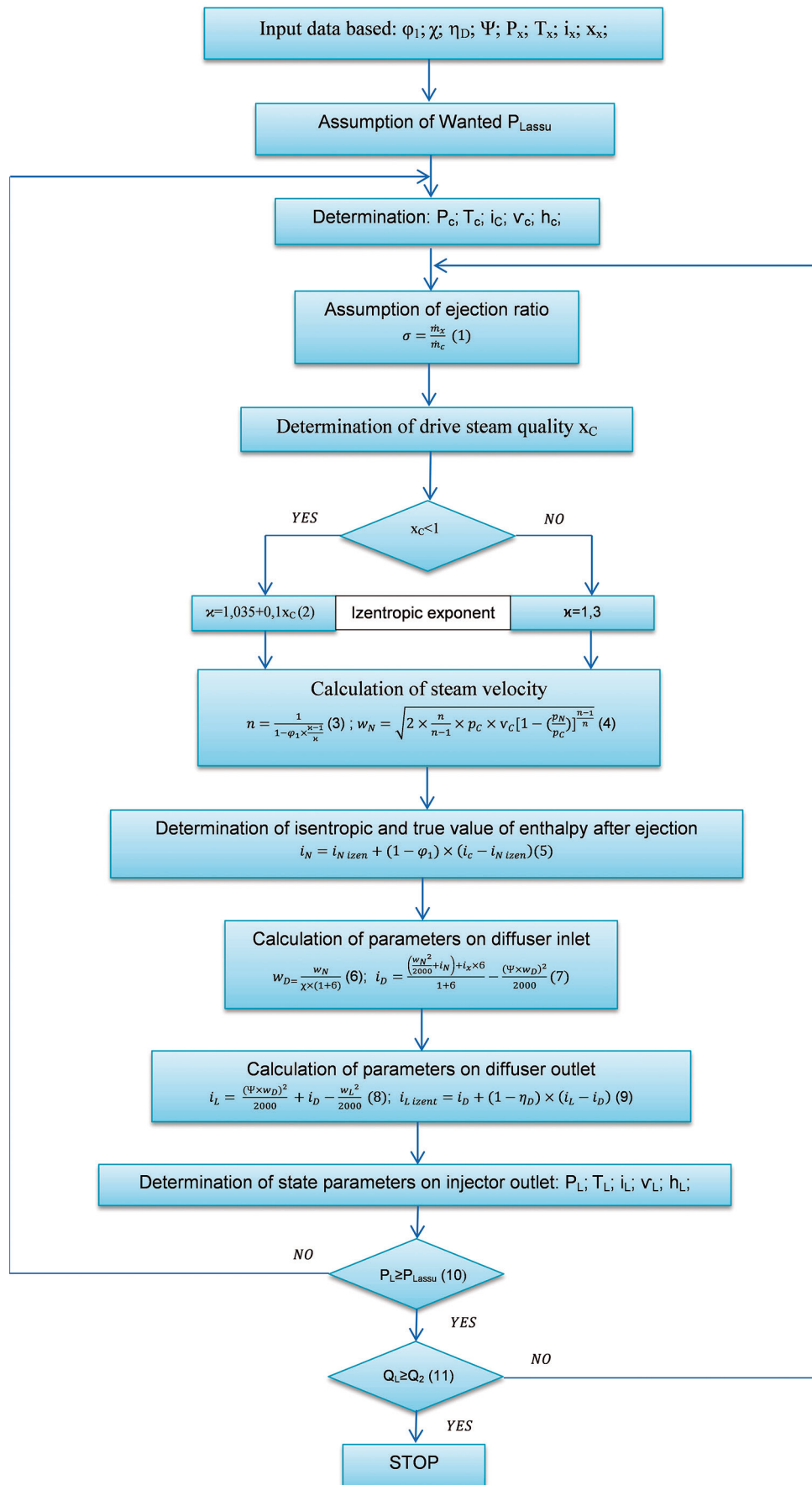


Figure 3. Regenerative injector calculation algorithm

Table 3. Calculation results for steam injectors at different drive steam pressures

HP Bleed 19.5 bar											
σ	[-]	Ejection Ratio – assumed	0.667	0.500	0.429	0.376	0.333	0.250	0.200	0.167	0.143
wd	[m/s]	Velocity of steam on diffusor inlet	883.2	981.3	1029.9	1069.8	1103.9	1177.5	1226.6	1261.6	1287.9
iD	[kJ/kg]	Enthalpy of steam on diffusor inlet	2521.4	2507.0	2496.9	2487.3	2478.0	2454.7	2436.8	2422.8	2411.7
iLizen	[kJ/kg]	Enthalpy of steam mixture after isentropic compression	2804.0	2856.3	2881.9	2902.8	2920.6	2958.5	2983.6	3001.4	30147
iL=	[kJ/kg]	Enthalpy of steam after diffusor	2835.4	2895.1	2924.7	2949.0	2969.8	3014.5	3044.4	3065.7	3081.7
tl	[°C]	Temperature of steam after diffusor	178.0	208.9	224.2	236.7	247.4	270.3	285.6	2966	3048
pl	[bar]	Pressure of steam after diffusor	0.368	0.525	0.633	0.745	0.86	1.19	1.5	1.835	2.025
Bleed 10 bar – determined from the expansion curve											
σ	[-]	Ejection Ratio – assumed	0.667	0.500	0.429	0.376	0.333	0.250	0.200	0.167	0.143
wd	[m/s]	Velocity of steam on diffusor inlet	797.3	885.9	929.8	965.7	996.6	1063.0	1107.3	1139.0	1162.7
iD	[kJ/kg]	Enthalpy of steam on diffusor inlet	2472.7	2460.1	2451.5	2443.2	2435.4	2415.8	2400.7	2389.0	2379.7
iLizen	[kJ/kg]	Enthalpy of steam mixture after isentropic compression	2702.7	2744.5	2764.9	2781.6	2795.8	2826.1	2846.1	2860,3	2870,8
iL=	[kJ/kg]	Enthalpy of steam after diffusor	2728.3	2776.1	2799.8	2819.2	2835.8	2871.7	2895.6	2912.6	2925.4
tl	[°C]	Temperature of steam after diffusor	122.7	147.905	160.3	170.5	179.3	198.1	210	219.7	226.4
pl	[bar]	Pressure of steam after diffusor	0.302	0.42	0.492	0.565	0.637	0.86	1.05	1.225	1.375
IP Bleed 6.6 bar											
σ	[-]	Ejection Ratio – assumed	0.667	0.500	0.429	0.376	0.333	0.250	0.200	0.167	0.143
wd	[m/s]	Velocity of steam on diffusor inlet	746.8	829.8	870.9	904.6	933.5	995.7	1037.2	1066.9	1089.1
iD	[kJ/kg]	Enthalpy of steam on diffusor inlet	2448.6	2437.2	2429.5	2422.1	2415.1	2397.7	2384.3	2373.9	2365.7
iLizen	[kJ/kg]	Enthalpy of steam mixture after isentropic compression	2650.2	2686.5	2704.3	2718.8	2731.1	2757.5	2774.9	2787.2	2796.4
iL=	[kJ/kg]	Enthalpy of steam after diffusor	2672.6	2714.2	2734.9	2751.8	2766.2	2797.4	2818.2	2833.1	2844.3
tl	[°C]	Temperature of steam after diffusor	93.4	115.4	126.3	135.3	142.9	159.5	170.5	178.4	184.3
pl	[bar]	Pressure of steam after diffusor	0.262	0.35	0.41	0.47	0.53	0.69	0.825	0.95	1.05
Feed pumps exhaust 3.1 bar											
σ	[-]	Ejection Ratio – assumed	0.667	0.500	0.429	0.376	0.333	0.250	0.200	0.167	0.143
wd	[m/s]	Velocity of steam on diffusor inlet	xxx	xxx	883.1	917.3	946.6	1009.7	1051.8	1081.8	1104.4
iD	[kJ/kg]	Enthalpy of steam on diffusor inlet	xxx	xxx	2569.0	2566.7	2564.0	2555.8	2548.5	2542.5	2537.5
iLizen	[kJ/kg]	Enthalpy of steam mixture after isentropic compression	xxx	xxx	2851.7	2871.8	2889.0	2925.8	2950.0	2967.5	2980.4
iL=	[kJ/kg]	Enthalpy of steam after diffusor	xxx	xxx	2883.1	2905.7	2925.1	2966.9	2994.8	3014.7	3029.6
tl	[°C]	Temperature of steam after diffusor	xxx	xxx	202.3	214.1	223.9	245.4	259.7	269.7	277.2
pl	[bar]	Pressure of steam after diffusor	xxx	xxx	0.333	0.371	0.41	0.51	0.598	0.67	0.732
Bleed 3 bar – determined based on expansion curve											
σ	[-]	Ejection Ratio – assumed	0.667	0.500	0.429	0.376	0.333	0.250	0.200	0.167	0.143
wd	[m/s]	Velocity of steam on diffusor inlet	xxx	xxx	762.3	791.8	817.1	871.5	907.9	933.8	953.2
iD	[kJ/kg]	Enthalpy of steam on diffusor inlet	xxx	xxx	2399.7	2394.1	2388.7	2375.4	2365.2	2357.2	2350.9
iLizen	[kJ/kg]	Enthalpy of steam mixture after isentropic compression	xxx	xxx	2609.8	2620.9	2630.4	2650.6	2664.0	2673.4	2680.5
iL=	[kJ/kg]	Enthalpy of steam after diffusor	xxx	xxx	2633.2	2646.2	2657.3	2681.2	2697.2	2708.6	2717.1
tl	[°C]	Temperature of steam after diffusor	xxx	xxx	73.3	80.2	86.2	99.0	107.6	113.7	118.3
pl	[bar]	Pressure of steam after diffusor	xxx	xxx	0.286	0.319	0.352	0.438	0.512	0.571	0.623

exhaust steam from the injectors to be used, depending on the degree of ejection, for both vacuum heat exchangers as well as for deaerator tanks. In addition,

the results obtained for the lower ejection levels at a supply pressure of 19.5 bar indicate the possibility of using the steam in overpressure exchangers.

The calculated results of the regenerative injector for intermediate steam bleed with an absolute pressure of 6.6 bar indicate that it is possible to use exhaust steam from the injector in the vacuum heat exchanger for the assumed ejection levels $\sigma = [0.142; 0.500]$.

Calculations for the steam supplying the steam injector with a pressure of 3.0 bar and the exhaust steam from the turbine feedwater pump at a pressure of 3.1 bar were carried out for the ejection ratio $\sigma = [0.142; 0.429]$. For higher ejection ratios, the exhaust steam pressure of the ejector was too low.

Due to the low values of the steam pressure after the injector, the calculation results of the injector fed with steam from the low-pressure bleed (LP Bleed – 1.5 bar) were omitted from further analysis.

Figure 4 shows the dependence of the steam pressure leaving the injector on the ejection degree used. The determined values are a set of possible parameters of injector exhaust steam for use in additional calculations of this proposed system (Figure 1).

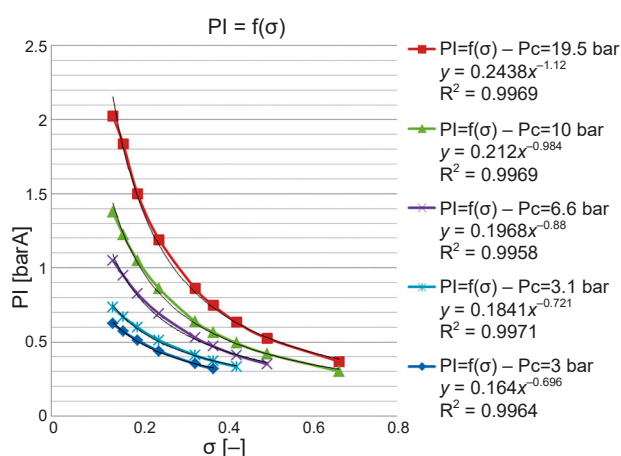


Figure 4. Correlation of injector steam exhaust pressure as a function of the ejection ratio

Conclusions

The obtained results indicate that increasing the ejection level (which positively impacts the degree of regeneration) decreases the pressure and enthalpy of the injector exhaust steam. On the other hand, this decrease will reduce the maximum achievable boiler feedwater temperature, which will result in a reduction in the regeneration degree of cycle.

Using steam with higher parameters to supply the injector (pressure and temperature of superheating) increased the steam pressure leaving the injector. This enabled feed water higher temperatures to be obtained and broadens the potential applications of the obtained steam. However, the use of high-parameter bleed steam from the turbine to drive injectors decreased the available enthalpy drop across the turbine stages and reduced the plant's efficiency.

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Selected issues of reliability and availability in marine vessel fire alarm systems

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Key words: reliability, safety, protection, availability, fire alarm system, human factor

Abstract

Today, every industry is striving for the highest efficiency and best economic results possible, with the greatest possible competitiveness. But in maritime affairs, human safety and environmental protection are the foundations of sustainability. To achieve this, marine systems must be reliable, high quality and easy to maintain. Because of this, reliability has become an important factor in safety, which remains relevant throughout the lifetimes of ship systems, including fire alarm systems. In this paper we address a number of issues connected with the reliability – and ‘availability’ of these systems. Firstly, ship fire alarm systems consist of various components whose individual reliability affect the system’s overall reliability. Discussions of reliability in ship fire alarm systems normally focus on the length of a system’s useful life or performance during design-based fire events. In addition to the reliability of systems, their availability for use is also crucial given the possibility that the system may need to operate at any point in time.

Introduction

The effectiveness of a marine vessel’s fire alarm system can greatly impact the safety of the lives on-board. It is important to know that the system is reliable, including that its components are functionally accurate. Ensuring the reliability of marine fire alarm systems throughout their useful lives requires quality processes in equipment manufacturing, system design, programming, on-board testing, registry testing, and maintenance.

The reliability of marine vessel fire alarm systems

Early detection of fires plays a crucial role in extinguishing them and preventing them from spreading. The development of fire alarm technology has been fueled by past fire incidents that resulted in major material losses and worse, human casualties. In recent decades, the development of fire alarm detectors, by integrating them with microelectronic

and information technologies, has achieved a high degree of system autonomy while increasing both reliability and availability.

We define reliability here as a function of time $R(t)$ yielding the probability that a device, such as a fire alarm system, will operate satisfactorily for a certain amount of time t , correctly without failure; that is, the reliability is determined by the total number of failures of the fire alarm system within an estimated time interval. According to the SFPE Fire Safety Manual, “reliability” is the ability of a product or system to operate under certain conditions for a specified period of time or series of cycles (Modarres & Joglar-Billoch, 2002).

The main measure of the reliability of any system, including fire alarms, is their availability $A(t)$, as defined by British Standard BS 4778: “the ability of an element or system to perform its required function at a specified current time or above a specified period of time” (BS 4778:Part 2, 2002).

In summary, fire alarm system reliability signifies time of useful life and performance during fire

events. Also, according to the manual, ensuring the reliability of fire alarm systems throughout their useful lives requires quality processes in the production of equipment and system design, proper installation, and adequate programming, testing, and maintenance.

Today's techniques for determining reliability can pre-determine the service life of a fire alarm system and its components. The mean time of failure can be calculated in the same way as the mean value of failure, which is important when maintaining the ship's fire alarm systems. In addition, a reliable fire alarm system must be able to signal any failure in a timely manner. Different types of fire alarm system failures include:

- complete or catastrophic component failures,
- failures due to their gradual degeneration,
- failures due to wear and tear on components during operation.

Each of these types of failures can be classified as either:

- primary or independent,
- secondary or dependent.

A diagram showing fault intensity across the life of a device is shown in Figure 1.

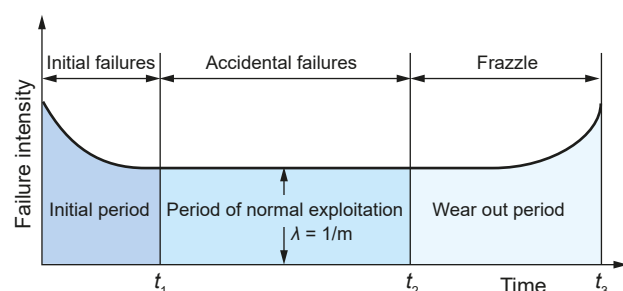


Figure 1. Fault intensity function

Figure 1 shows the failure rate during each of three fault phases:

- the first phase – initial period of operation (t_1),
- the second phase – period of regular exploitation of the system ($t_2 - t_1$),
- the third phase – weariness of the system and tears ($t_3 - t_2$).

In the first phase, during the testing of a system and its components, and its commissioning, failures occur more frequently, with a tendency to gradually settle down, as factory and assembly errors are eliminated. The second phase, the standard operating life of the system, is generally expected to witness the fewest failures. After a successful working life, the system and its components slowly lose their abilities to function properly and the system becomes unreliable, requiring replacement of worn out components.

In addition to on-board periodic testing of the fire alarm system, which is carried out at least once a year, the condition of the system is also periodically tested by the flag carrier's registration companies for the purpose of obtaining the system's and ship class's certificate of safety, in accordance with international standards and rules.

It is important to note that the port authorities of any state have the right to request the testing of a ship fire alarm system and, in case of malfunction, to prohibit the entry of a ship into its port of destination.

Counteracting the reliability of fire alarm systems are several factors, including failure due to software elements, failure due to human factors or operating documents, and failure due to weather conditions and other environmental factors. According to one of the three basic probability theorems, the sum of reliability $P(q)$ and unreliability $P(\bar{q})$ equals one:

$$P(q) + P(\bar{q}) = 1 \quad (1)$$

One of the most commonly used methods of increasing the reliability of ship fire alarm system is certainly the redundancy method, which has been strictly applied on passenger ships since 2010, in line with the SOLAS regulations for safe return to port (IMO, 2006; Bistović et al., 2014). The redundancy method is implemented with 'dual systems,' in which a functional component remains in operation, filling the role of a defective or deactivated component while the system is restored or repaired. I.e., system operation does not have to be interrupted for maintenance intervention on a failing component, making system reliability completely independent of its time operating, the "t," of the system. Suppose a short time "t" is required to replace a defective component. While the backup component works, the dual system can schedule to replace the defective component only if it fails during a short time (Lovrić, 1989). The probability that this happens $Q(t)$ is given by:

$$Q(t) = 1 - e^{-\lambda t} \quad (2)$$

If "t" becomes infinitesimal, that is, if replacement is made instantaneously, this expression becomes zero, which means that the system will never schedule replacement. While it is not realistic to assume that the time required for replacement will ever be zero, it can still be made relatively short. The reliability of such a dual system depends then on the chances that the other component will fail over the

time “ t ” from the failure of one component until the completion of its replacement or repair:

$$R(t) = e^{-\lambda t} \quad (3)$$

Thus, the reliability of the system becomes independent of its hours operating and depends only on the short time “ t ” required to replace or repair a component.

Using this probability theorem, the unreliability of fire alarm elements can be represented by the equation:

$$Q(t) = 1 - R(t) = 1 - e^{-\lambda t} \quad (4)$$

where:

Q – unreliability,

R – reliability,

λ – proportional failure rate,

t – time.

From this it can be concluded that, while the fire alarm system is new, its reliability is high and the probability of failure is low ($t \rightarrow 0, R = 1$), however, as the life expectancy of an on-board fire alarm system comes to an end ($t \rightarrow \infty, R = 0$), reliability decreases and unreliability increases while increasing the likelihood of a fire alarm system and its components.

Redundancy of passenger ship systems, including the fire alarm system (Figure 2), provides reliability, security, and the ability of the system to continue its deadlock avoidance function even when some components are subject to new regulations or failures (Bistrović et al., 2014).

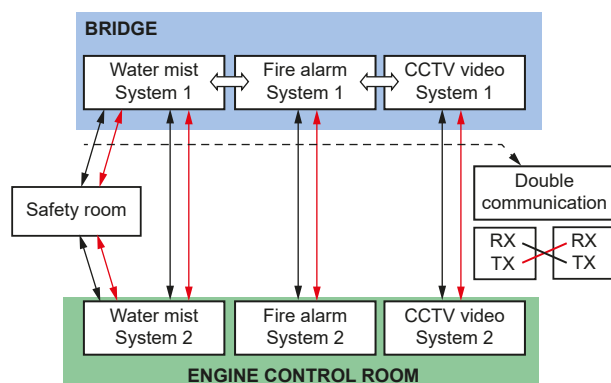


Figure 2. Display of high redundancy, according to SOLAS regulations, for safe return to the port

Figure 2 shows that passenger ships sailing since 2010 must have two fire alarm systems that communicate with each other via a dual communication line. If one of them fails, the system will still function normally, while giving an error message. Also,

if one fire alarm system fails, the other must continue to operate normally even if the system’s fault alarm does not function properly.

Availability of marine vessel fire alarm systems

Like reliability, availability is the likelihood that a component or system performs its required function at a predetermined point in time or beyond a specified period of time when, it is operated and maintained as intended.

To calculate availability $A(t)$, the expression below is used:

$$A(t) = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} e^{-(\lambda + \mu)t} = A_s + A_{tr}(t) \quad (5)$$

or:

$$A(t) = \frac{\mu}{\lambda + \mu} \quad (6)$$

where:

μ – intensity of repair,

λ – failure intensity.

Accordingly, the availability $A(t)$ of a fire alarm system can be determined by the expression:

$$A(t) = \frac{MTBF}{MTBF + MTTR} \quad (7)$$

where:

MTBF – mean time between failure;

MTTR – mean time to repair – that is, until the components are restored.

As a rule, there must be a reserve on-board holding at least one copy of each module of the central fire alarm system. A number of each detector type must also be in the reserve.

MTTR on a ship depends on three factors:

- type of fault,
- number of spare parts on-board,
- crew training in proper handling of the system.

The success of the fire alarm system requires the seamless functioning of many interconnected components. Figure 3 shows the fire detection and alarm fault tree, divided into six subsystems, and the following:

- a map of detector faults,
- a map of faults of alarm system components,
- a map of errors signaling subsystem communications,
- a map of faults of the auxiliary control subsystems,
- a map of power errors,
- a map of false alarms.

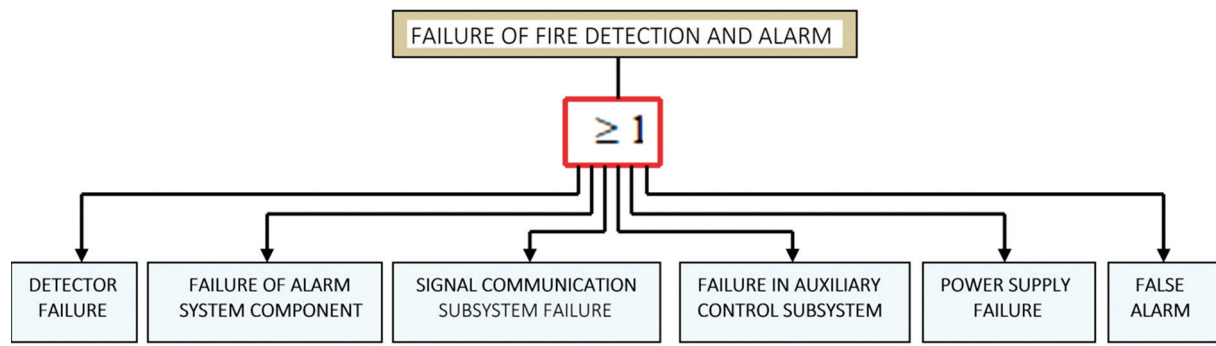


Figure 3. Map of fault detection and fire alarm divided into six subsystems

Each of the six subsystems can further be displayed with its own fault tree. When we know that λ is the fault index and X the number of failures, T the time interval to failure can then be estimated as the error rate of the fire alarm system:

$$\lambda = \frac{X}{T} \quad (8)$$

The availability of each system, including the fire alarm system, is the likelihood that the system works smoothly, performing functional tasks at any given moment. The basic factors that go into availability are the properties of the system itself, the environment in which it operates, and the quality of maintenance. The literature describes several types of availability, such as 'own availability,' 'reach availability,' and 'operational availability.'

In Figure 4 are shown the links between reliability, maintenance, and availability (Mihai et al., 2010).

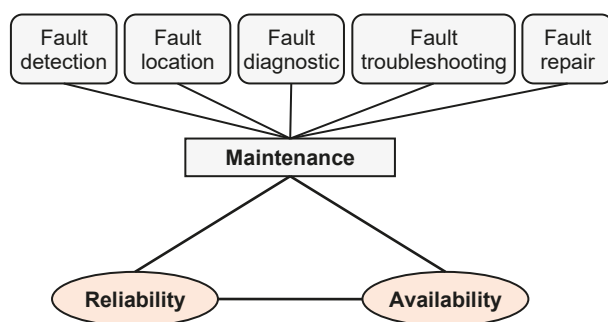


Figure 4. Connections between reliability, maintenance and availability

Figure 4, underlines the fact that the reliability of a system is characterized by a set of measures that give information on the performance of the system functionality over a period of time.

'Own availability' is an indicator of the readiness of the system itself, and speaks to its reliability.

The assumption of self-availability is the proper operation of the system until failure or shutdown and repair, when the conditions for repair obtain.

'Reach availability' includes downtime, in addition to repair and maintenance time, and is calculated using the equation:

$$A_0 = \frac{MTBM}{MTBM + \bar{M}} \quad (9)$$

where:

MTBM – mean time between maintenance,

$\bar{M}$ – average active maintenance time.

The average time between maintenance sessions is determined by the expression:

$$MTBM = \frac{1}{\lambda + f_p} \quad (10)$$

where

f_p – frequency of preventative maintenance.

The average active maintenance time is calculated as:

$$\bar{M} = \frac{\lambda \cdot MTTR + f_p \cdot MPT}{\lambda + f_p} \quad (11)$$

where

MPT – average preventative maintenance time.

Operational availability takes into account the total downtime due to required maintenance. It shows the availability of the system in a real work environment and is expressed as:

$$A_0 = \frac{MTBM}{MTBM + MDT} \quad (12)$$

where:

MDT – mean down time,

MTBM – mean time between maintenance.

It is usual to have the average downtime displayed and counted according to the expression:

$$MDT = M + T_C + T_L + T_A \quad (13)$$

where:

T_c – average waiting time for maintenance,

T_L – average logistic waiting time for maintenance resources,

T_A – average downtime for administrative reasons.

In order to calculate the total downtime due to system maintenance, it is necessary to take into account the total time, from the observation of a malfunction or system shutdown for preventive maintenance, until restoration of the system.

The problem of false alarms for the reliability of marine vessel fire alarm systems

False alarms from a ship's fire alarm system are defined as the activation of the detector when there is no indication of smoke or fire. We know that smoke detectors respond to the presence of smoke particles in the air, temperature detectors to ambient heat, and flame detectors to light. In order to reduce the number or percentage of false alarms and therefore increase the reliability, it is necessary to pay attention to the placement of detectors in a specific ship space. Common causes of false smoke alarms include ship ventilation, through which certain quantities of dust particles sufficient to cause false alarms gather in the smoke detector chambers. Therefore, it is necessary to avoid proximity to ventilators during installation.

Table 1. Sources of false alarms related to detection methodology

Smoke detector	Dust
	Exhaust gases of main engine, auxiliary engines
	Oils or grease on a hot surface
	Aerated water
	Cigarette smoke
	Accidental damage
Heat detector	Detector error
	Hot surfaces and high ambient temperatures such as in the accommodation spaces of fuel units, separator and incinerator spaces, and near boilers, main and auxiliary engine exhaust pipes, heated fuel tanks, etc.
	Detector error
	Flash Arc Welding
	Autogenous cutting flame
	Cigarette ash
Flame detector	Lighters
	Boat lighting flash
	Accidental damage
	Detector error
	Inappropriate human action (e.g., activation of manual malicious call points)
	Accidental damage
Manual detector	Detector error

Also, temperature detectors should not be placed near heat-emitting objects. In terms of flame detectors, today's technology has produced smart detectors that recognize false flames from real by covering the full range of colors visible to the human eye. Table 1 provides a list of possible sources of false alarms for different types of detectors.

It is important that ship fire detection systems are not sensitive to false alarm sources since reoccurring false alarms become a nuisance and suppression systems may be unnecessarily activated.

Human factors in reliability

Early detection of fires plays a crucial role in extinguishing them and preventing them from spreading. History is full of cases where the human factor has caused fires on ships. Human causes are known to account for 80% of maritime accidents (O'Neil, 2003). The relative causal factors of maritime accidents are shown in Figure 5, according to the UK Maritime Accident Research Unit (MAIB, 2003; Baker, McSweeney & McCafferty, 2002).

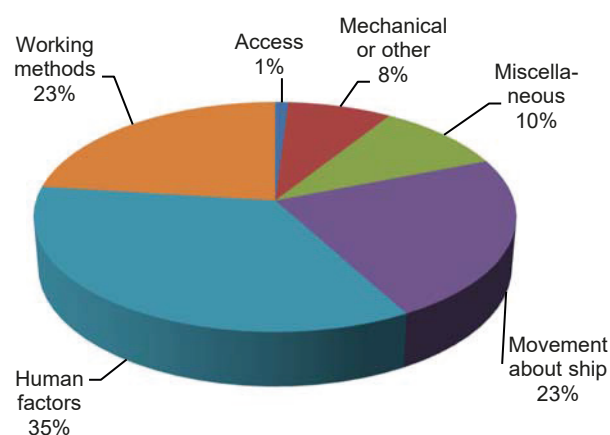


Figure 5. Causal factors of maritime accidents

Research has shown (Rothblum, 2000) that human error contributes to 84–88% of tanker accidents, 89–96% of ship crashes, and 75% of fires and explosions.

Any person involved in the chain, from designing, constructing, and navigating a ship or its components, to maintaining a ship fire alarm system can contribute to causing a fire on board. This applies in particular to poorly constructed fire alarm systems, inadequate maintenance, and poor training on the proper use of the system. The intensification of maritime trade over the past ten years has increased the potential for human error that could risk the safety of a ship.

Today, research into human factors as major causes of ship-related accidents, including fires and explosions, includes:

- identifying system hazards;
- estimating the frequency of each type of accident;
- estimating the consequences of an accident;
- calculating risk measures, such as the frequency of accidents of a particular type.

Human factors also include operational errors resulting from (Caridis, 1999):

- human physical, mental, and personal conditions,
- situational errors due to the design of the work environment,
- management problems,
- human-machine interface problems.

Application of multicriteria technology in fire detection reliability

The application of multicriteria fire detection technology began with the introduction of addressable analogy detectors. With the advancement of electronics and microprocessors within fire alarm systems, the first intelligent detectors were monitored and controlled by central units. The further development of microprocessors and electronics has enabled the creation of intelligent detectors, where data processing can be performed in the detector itself, independent of the central control unit.

It should be noted that much of the research on multicriteria fire detection technology has focused on the development of algorithms that use fuzzy logic and neural networks to classify events from fires to interference sources.

The idea of advanced phase logic (fuzzy logic) was first described by Professor Lotfi Zadeh of Berkeley University, California in 1960. Today, fuzzy logic has emerged as a profitable tool for managing and controlling various systems and applications. In the fire alarm system, the algorithms for light intensity, smoke density, humidity, and temperature, act as the phases of the input variable, on the basis of which the probability of fire occurrence is output.

Due to the possible errors and inaccuracies of fire detectors, many manufacturers of fire alarm systems use the logic of reviewing the detector signal three or more times; only after confirmation, the signal is allowed to continue. Fire detection can be based on the variables of smoke dimming (smoke density), smoke dimming rate, temperature, temperature change rate, and / or flame color. Most often, three values are assigned to these variables for detection – low, medium, and high. The higher the values of the

variables, the more accurate the detection. Table 2 shows the ten phases of fire detection rules (Maksimović et al., 2014; Bistrović et al., 2014).

Table 2. Ten phase rules for detection of fire problems

Rule	Temp	Smoke	Light	Humidity	Distance	Output
1	L	L	L	H	Far	VL
2	L	L	L	H	Avg	VL
3	L	L	L	H	Close	VL
4	L	L	L	M	Far	VL
5	L	L	L	M	Avg	VL
6	L	L	L	M	Close	L
7	L	L	L	L	Far	VL
8	L	L	L	L	Avg	L
9	L	L	L	L	Close	L
10	L	L	M	H	Far	VL

In a fire detecting system, five input measures that can be taken are Temperature, Smoke, Light, Humidity, and Distance. Membership function for output is the probability of fire, having two variables: Very Low (VL), Low (L). For distance, we have three variables: Close, Average, Far. The other inputs include the variables: Low (L), Medium (M), High (H). These fuzzy inputs are then fed into inference, in which the fuzzy rule base manages inference to yield a fuzzy output (Kaur, Sethi & Kaur, 2014).

Conclusions

Fire alarm systems are composed of components. It is clear that the reliability of these components affects the reliability of the fire alarm system. Ensuring the reliability of a fire alarm system during its working life on-board a ship requires quality production processes for the system and its components from the beginning of production. It is unreasonable to expect as much as 100% system reliability during operation, because it is generally difficult to predict the frequency and types of possible failures. Knowing that the human factor sometimes reduces the reliability of systems due to inadequate maintenance, disinterest, and misbehavior, it is necessary to continually conduct training with an emphasis on the seriousness of proper handling and maintenance of the systems. It should also be emphasized that the reliability of the system is not complete without reliability of the power systems, both primary and secondary.

In the end, the impact of wear and tear on the reliability and availability of the system and its components over time cannot and should not be neglected.

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An analysis of vertical shear forces and bending moments during nodule loading for a standard bulk carrier in the Clarion-Clipperton Zone

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Key words: shear force, polymetallic nodules, ship, loading, bulk carrier, waves

Abstract

This article presents an analysis of vertical shear forces and bending moments during nodule loading in the case of a standard bulk carrier around the Clarion–Clipperton Zone. An operational efficiency index was applied to an assessment of internal forces during loading which took into account wave heights and periods around this zone. The aim of this research was to investigate whether waves could have a negative effect on loading efficiency and to estimate the nodule mass that can safely be loaded onto a standard bulk carrier taking these waves into account. Moreover, a calculation was made to discover the acceptable vertical shear force percentage limit, while also taking into account wave activity during loading.

Introduction

The search for raw materials and their extraction from small and medium seabed depths has taken place for several decades. Since the 1970s, research has also been carried out on the possibility of extracting polymetallic nodules located on the seabed at depths of 4000–6000 m (Abramowski & Szelangiewicz, 2011). Currently, Poland has the right to explore seabed deposits containing polymetallic nodules in the Clarion-Clipperton zone. The Clarion-Clipperton zone is a geological submarine fracture zone of the Pacific Ocean spanning an area of 5000 km at depths of 4000 to 5500 meters. The seabed of the Clarion-Clipperton zone is rich in concrete nodules, which are very attractive sources of rare metals. Various mining systems have been designed to collect the polymetallic nodules in this zone. Abramowski and Szelangiewicz (Abramowski & Szelangiewicz, 2011) argued that these systems should perform the following functions:

- 1) collect nodules from the seabed,
- 2) mine them from the ocean surface (per mining unit),
- 3) perform preliminary cleaning,
- 4) periodically store nodules in the mining unit hold,
- 5) load nodules into bulk carrier holds on the ocean surface.

Current publications have only focused on nodule extraction methods, efficiency of the mining system, and organization of mining equipment work. There is only a relatively small amount of research addressing the problem of polymetallic nodule loading onto vessels at sea.

Research focusing on methods of nodule transfer ('transshipment') at sea, from mining vessels to transport vessels, was contracted by the American government in 1977 (Dames and Moore and EIC Corporation, 1977). A key finding of this research was that polymetallic nodules can be loaded in solid, semi-solid, and dry form. The following reloading systems can be used to transport nodules in these states:

- hydraulic transport systems,
- belt conveyor systems,
- pneumatic conveyor systems.

According to (US NOAA, 1981, pp. 232–235), polymetallic nodules crushed at the extraction stage can be transhipped in a water/nodule suspension. However, in this case, larger pieces of nodules would need to be reloaded onto the destination vessel by means of conveyor belts. The second method is crushing and grinding nodules on the mining ship and then pumping that material onto the transport ship. Another method is to crush, grind, and dry polymetallic nodules on the mining ship and reload this mass on the transport ship using a pneumatic transport system. Research presented in (US NOAA, 1982, p. 41) shows that hydraulic transport systems are the most forward-looking for nodule transport. These studies focused only on the problems of reloading systems. However, the problem of selecting a suitable transport ship-type has not been addressed.

Wakefield and Myers (Wakefield & Myers, 2018) propose a barge as transport unit, which would be towed to the nearest processing station. Deepak et al. (Deepak et al., 2001) propose crushing the nodules at the extraction stage to a thickness of 30 mm (or less) and then transporting them to the barge or bulk carrier by means of pumps. Brockett et al. (Brockett, Huizingh & McFarlane, 2008) propose moving the nodules in a dense suspension to the transport ship using pumps and flexible pipes. It was assumed in this research that nodules in a suspension would be loaded into ship tanks rather than holds. Brockett et al. (Brockett, Huizingh & McFarlane, 2008) also propose transporting concretions from mining vessels to transport vessels using flexible pipes floating on the sea surface. Additionally, recent research conducted by Blue Nodules consortium worked on the assumption that nodules will be de-watered and moved to the transport vessel using pumps and flexible pipes. It has been suggested that de-watering nodules would happen on the mining vessel – but this would take too much space. To solve this problem, the consortium is working on a more effective, mechanical drying method that would also take up much less space on the mining vessel (Lennartz, 2019). During reloading operations, the mining of the nodules by the mining vessel will have to be stopped if using this solution. The possibilities for simultaneous transhipment and mining operations in given environmental conditions still constitute the subject of this research. Meanwhile Vercruijssse and Kovács (Vercruijssse & Kovács, 2018) argues that

research has to be carried out using hydrodynamic calculations and model tests.

The Royal IHC Consortium which conducts research on the transhipment of nodules in a wet state, has a different approach. Knight (Knight, 2017) proposes that before transhipment, the concretion will have to be cleared of sediment on the mining vessel and then transhipped in a wet state to a bulk carrier equipped (additionally) with a drainage system.

Taking into account the above solutions, the following types of ship could be used for polymetallic nodule transport:

- a tanker adapted to transport nodules in a wet state in cargo tanks,
- a bulk carrier adapted to transport nodules in a wet state in a hold equipped with a bilge-drainage system,
- a standard bulk carrier for transporting nodules in a dry state.

Either one type of ship alone or several types simultaneously could be used for nodule transport. In any case, the equipment of a mining vessel would have to be optimized with regard to the types of transport ships used. Using multiple types of transport vessels simultaneously would offer the following advantages:

- a portion of the nodules could be transported in a dry state using a standard bulk carrier,
- the remaining nodules, in a wet state, could be transported using an adapted tanker or bulk carrier.

This study presents an analysis for using a standard bulk carrier to transport nodules in a dry state. The study was performed on a **B-517 series** bulk carrier with the following characteristics:

- length between perpendiculars: LBP = 185 m,
- breadth moulded: $B = 24.4$ m,
- design draught: $T = 11$ m,

The B-517 series bulk carriers, characterised by 32,000 DWT, were designed and built in the 1980s at the Szczecin Shipyard and used to transport coal, ore, phosphorites, and grain cargo. Figure 1 shows the section lines of the B-517 series ship.

Polymetallic nodules are characterized by high density, from 2 to 3 t/m³. While loading a ship with such substantial cargo, large vertical shear forces and bending moments can occur.

Standard bulk carriers carrying heavy cargo are designed with the assumption that loading takes place in port. Typical loading/unloading sequences are developed to ensure safe loading in port. Guidelines have yet to be created to develop a sequence for heavy cargo loading at sea.

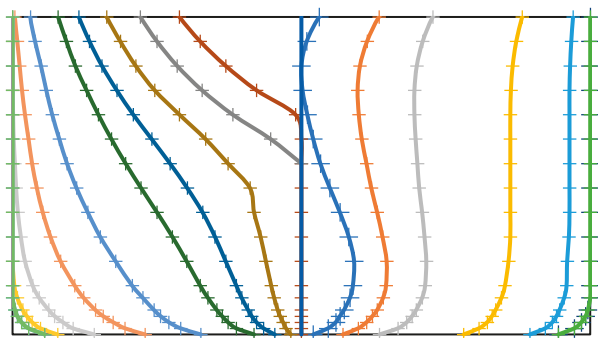


Figure 1. Bulk carrier B517 Body Lines Plan

During ship loading operations at sea, high waves may occur increasing internal forces on the vessel to their limits. The aim of this research was to analyse these internal forces during nodule loading operations and investigate whether these waves could have negative effect on loading efficiency. An additional aim was to estimate the nodule mass that can be safely loaded onto a standard bulk carrier taking waves around the Clarion-Clipperton Zone over a one year period.

Research method

An operational effectiveness index was applied to assess vertical shear forces and bending moments at loading. This index enables quantitative assessment of the sea-keeping performance of a given ship for a particular operation. The index was introduced by Karppinen (Karppinen, 1987) to estimate how long various ship operations would take under given wave conditions. Szelangiewicz (Szelangiewicz, 2000) applied this index to estimate the design characteristics required for a ship. Cepowski, (Cepowski, 2007) applied this index to the assessment of sea-keeping performance for a ballast-loaded bulk carrier.

In this study, the operational effectiveness index E_T expresses the probability P of an event where the internal forces of a ship do not exceed a certain limited level under given wave parameters, such as significant wave height H_S and characteristic period T . This E_T index is calculated as follows (Szelangiewicz, 2000):

$$E_T = \sum_{H_S, T} P(G = 1) \quad (1)$$

where:

E_T – operational effectiveness index,

H_S – significant wave height,

T – characteristic wave period,

P – probability that ship internal forces do not exceed limited level,

G – a bivalent function that has only two values for given wave conditions:

- “0” when ship internal forces exceed the acceptable level or
- “1” when ship internal forces do not exceed the acceptable level.

The index E_T is the sum of the probabilities of wave conditions for which ship internal forces will not exceed the acceptable level. Hence, the index E_T takes values between 0 and 1. Higher index values mean the ship has better sea-keeping properties. The following procedure was used to calculate E_T :

- 1) collecting statistical data on wave occurrence probability for a given area and time period,
- 2) calculating vertical shear forces and bending moments during ship loading for given wave conditions,
- 3) comparing the shear force and bending moment values with their assigned limits,
- 4) calculating the G function values,
- 5) calculating E_T as the sum of the H_S and T probabilities for which $G = 1$, using formula (1).

Statistical data

In this study the wave parameters around the Clarion-Clipperton Zone for one year were taken as givens. Table 1 shows wave distributions around this zone throughout the year based on 1,000,000 waves. On the basis of this distribution, the probability of wave height and period occurrence was calculated by dividing the number of waves occurring under given weather conditions by the total number of all observed waves. The results are presented in Table 2. Calculations have shown that the probability of waves over 8 m high is close to zero, so these conditions were not included in this study.

Numerical method

Cross-sectional loading can be calculated using the following general methods (Phelps, 1997):

- for still-water loading – when a ship is floating at rest in still water – the total net forces and moments on the ship should be zero for equilibrium;
- the static-balance or quasi-static method, in which the ship is momentarily balanced upon a design wave, so that net forces and moments on the ship are zero. This method provides a yardstick by which to assess the adequacy of existing or proposed designs, but does not provide a realistic assessment of loads imposed on a ship by particular seaways;

Table 1. Distribution of significant wave height (H_S) and characteristic period (T) in the Clarion-Clipperton Zone (Nimmo, 2012)

H_S [m]	T [s]										
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13
> 14							1	1	2	2	1
13 to 14							1	1	1	1	1
12 to 13						1	2	2	2	2	1
11 to 12						1	3	4	4	3	2
10 to 11					1	3	6	8	7	5	3
9 to 10					2	7	13	15	13	8	5
8 to 9				1	7	21	36	39	30	18	9
7 to 8				6	35	94	140	137	97	54	25
6 to 7			3	44	220	503	659	571	363	182	76
5 to 6			29	342	1405	2721	3060	2307	1290	576	216
4 to 5		6	270	2482	8126	12851	12036	7684	3690	1432	473
3 to 4		77	2248	14994	36987	45414	33875	17593	7002	2289	646
2 to 3	5	811	14312	62200	105325	92690	51355	20410	6381	1675	387
1 to 2	89	5696	47330	109935	109092	60473	22327	6190	1399	273	48
0 to 1	475	6365	19086	18471	8166	2131	391	57	7	1	

Table 2. The significant wave height (H_S) and characteristic period (T) occurrence probabilities for one year in the Clarion-Clipperton Zone

H_S [m]	T [s]										
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13
7 to 8				0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
6 to 7			0.0000	0.0000	0.0002	0.0005	0.0007	0.0006	0.0004	0.0002	0.0001
5 to 6			0.0000	0.0003	0.0014	0.0027	0.0031	0.0023	0.0013	0.0006	0.0002
4 to 5		0.0000	0.0003	0.0025	0.0081	0.0129	0.0120	0.0077	0.0037	0.0014	0.0005
3 to 4		0.0001	0.0022	0.0150	0.0370	0.0455	0.0339	0.0176	0.0070	0.0023	0.0006
2 to 3	0.0000	0.0008	0.0143	0.0623	0.1054	0.0928	0.0514	0.0204	0.0064	0.0017	0.0004
1 to 2	0.0001	0.0057	0.0474	0.1100	0.1092	0.0605	0.0223	0.0062	0.0014	0.0003	0.0000
0 to 1	0.0005	0.0064	0.0191	0.0185	0.0082	0.0021	0.0004	0.0001	0.0000	0.0000	

- the linear strip theory method, based on two-dimensional potential flow theory, where the solution is simulated only for the domain of wave frequency;
- a non-linear method based on three-dimensional potential flow theory, where the solution is most often simulated for the time domain.

Of the above methods only the linear strip theory and non-linear methods take into account wave impacts. The linear strip method is less accurate than the nonlinear method, but much simpler to apply. Non-linear methods are more accurate, but more complex and difficult to use. These methods require model test verification.

Jensen and Petersen (1981) noted that the effects of wave nonlinearity induced bending moments and shearing forces for a sailing VLCC carrier were small under moderate conditions at sea. For vessels with high block coefficient value, such as bulk

carriers and tankers, linear models are sufficiently accurate and effective. This study was conducted for bulk carriers characterised by high block coefficient values. Therefore, the linear strip method was used in this study to calculate internal forces on ships from waves.

A solution under the strip method comprises a set of vertical shear forces and bending moment transfer functions. Statistics for internal forces can then be calculated on the basis of these transfer functions and the wave energy spectrum. The energy spectrum for sailing ship motions in irregular waves is calculated by multiplying squared motion transfer functions and wave energy spectra. A common ITTC spectrum (ITTC, 1978) based on the Bretschneider wave energy spectrum, was used here.

Vertical shear forces and bending moment values in still water were calculated using the author's own software. Whereas internal force values for waves

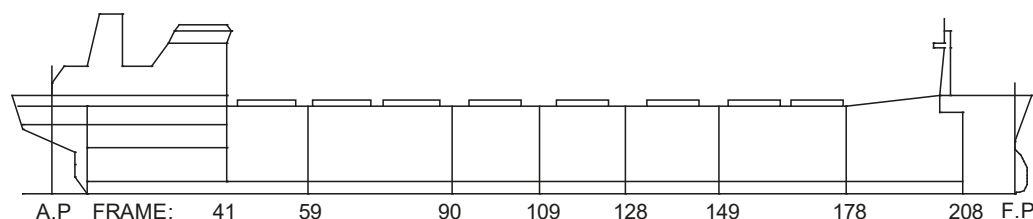


Figure 2. Bulk carrier section number map

were calculated using SEAWAY software. SEAWAY is a frequency-domain ship-motion computer program, based on linear strip theory, to calculate wave-induced loads, motions, added resistances, and internal loads for six degrees of freedom of displacement among ships sailing over regular and irregular waves (Journée, 2001).

Limit values

In this study, the values of shear forces and bending moments were compared with their permissible values in order to calculate the E_T index. The seagoing limit-values presented in the loading manual (Szczecin Shipyard, 1986) were used as acceptable values of vertical shear force (SF) and bending moment (BM). Table 3 presents these limit-values. Figure 2 shows forces per bulk carrier section, by section number.

Table 3. Acceptable values of vertical shear force (SF) and bending moment (BM) (Szczecin Shipyard, 1986)

	Section							
	41	59	90	109	128	149	178	208
SF [kN]	28822	32530	36434	38337	38210	31784	43929	55004
BM	934795 kNm							

Results and discussion

Initially, we checked typical loading sequences from the loading manual for ship B-517. Shear forces and bending moments were compared with acceptable values for still water. It was noted that shear forces exceeded the limit values during loading in still water during the third loading stage according to a typical loading sequence. Therefore, a new loading sequence was developed in which internal forces would not exceed the limit values under seagoing conditions. This new loading sequence consisted of nine loading stages.

Internal force results during the loading simulation for calm water showed that shear forces rather than bending moments are limiting loading process.

Therefore, only shear forces have been taken into account in further analysis. In particular, the highest shear forces value was 34,600 kN at stage 7 in section 90 (Figure 2). Next, we analysed sectional forces at stage 7, section 90, taking into account shear force and the influence of waves. Figure 3 shows the wave direction coordinate system used in this study.

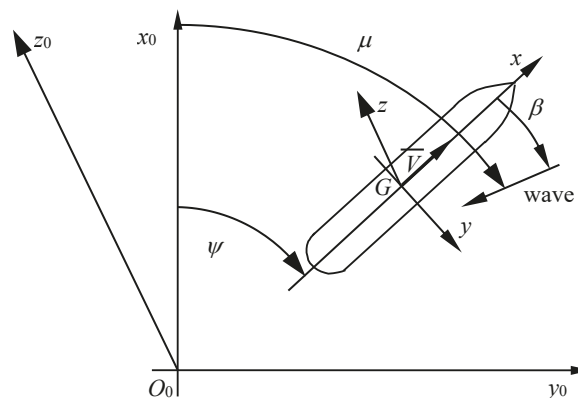


Figure 3. Coordinate system Rigid body, O_0, x_0, y_0, z_0 – global, G, x, y, z – local of the ship

Figure 4 shows the influence of wave angle on shear forces at stage 7, section 90, assuming constant significant wave height ($H_s = 1$ m) and peak wave period ($T = 7$ s). This figure confirmed that the maximum forces occur at a 180 degree wave angle.

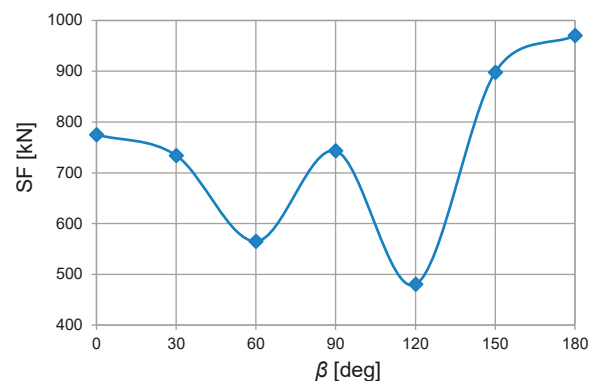


Figure 4. The influence of wave angle on shear forces at stage 7, section 90, significant wave height $H_s = 1$ m, characteristic wave period $T = 7$ s

Table 4. Shear forces on irregular waves at stage 7, section 90, wave angle $\beta = 180^\circ$

H_s [m]	T [s]										
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13
7 to 8	3200	4400	6400	7600	7680	7600	7360	6560	6000	5440	4800
6 to 7	2800	3850	5600	6650	6720	6650	6440	5740	5250	4760	4200
5 to 6	2400	3300	4800	5700	5760	5700	5520	4920	4500	4080	3600
4 to 5	2000	2750	4000	4750	4800	4750	4600	4100	3750	3400	3000
3 to 4	1600	2200	3200	3800	3840	3800	3680	3280	3000	2720	2400
2 to 3	1200	1650	2400	2850	2880	2850	2760	2460	2250	2040	1800
1 to 2	800	1100	1600	1900	1920	1900	1840	1640	1500	1360	1200
0 to 1	400	550	800	950	960	950	920	820	750	680	600

Table 5. Total shear forces in steel water and irregular waves at stage 7, section 90, wave angle $\beta = 180^\circ$

H_s [m]	T [s]										
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13
7 to 8	37800	39000	41000	42200	42280	42200	41960	41160	40600	40040	39400
6 to 7	37400	38450	40200	41250	41320	41250	41040	40340	39850	39360	38800
5 to 6	37000	37900	39400	40300	40360	40300	40120	39520	39100	38680	38200
4 to 5	36600	37350	38600	39350	39400	39350	39200	38700	38350	38000	37600
3 to 4	36200	36800	37800	38400	38440	38400	38280	37880	37600	37320	37000
2 to 3	35800	36250	37000	37450	37480	37450	37360	37060	36850	36640	36400
1 to 2	35400	35700	36200	36500	36520	36500	36440	36240	36100	35960	35800
0 to 1	35000	35150	35400	35550	35560	35550	35520	35420	35350	35280	35200

The E_T index value for this loading stage was calculated as follows; Firstly, the shear force values for irregular waves at stage 7, on section 90, were calculated for all waves presented in Table 2 using SEAWAY software. Table 4 shows the results of these calculations. Then, these shear forces were increased by the value of shear force in calm water, 34,600 kN. Table 5 shows total shear forces calculated for still water and for irregular waves.

Next, the shear force values from Table 5 were compared with the limit-value from Table 3. In cases when the shear force value did not exceed the limit-value, the value of $G = 1$ was assumed. Otherwise, $G = 0$ was assumed. Shear force values within the

allowable range are shown in bold in Table 4. Table 6 shows the G function values.

Table 6 presents dangerous wave-activity ranges in detail, taking into account shear forces at stage 7. This table shows that loading can be safely carried out in waves up to:

- 1 metre in height and for any wave period,
- 2 metres in height for a wave period of less than 6 s and greater than 10 s.

To calculate the E_T operational effectiveness index according to equation (1), the probabilities p' for which $G = 1$ need to be calculated. The probabilities p' were calculated as follows:

$$p'(H_s, T) = p(H_s, T) \cdot G(H_s, T) \quad (2)$$

Table 6. Values of the function G calculated by the use of shear forces at stage 7, section 90

H_s [m]	T [s]										
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13
7 to 8	0	0	0	0	0	0	0	0	0	0	0
6 to 7	0	0	0	0	0	0	0	0	0	0	0
5 to 6	0	0	0	0	0	0	0	0	0	0	0
4 to 5	0	0	0	0	0	0	0	0	0	0	0
3 to 4	1	0	0	0	0	0	0	0	0	0	0
2 to 3	1	1	0	0	0	0	0	0	0	0	1
1 to 2	1	1	1	0	0	0	0	1	1	1	1
0 to 1	1	1	1	1	1	1	1	1	1	1	1

Table 7. Probability values p' for which $G = 1$, sum of p' values equals 0.117

H_s [m]	T [s]										
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13
7 to 8	0	0	0	0	0	0	0	0	0	0	0
6 to 7	0	0	0	0	0	0	0	0	0	0	0
5 to 6	0	0	0	0	0	0	0	0	0	0	0
4 to 5	0	0	0	0	0	0	0	0	0	0	0
3 to 4	0	0	0	0	0	0	0	0	0	0	0
2 to 3	0	0.0008	0	0	0	0	0	0	0	0	0.0004
1 to 2	0.0001	0.0057	0.0474	0	0	0	0	0.0062	0.0014	0.0003	0
0 to 1	0.0005	0.0064	0.0191	0.0185	0.0082	0.0021	0.0004	0.0001	0	0	0

where:

p' – probability for which $G = 1$,

p – wave occurrence probability values from Table 2,

G – G function values from Table 6.

Table 7 shows probability values p' .

Finally, the E_T index value was calculated as the sum of probability values p' given in Table 7:

$$E_T = \sum_{H_s, T} p' = 0.117 \quad (3)$$

The E_T index value can be interpreted as the percentage of the time during which a ship can be safely loaded due to internal forces. In this way, the number of hours during a year when the ship can be safely loaded could be estimated, as follows:

$$h = 0.117 \cdot 365 \cdot 24 = 1025 \quad (4)$$

where:

h – hour number.

Assuming that approximately 3000 tons of cargo can be loaded within 1 hour, the maximum mass of polymetallic nodules loaded in one year is around:

$$Q = h \cdot 3000 = 3\,074\,760 \text{ t} \quad (5)$$

where:

Q – mass of polymetallic nodules loaded in one year.

It follows that this type of bulk carrier can safely load about 3 million tons of polymetallic nodules in the Clarion-Clipperton Zone in one year.

Table 4 shows shear force values here for irregular waves. On the basis of these values, the percentage limit of the acceptable vertical shear force for these waves can be calculated as follows:

$$\%SF_{w\text{limit}} = 100 \frac{SF_{\text{limit}} - SF_w}{SF_{\text{limit}}} \quad (6)$$

where:

$\%SF_{w\text{limit}}$ – the percentage limit of the acceptable vertical shear force for waves,

SF_{limit} – acceptable vertical shear force taken from Table 3,

SF_w – shear force for irregular waves taken from Table 4.

Table 8 shows values calculated using Equation (6). Column “MIN”, last in this table, showing the most limiting values for a given wave height range.

On the basis of Table 8, the range of permissible shear forces can be limited by assuming the wave-activity parameters for the loading period. For example, acceptable shear force can be reduced to 92% when the ship is loaded on a wave of up to 3 metres in height.

Table 8. Percentage limit of acceptable vertical shear force for calm water and irregular waves

H_s [m]	T [s]											MIN
	< 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	> 13	
7 to 8	91%	88%	82%	79%	79%	79%	80%	82%	84%	85%	87%	79%
6 to 7	92%	89%	85%	82%	82%	82%	82%	84%	86%	87%	88%	82%
5 to 6	93%	91%	87%	84%	84%	84%	85%	86%	88%	89%	90%	84%
4 to 5	95%	92%	89%	87%	87%	87%	87%	89%	90%	91%	92%	87%
3 to 4	96%	94%	91%	90%	89%	90%	90%	91%	92%	93%	93%	89%
2 to 3	97%	95%	93%	92%	92%	92%	92%	93%	94%	94%	95%	92%
1 to 2	98%	97%	96%	95%	95%	95%	95%	95%	96%	96%	97%	95%
0 to 1	99%	98%	98%	97%	97%	97%	97%	98%	98%	98%	98%	97%

Conclusions

In this research, internal forces during nodule loading onto a standard bulk carrier at sea were analysed. This study has shown that standard loading sequences available in the loading manual cannot be used for loading polymetallic nodules at sea. Therefore, a new alternative sequence has been developed, taking into account wave conditions at sea, as well as shear forces and bending moments. Studies have also shown that shear forces rather than bending moments are limiting the loading process.

This study clearly shows that a B-517 bulk carrier can be safely loaded while enduring internal forces caused by waves of up to:

- 1 metre in height for any wave period,
- 2 metres in height for a wave period of less than 6 s and greater than 10 s.

This study also shows that:

- a B-517 bulk carrier can be safely loaded while enduring internal forces for 1025 hours,
- while loading a maximum of 3 million tons of polymetallic nodules, within one year in the Clarion-Clipperton Zone.

To increase this range, the range of permissible shear forces can be limited using the values shown in Table 3. This study shows that, to safely load a B-517 bulk carrier on a wave of up to 3 m in height, the acceptable shear force should be reduced to 92%.

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Laboratory tests of a car seat suspension system equipped with an electrically controlled damper

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Abstract

The paper presents the results of laboratory simulation tests of a suspension system for a car seat. The first part of the paper contains a description of the experiment, paying particular attention to the conditions in which the tests were conducted and the properties of the electrically controlled damper, which was mounted in the tested car seat's suspension. Graphs of the damper's operation were determined for different values of current intensity and the signal controlling the damper's damping ratio and then the damping characteristics were determined on this basis. Simulated tests of the car seat's suspension were carried out on a car component test station. During the tests, the values measured were the acceleration recorded at selected points on the dummy, which was placed on a seat equipped with suspension using a magnetorheological (MR) damper during the experiment. The second part of the paper presents an analysis of the results of the experimental tests with particular emphasis on the influence of the current that controls the operation of the damper on the values of the RMS index of the acceleration at selected points of the dummy.

Introduction

Semi-active suspension systems are a compromise between the effectiveness of vibration reduction and energy consumption. The operation of semi-active vibration isolation systems is based on modifying the damping and stiffness coefficients during the vibration cycle. For this purpose, actuators with adjustable damping and stiffness coefficients are used. It is becoming increasingly common for these elements to be designed with the use of smart materials, such as piezoelectrics, shape-memory materials, and magnetorheological fluids (Gromadowski, Osiecki & Stępiński, 1992; Gromadowski, Osiecki & Stępiński, 2001; Islam, Ahn & Truong, 2009; Truong & Ahn, 2012). Nowadays, controlled dampers that use magnetorheological and electrorheological fluids can be found in the offerings of a number of companies, and magnetorheological dampers are

becoming more common in the automotive industry. There are many strategies for controlling the damping coefficients, the most common control methods include: SkyHook, GroundHook, and “clipped” LQR (Rakheja & Boileau, 1998; Islam, Ahn, & Truong, 2009; Truong & Ahn, 2012; Wu et al., 2018).

The principle of the operation of magnetorheological dampers (Islam, Ahn & Truong, 2009; Truong & Ahn, 2012; Jaśkiewicz & Więckowski, 2018) is based on a damper filled with a magnetorheological fluid, which is a combination of ferromagnetic filings and synthetic oil as the carrier fluid. A solenoid coil is placed in the piston of the damper, to which the current signal that controls the damper is supplied. The magnetic field lines that are generated by the coil envelop the MR fluid within the gap through which the MR fluid flows. The volume flow rate of the fluid between the damper chambers depends on the pressure difference in the

fluid chambers. The pressure difference is proportional to the forces acting on the individual columns of the MR damper. When there is no current in the coil, the ferromagnetic particles are dispersed in the carrier fluid and the MR damper behaves like a normal viscous damper. The movement of the piston is counteracted by the friction force in the seals and the force resulting from the flow of the fluid. If current is passed through the coil of the damper, the ferromagnetic particles are aligned parallel to the direction of the magnetic field (perpendicular to the direction of the fluid flow). The movement of the piston is also counteracted by the force of the magnetoresistance effect; the essence of this effect is that a change in the viscosity of the fluid in the working chamber can occur in mere milliseconds, as a result of the changes in the magnetic field.

As a result of changes in the viscosity, the flow of fluid through the gap is limited, which increases the hydraulic resistance of the movement of the piston and generates a damping force that corresponds to these changes. The control range of this force is limited by the maximum current in the coil.

Methodology and experimental tests

The element that was studied was the suspension for a car seat, equipped with a magnetorheological damper (Lord RD-1005-3) (Figure 1, Table 1). The damper is a monotube shock absorber filled with nitrogen gas and it has a high compression ratio. During the movement of the piston, the magnetorheological fluid passes from one chamber of the damper to the other through small holes in the piston that are surrounded by the solenoid coils. By controlling the current flowing through the coil by means of a control system, the value of the magnetic field strength can be changed, resulting in a change in the viscosity of the fluid, which in turn results in a change in the damping force. In addition, a gas accumulator is placed in the vibration damper, which compensates for the change in the volume of fluid caused by the presence of a piston rod that moves the piston. The damping element is mounted in the seat's suspension in such a way that, by changing the damping force, it

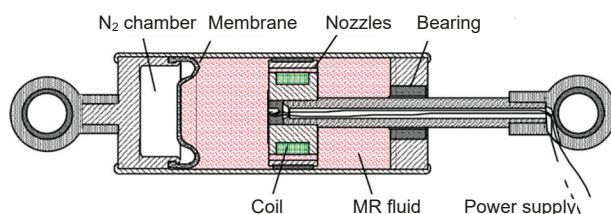


Figure 1. Structure of the damper (Truong & Ahn, 2012)

Table 1. Technical specification of the damper (MR RD1005-3) (Truong & Ahn, 2012)

Parameter	Value
Length of the retracted piston rod, mm	155
Maximum length of the piston rod, mm	208
Diameter of the body, mm	41.4
Diameter of the shaft, mm	10
Mass, g	800
Electrical characteristics:	
Maximum input current, A	2
Input voltage, V DC	12
Resistance	5 Ω at 25°C, 7 Ω at 71°C
Mechanical characteristics:	
Maximum tensile force, N	4448
Maximum operating temperature, °C	171
Response time, ms (depending on the amplifier and power supply)	< 25 (time to reach 90% of the maximum level at the input with a jump from 0 to 1 amps)

is possible to affect the vibrations that are transferred from the test station's platform to the car seat.

The first stage of the research consisted of determining the characteristics of the Lord RD-1005-3 damper. For this purpose, the damper was mounted on a strength test station (Figure 2).



Figure 2. Testing the damper in the test station

The inducer of the testing station generated a kinematic sine induction with constant amplitude (0.04 m) and an induction frequency of 0.5 Hz, 1 Hz, 1.5 Hz, 2 Hz, 2.5 Hz and 3 Hz. These inductions made it possible to determine six graphs of the operation for each of the six current values – the signal controlling the damper (0 mA, 192 mA, 381 mA, 570 mA, 758 mA and 942 mA). The examples of the damper's operation diagrams presented in Figures 3, 4, 5 and 6 confirmed that increasing the current intensity of the input signal, which controlled the damper operation, resulted in an increase of the

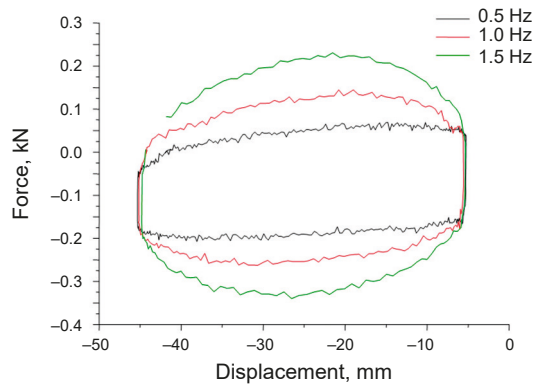


Figure 3. Damping force characteristics as a function of piston stroke for a current of 0 mA

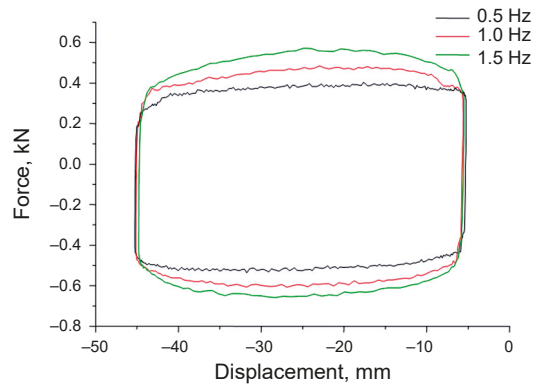


Figure 4. Damping force characteristics as a function of piston stroke for a current of 192 mA

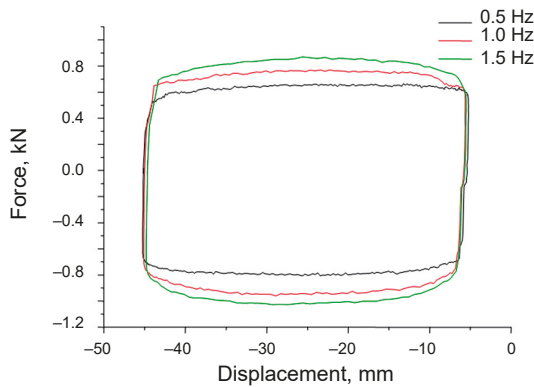


Figure 5. Damping force characteristics as a function of piston stroke for a current of 381 mA

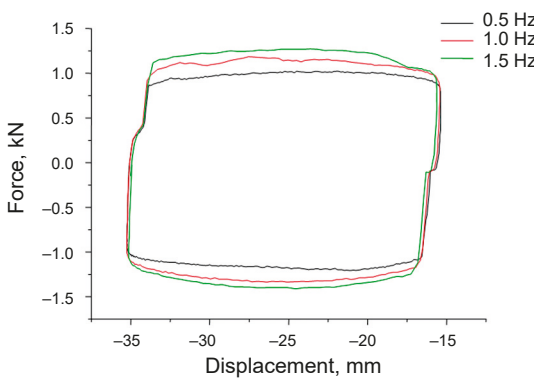


Figure 6. Damping force characteristics as a function of piston stroke for a current of 758 mA

damper's damping force (Osiecki, Gromadowski & Stępiński, 2006).

On the basis of the operation graphs, the damping characteristics were determined; indicating the dependency of the damping force on the piston's displacement velocity. The determined damping characteristics of the damper are presented in Figures 7, 8, 9 and 10.

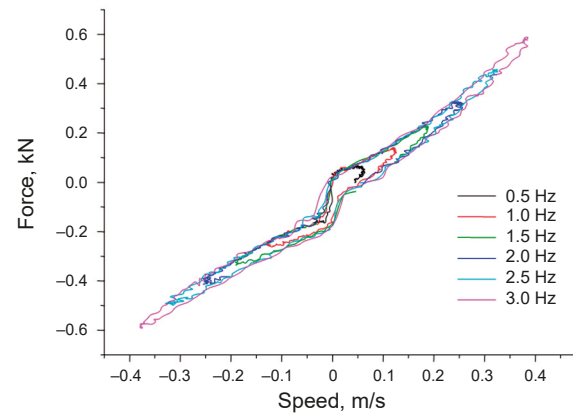


Figure 7. Damping force characteristics as a function of piston displacement velocity for a current of 0 mA

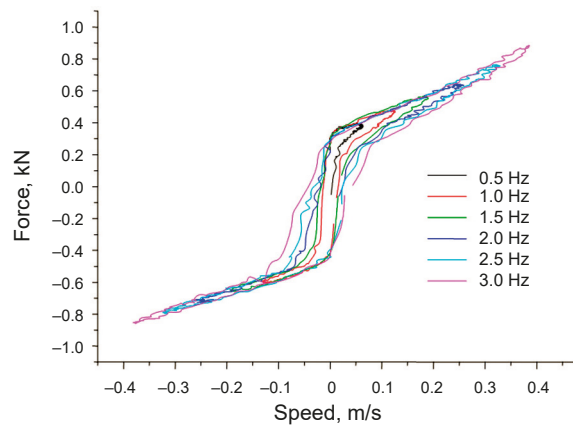


Figure 8. Damping force characteristics as a function of piston displacement velocity for a current of 192 mA

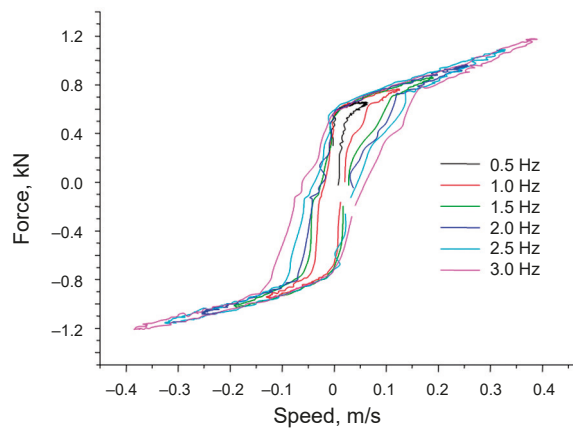


Figure 9. Damping force characteristics as a function of piston displacement velocity for a current of 381 mA

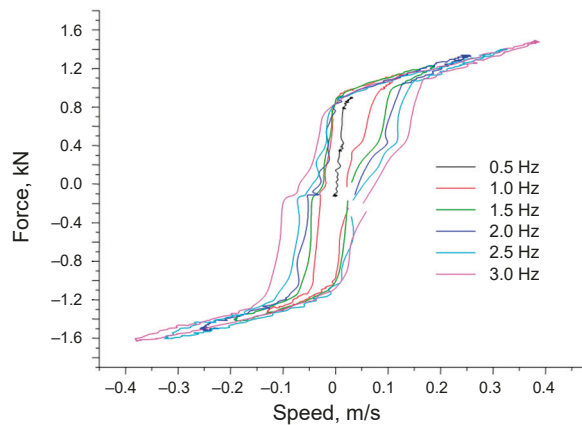


Figure 10. Damping force characteristics as a function of piston displacement velocity for a current of 570 mA

The results of the stationary tests of the damper and their analysis allowed the next stage of the research to be carried out, which was aimed at analyzing how the value of the current that controls the damper affects the travel comfort of the passengers. The tests were carried out at the M.A.S.T. test station shown in Figure 11. Such test stations are built to test the fatigue life of vehicle components and functional tests of complete cars as well as those of individual assemblies or components of vehicles (Gromadowski & Więkowski, 2012; Więkowski, 2015). The test station consists of a movable platform at the top which is connected to a fixed base by a system of six synergic inducers; the inducers generate time-varying displacements and these displacements cause vibrations that affect the tested object. The test station uses measurement and diagnostic equipment based on technology from MTS Systems Corporation.



Figure 11. Testing on the M.A.S.T. test station using a dummy

The conducted tests consisted of the analysis of the impact of a constant acceleration of 4 m/s^2 in the vertical direction on a car seat's suspension equipped with a damper with variable damping characteristics. A dummy of an adult male was placed on the tested seat. In the course of the study, the value of the current of the damper control signal was changed, while the recorded values were the acceleration of the dummy's head and torso, the base of the seat and the top platform of the test station (Zuska & Stańczyk, 2015; Zuska, 2017). The M.A.S.T. test station allowed tests to be carried out simulating mechanical vibrations in the frequency range of 1 to 20 Hz.

Examples of the waveforms of the acceleration recorded at the head and torso of the dummy and on the base of the seat and the top platform for induction frequencies of 4 Hz and 7 Hz are presented in Figures 12, 13 and 14, 15.

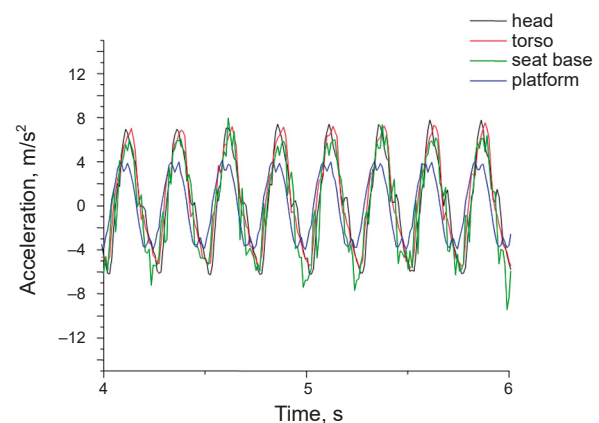


Figure 12. Waveforms of the accelerations recorded for an induction frequency of 4 Hz and a damper controlling current of 0 mA

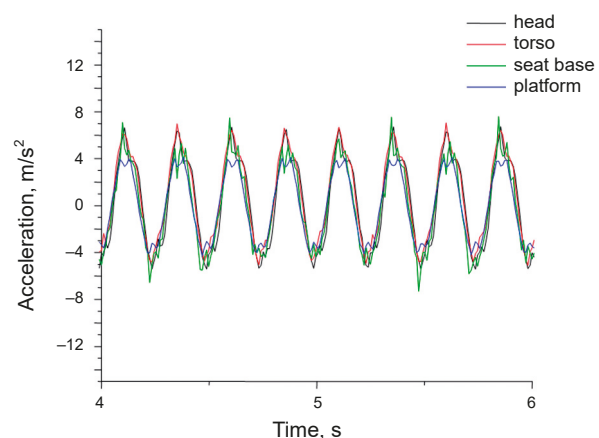


Figure 13. Waveforms of the accelerations recorded for an induction frequency of 4 Hz and a damper controlling current of 381 mA

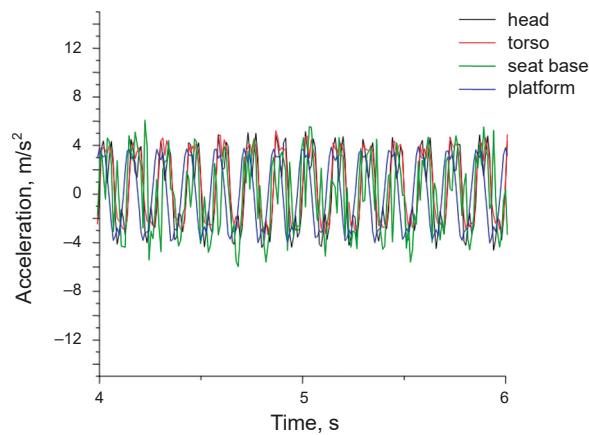


Figure 14. Waveforms of the accelerations recorded for an induction frequency of 7 Hz and a damper controlling current of 0 mA

Based on the recorded waveforms of the accelerations, the RMS indices were determined for the different values of the current controlling the

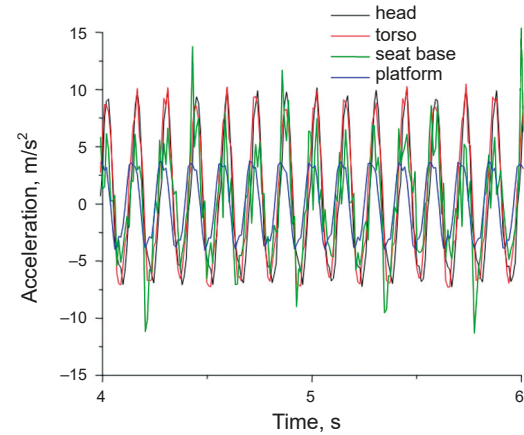


Figure 15. Waveforms of the accelerations recorded for an induction frequency of 7 Hz and a damper controlling current of 381 mA

damper's operation, which are presented in Table 2. The impact of the value of the current of the damper control signal on the RMS accelerations, recorded

Table 2. The values of the RMS index of accelerations for induction frequencies in the range 1–20 Hz

0 mA	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	6 Hz	7 Hz	8 Hz	9 Hz	10 Hz	15 Hz	16 Hz	20 Hz
head	2.00	3.12	3.72	3.63	3.47	2.9	2.7	3.12	3.41	3.07	2.71	2.29	1.46
torso	2.71	3.07	3.41	3.68	3.7	3.2	2.63	2.6	2.65	2.56	1.91	2.26	1.52
seat base	2.88	3.17	3.55	3.11	3.68	3.3	2.73	2.24	2.26	2.19	1.73	2.13	1.6
platform	2.42	2.44	2.39	2.49	2.5	2.43	2.35	2.27	2.2	2.11	1.88	1.83	1.79
192 mA	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	6 Hz	7 Hz	8 Hz	9 Hz	10 Hz	15 Hz	16 Hz	20 Hz
head	2.70	2.94	3.36	3.28	3.89	4.14	3.8	4.27	4.67	3.97	3.08	2.52	1.69
torso	2.75	2.88	3.12	3.26	3.63	3.93	3.95	4.41	4.67	4.02	2.32	2.49	1.55
seat base	2.91	2.91	3.15	3.11	3.25	3.61	3.3	2.77	3.02	2.96	1.87	1.94	1.64
platform	2.48	2.44	2.45	2.46	2.47	2.34	2.27	2.21	2.21	2.06	1.88	1.95	
381 mA	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	6 Hz	7 Hz	8 Hz	9 Hz	10 Hz	15 Hz	16 Hz	20 Hz
head	2.68	2.89	3.41	3.31	3.98	4.92	4.76	5.5	5.2	3.85	3.18	2.6	1.95
torso	2.72	2.84	3.05	3.27	3.68	4.39	4.8	5.44	5.07	3.89	2.44	2.4	1.56
seat base	2.88	2.86	3.11	3.1	3.39	4.1	3.91	3.76	3.71	3.13	2.08	1.92	1.7
platform	2.45	2.39	2.38	2.48	2.48	2.41	2.33	2.27	2.24	2.09	1.92	1.84	1.76
570 mA	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	6 Hz	7 Hz	8 Hz	9 Hz	10 Hz	15 Hz	16 Hz	20 Hz
head	2.69	3.03	3.76	3.32	3.93	4.81	4.82	5.55	5.02	3.88	2.96	2.47	1.86
torso	2.75	2.95	3.31	3.26	3.64	4.5	4.96	5.6	4.89	3.94	2.29	2.3	1.51
seat base	2.87	2.94	3.27	3.06	3.25	4.06	4.43	3.72	3.71	3.22	1.97	2.13	1.61
platform	2.46	2.46	2.55	2.49	2.51	2.43	2.35	2.31	2.17	2.08	1.87	1.77	1.78
758 mA	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	6 Hz	7 Hz	8 Hz	9 Hz	10 Hz	15 Hz	16 Hz	20 Hz
head	2.74	3.13	3.63	3.31	3.81	4.76	4.9	5.4	5.07	3.89	2.91	2.35	1.79
torso	2.80	2.99	3.21	3.28	3.59	4.58	5.08	5.49	5.03	4.02	2.19	2.16	1.51
seat base	2.92	2.96	3.19	3.2	3.37	4.18	4.23	3.66	3.64	3.53	2.02	2.04	1.6
platform	2.49	2.46	2.44	2.48	2.44	2.46	2.35	2.25	2.17	2.09	1.9	1.79	1.74
947 mA	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	6 Hz	7 Hz	8 Hz	9 Hz	10 Hz	15 Hz	16 Hz	20 Hz
head	2.76	3.1	3.67	3.27	3.87	4.77	5.24	5.58	5.17	4.13	3.09	2.52	2
torso	2.82	3.01	3.29	3.26	3.67	4.65	5.35	5.66	5.14	4.26	2.27	2.28	1.67
seat base	2.92	2.96	3.3	3.13	3.29	4.29	4.43	4.09	3.55	3.24	2.15	2.1	1.52
platform	2.49	2.47	2.5	2.46	2.49	2.48	2.43	2.31	2.18	2.11	1.92	1.86	1.78

at selected points on the dummy and the base of the seat, at the individual induction frequencies is presented in Figures 16, 17, 18, 19, 20, 21, 22 and 23.

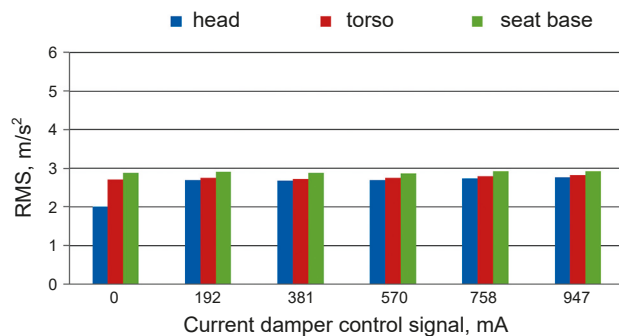


Figure 16. RMS acceleration values for an induction frequency of 1 Hz

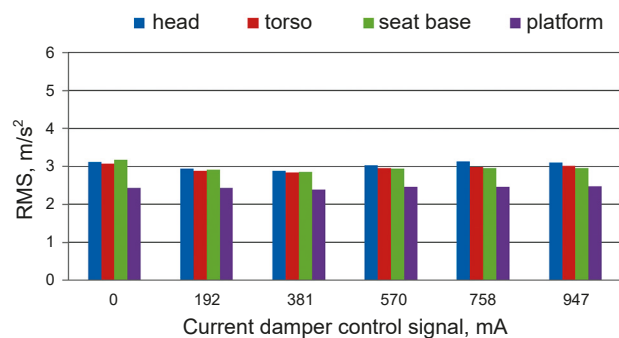


Figure 17. RMS acceleration values for an induction frequency of 2 Hz

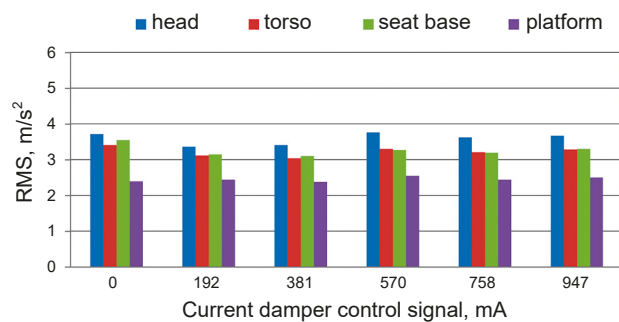


Figure 18. RMS acceleration values for an induction frequency of 3 Hz

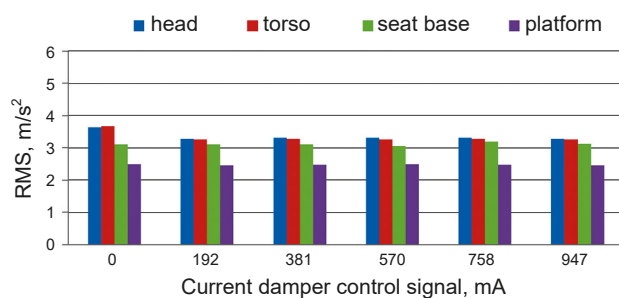


Figure 19. RMS acceleration values for an induction frequency of 4 Hz

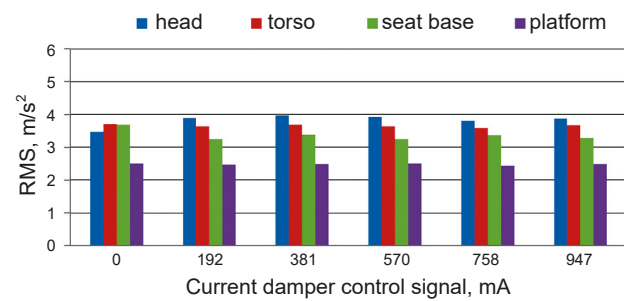


Figure 20. RMS acceleration values for an induction frequency of 5 Hz

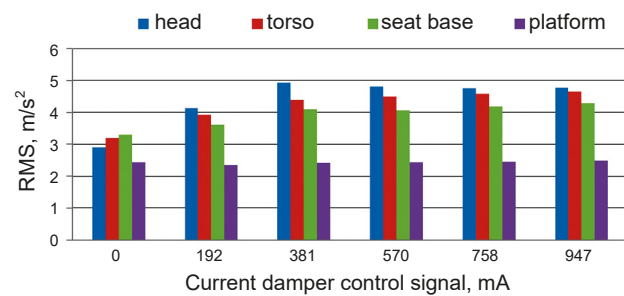


Figure 21. RMS acceleration values for an induction frequency of 6 Hz

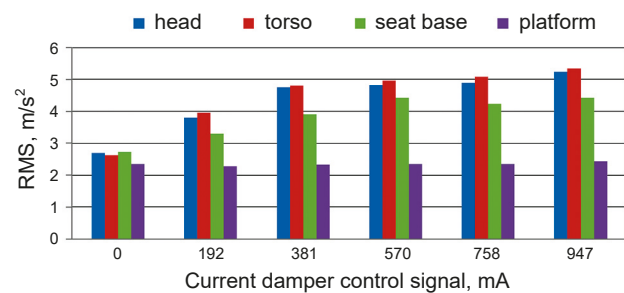


Figure 22. RMS acceleration values for an induction frequency of 7 Hz

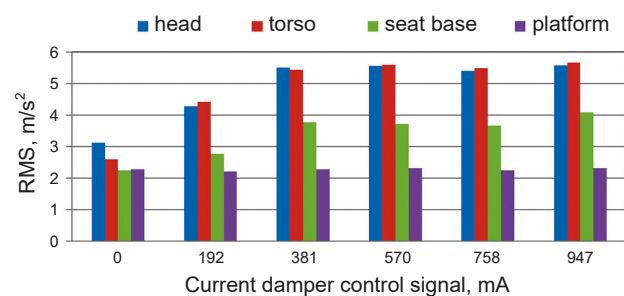


Figure 23. RMS acceleration values for an induction frequency of 8 Hz

Analysis of the test results

After the tests were carried out using the test station, the performance of the damping element installed in the seat's suspension could be evaluated on the basis of the results obtained.

The characteristics (waveform of the accelerations) determined for the selected points on the dummy allowed the influence of the change in the damping force of the damper, mounted in the seat's suspension, on the transmission of vibrations to the human body to be assessed. By comparing the waveforms of the accelerations it can be seen that, for an induction frequency of 4 Hz at different values of the current controlling the damping force, the influence of this force on the values of the obtained acceleration for all of the measurement points is small.

This dependency is noticeable at lower frequencies, from 1 to 4 Hz. The same comparison was made for an induction frequency of 7 Hz, and it was noted that as the damping force increased, so did the acceleration. The highest acceleration values of approximately 10 m/s^2 were recorded at 7 Hz and 8 Hz for values of the damper control signal current of 570 mA, 758 mA and 947 mA. The operation of the damper at these parameters has an adverse effect due to the overlap with the natural frequencies of the system.

The analysis of the RMS index values indicated a disadvantageous influence of the damper's operation mainly in the frequency range of 5 to 10 Hz. When the damper current was 0 mA, the RMS values did not exceed 4 m/s^2 . For the other current values, the RMS index reached values in the range of $4\text{--}6 \text{ m/s}^2$. In this case, increasing the damper's damping force caused the acceleration amplitudes to increase as well.

Conclusions

The subject of this research fits into the subject matter of the impact of vertical vibrations on people when they are driving a car. The paper presents the results of empirical research on this topic carried out using a test station.

At the turn of the 21st century, there was a step forward in terms of digital signal processing and control technologies. This created new opportunities for active and semi-active vibration damping systems in suspension, e.g. car seats. These technologies can complement traditional passive vibration damping methods, as they are best suited to low-frequency interference in vehicles.

The development of active and semi-active suspension covers interdisciplinary issues, including the theory of car movement, modeling and simulation of car movement, and car dynamic control. This requires combining areas such as mechanics, automation, electronics, computer science and

computational techniques, control theory, signal processing and experimental research.

The results of the conducted research have indicated that when the influence of vibration transmission on people while driving is assessed, it is necessary to take into account not only the impact of the value of the current controlling the damper's operation, but also the frequency range of the vibrations transmitted to the vehicle's body. This requires the use of a damper control system combined with time and frequency analysis.

The potential of controlled mechanical vibration damping systems in vehicles are an area which has been known about for decades. However, widespread implementation of controlled suspension systems has become possible relatively recently with the development of cheap processors.

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Miscellaneous

Phytochemical screening and *in vitro* antimicrobial properties of *Annona muricata* extracts against certain human pathogens

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Key words: *Annona muricata*, pathogens, bacteria, fungi, antibiotics, medicinal plants

Abstract

All over the world, the use of medicinal plants is gaining more acceptability due to the possibility of discovering novel drugs from them and solving the problem of antimicrobial resistance associated with conventional antibiotics. The phytochemical composition and antimicrobial properties of crude extracts of the leaves, stems, and bark of *Annona muricata* were evaluated on *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella typhimurium*, while the antifungal properties were evaluated against *Candida albicans* and *Candida tropicalis*. The Agar well method was used for the study. At concentrations of 150 mg/ml and 300 mg/ml, inhibitory effects were observed on *E. coli* and *S. aureus*, with a visible zone of inhibition ranging from 15 mm to 21 mm respectively, and with respect to N-hexane, an antimicrobial activity range of 5 mm to 20 mm, for the leaf extract, which shows effective antimicrobial action against *E. coli* and *S. aureus*. Hot water extracts were observed to possess more bioactive compounds compared to organic solvent extracts, and exhibit higher ranges of activity against the tested bacterial species. All extracts exhibited low anti-fungal activity in the range of 8 mm to 15 mm. The phytochemical screening of the extracts of different parts of *A. muricata* revealed the presence of secondary metabolites such as tannins, alkaloids, saponins, flavonoids, steroids, and cardiac glycosides. The antimicrobial activity of the extracts was compared with a standard antibiotic, ketoconazole, and with ampicillin, which served as the controls. The results showed that *A. muricata* can be used as an anti-bacterial substance, since it shows broad spectrum activity against a range of bacteria responsible for the most common bacterial illnesses. Further research will be necessary to ascertain its full spectrum of efficacy.

Introduction

All over the world, herbal medicine has served as perhaps the most valuable and popular field of traditional medicine. Medicinal plants have been used to treat illnesses since before recorded history (Gajalakshmi, Vijayalakshmi & Rajeswari, 2012). The study of medicinal plants is essential to promoting proper use of herbal medicines and in order to identify potential sources of new drugs (Parekh & Chanda, 2007). According to a World Health Organization (WHO) report, greater than 80% of the world's population depends on traditional medicine to satisfy their primary health care needs (Vashist & Jindal, 2012). Finding new naturally active

components of plants and plant-based products has interested many scientific researchers. In this regard, the antimicrobial properties of botanicals have attracted a great deal of attention as a promising potential source of novel pharmaceutical drugs.

Soursop is one of the medicinal plants reported to have properties beneficial to health. Its scientific name is *Annona muricata* (Sarah, Mustafa & Rehab, 2015). *Annona muricata*, commonly known as graviola or soursop, belongs to the family of *Annonaceae*. It is a typical tropical tree, with heart-shaped edible fruits and widely distributed in most tropical countries (Foong & Hamid, 2012). It is a small tree, native to and widespread in Central America and the Caribbean, but now also widely

cultivated, and in some areas becoming invasive, in tropical locales throughout the world (Le Ven et al., 2011; Moghadamtousi et al., 2015). It has become an important crop because of its tasty flavor, high pulp content, nutritional value, and antioxidant properties (Moghadamtousi et al., 2015). The plant has various native names, depending on the country where it is found. It is called Guanabana in China and, in Nigeria, it is proudly called Shawahopu in the Igbo language (Le Ven et al., 2011; Moghadamtousi et al., 2015).

Gajalakshmi et al. (2012) reports that *A. muricata* is a traditional medicinal plant with phytochemical constituents and bioactive compounds possessing diverse medicinal properties. Intensive chemical investigation of the leaves and seeds of the species have resulted in the isolation of a great number of acetogenins (Moghadamtousi et al., 2015). The isolated compounds display some desired biological and pharmacological effects such as anti-tumoral properties, cytotoxicity, and pesticidal properties (Moghadamtousi et al., 2015). These conclusions are supported by the use in traditional medicine of the roots of the species for their anti-parasitical and anti-pesticidal properties (Moghadamtousi et al., 2015; Sarah, Mustafa & Rehab, 2015). *A. muricata* has been traditionally used to treat headaches, hypertension, cough, and asthma and used as an antispasmodic, sedative, and nervine for heart conditions (Sarah, Mustafa & Rehab, 2015).

Soursop leaves contain flavonoids, tannins, alkaloids, saponins, calcium, phosphorus, carbohydrates, vitamins A, B, and C, phytosterol, and calcium oxalate (Edeoga, Okwu & Mbaebie, 2005; Abdul Wahab et al., 2018). The leaves are traditionally used to prevent and treat asthma, bronchitis, biliary disorder, diabetes, heart diseases, hypertension, worm disease, liver disorder, malaria, rheumatism, arthritis, other sources of joint pain, tumors, and cancer (Padma et al., 2001; Wicaksono et al., 2011). The leaves are also used to treat several types of bacterial disease, such as pneumonia, diarrhea, urinary tract infection, and various skin diseases (Gajalakshmi, Vijayalakshmi & Rajeswari, 2012). Additionally, the leaves, roots, and seeds of soursop have been reported to demonstrate significant insecticidal properties (Tattersfield, 1940). It has also been documented to possess both hypoglycemic and antioxidant properties without any adverse effects (Lenk et al., 1992). The leaves act also as molluscicidal and anti-parasitical agents (De S. Luna et al., 2005). Extracts from the roots, leaves, and stem are used to make tea and other solutions for patients (Padma, Chansouria

& Khosa, 2009). The leaves can be crushed along with raw fruit from the plant and mixed with olive oil to treat various skin disorders, such as rashes, boils, and sores (Padma et al., 2001; Vijayameena et al., 2013). The plant has also been reported to exhibit anti-inflammatory and analgesic effects (Lans, 2006; Roslida et al., 2010; Sarah, Mustafa & Rehab, 2015).

Considering the widespread traditional use of this plant among local communities in Nigeria, it is pertinent to provide scientific support for its application. There is a dearth of such information in some communities, particularly in Ekiti State, where the plants is voraciously exploited for herbal medicinal purposes. Hence, this study was carried out to add to the existing lean body of knowledge on the phytochemical composition as well as antimicrobial properties of the leaves, stem, and bark of *A. muricata* plant on some human pathogens of public health concern.

Materials and methods

Sources of plants for extraction

The fresh leaves, stems, and bark of soursop (*Annona muricata*) (Figure 1) were acquired from a market in Ado-Ekiti, Ekiti State, Nigeria, and transported to the laboratory. These parts of the plant were identified at the herbarium unit of the Plant Science Department of Ekiti State University, in Ado-Ekiti.



Figure 1. *Annona muricata* plant (Moghadamtousi et al., 2015)

Source of test microorganisms

The bacteria and fungi used in this study were clinical isolates from the Department of Medical Microbiology, Federal Teaching Hospital, Ado-Ekiti. They included *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhi*, *Candida albicans*, and *Candida tropicalis*. The bacteria were maintained on nutrient agar slant at 4°C, while the fungi were maintained on the Potato Dextrose agar slant until needed for assay.

Preparation of various solvent extracts

The extraction of the leaves, stem, and bark of *Annona muricata* was carried out by the maceration method, using the solvent polarity of, in order, ethyl acetate, n-hexane, and hot water (100°C). The maceration method used was that described by Ginda et al. (Ginda, Niky & Erly, 2014) and Rarassari and Maftuch (Rarassari & Maftuch, 2016). The soursop leaves, stems, and bark were macerated separately with disinfected mortars and pestles. Exactly 100 g each of the coarsely powdered plant parts were placed in stoppered containers containing 250 ml of solvent (ethyl acetate, n-hexane, or water). They were each labeled appropriately and allowed to stand at room temperature for three days with frequent agitation, until the soluble matter was dissolved. The mixture was strained, the “marc” (the damp solid materials) pressed, and the liquids clarified by filtration after standing (Sukhdev et al., 2008; Sasidharan et al., 2011). These extracts were then concentrated using a rotary evaporator with the temperature not exceeding 40°C until the concentrated extracts were obtained (Rarassari & Maftuch, 2016).

Phytochemical screening

Qualitative tests were carried out on the crude solvent extracts for alkaloids, flavonoids, carbohydrates, glycosides, saponins, tannins, terpenoids, proteins, and anthraquinone (Harborne, 1973). These tests were carried out at the Federal University of Technology, Akure, Ondo State, Nigeria, as described below:

Test for alkaloids

Exactly 5 ml of the extract was diluted with sulphuric acid to make it acidic. Mayer's reagent was added to the acidic extract, a white precipitate indicating the presence of alkaloids, as a positive result.

Test for saponins

Exactly 20 ml of the extract was evaporated to dryness and the extract dissolved in 3 ml of chloroform, the filtrate treated with 3 drops of a mixture of concentrated sulphuric acid and acetic anhydride, and a colour of different shade was observed, indicating a positive test for saponins.

Test for steroids and terpenes

Five milliliters (5 ml) of the extract was divided into 2 equal parts and evaporated to dryness and the extract dissolved in 3 ml of chloroform. The filtrate was then treated with 3 drops of a mixture of concentrated sulphuric acid and acetic anhydride. Colors of different shades were observed indicating a positive test. The second portion of the extract was heated with hot acetic anhydride, allowed to cool and six drops of concentrated sulphuric acid added, and a blue-green color was observed, indicating terpenes.

Test for tannins and phenols

Exactly 3 ml of extract was treated with 5% ferric chloride solution; a green to blue color was observed indicating a positive test for tannins. Similarly, 3 ml of extract was added to 3 ml of lead acetate solution and a white precipitate occurred, indicating tannins and phenols.

Test for proteins

Exactly 1 ml of 4% sodium hydroxide and 1% dilute copper sulphate was added to 5 ml of the extract, and a red solution confirmed proteins. Additionally, a xanthoprotein test was also done by adding 3 ml of extract to 1 ml of concentrated sulphuric acid. The presence of white precipitate which turned to yellow on boiling, and orange on addition of 1 ml ammonium hydroxide, indicated the presence of proteins.

Test for carbohydrates

To 2 ml of the extract, 2–3 drops of alpha naphthalene solution in alcohol were added, the solution shaken for 2 minutes, and 1 ml of concentrated sulphuric acid added slowly from the side of the test tube, until it gave a deep purple color at the junction of two layers, indicating the presence of carbohydrate. Adding Benedict's reagent to the extract, it

yielded a yellow to brown precipitate after boiling in a water bath.

Test for glycosides

Into 2 ml of extract, 1 ml of pyridine and 1 ml of sodium nitro-prusside were added. A red color indicated the presence of cardiac glycosides.

Keller-killiani test

To a test tube containing 2 ml of extract, 1 ml of glacial acetic acid was added with 3 drops of 5% ferric chloride and concentrated sulphuric acid, and the disappearance of the reddish brown color at the junction of the two layers and bluish green in upper layer indicated the presence of cardiac glycosides.

Test for flavonoids

Into 2 g of dry extract, 5 ml of ethanol, 5 drops of hydrochloric acid, and 0.5 g of magnesium were added; a pink color indicated the presence of flavonoids.

The preparation of extract concentration for antibacterial application

About 3 g each of the concentrated aqueous, ethyl acetate, and n-hexane extracts were dissolved separately in dimethyl sulfoxide (DMSO) until 10 ml of volume was obtained of concentrate from the extract of 300 mg/ml. The dilution was made in order to obtain extracts with concentrations of 5 mg/ml, 10 mg/ml, 50 mg/ml, 150 mg/ml, and 300 mg/ml.

Antimicrobial activity assay

The test bacterial innocula (*S. aureus*, *E. coli*, and *S. typhi*) were prepared from an overnight culture of nutrient agar slant. The bacterial cultures were directly suspended in sterile Mueller Hinton broth (oxid) and the suspension adjusted to the 0.5 Macfarland turbidity standard (10^5 cells/ml) needed for the experiment. The fungi innocula were prepared directly using Sabouraud dextrose broth. The already dried Mueller Hinton plate was inoculated with test bacteria using sterile swabs by rotating the plate 3 times between each smear and leaving to dry for 10 minutes at ambient temperature before wells were made. This was repeated for the fungi using a Sabouraud dextrose plate. Exactly 20 μ l of each extract concentration (300 mg/ml,

150 mg/ml, 50 mg/ml, 10 mg/ml, and 5 mg/ml (w/v)) was introduced into the wells on already inoculated culture plates with the test bacterial and fungal isolates. These were incubated at 37°C for 24 hours for the bacteria and 48 hours for the fungi. After incubation, each extract's zone of inhibition was noted for each isolate. All tests were done in triplicate. The reference antimicrobial agent, ampicillin, was used as a positive control, while DMSO was used as a negative control. The diameters of zones of inhibition were measured in mm using a Vernier caliper (Vijayameena et al., 2013).

Results

The phytochemical compositions of extracts of *A. muricata* showed that the leaf, stem, and fruit possess mainly tannins, flavonoids, saponins, reducing sugars, carbohydrates, alkaloids, steroids, proteins, nitrate ions, and starch (Table 1). They also show that only the leaves of *Annona muricata* possess glycosides and there are no phlobatannins and anthraquinone in the leaves, stems, or fruits.

The antimicrobial activities of n-hexane leaf extract of *Annona muricata* on the selected clinical isolates are presented in Table 2. The n-hexane leaf extract showed zone of inhibition diameters of 21 mm against *S. aureus* at 300 mg/ml and 18 mm against *E. coli* at 150 mg/ml. Similarly, the same extract showed 15 mm and 8 mm against *C. tropicalis* at concentrations of 300 mg/ml and 150 mg/ml respectively. Similarly, Tables 3 and 4 show that n-hexane stem extract showed 22 mm and 15 mm against *S. aureus* and *E. coli* respectively.

The ethyl leaf extract at concentrations of 300 mg/ml showed zones of inhibition of 12 mm and 13 mm against *E. coli* and *S. aureus* respectively, while at concentrations of 150 mg/ml, 8 mm was recorded against *E. coli* and *S. aureus* (Table 5). *E. coli* and *S. aureus* showed zones of inhibition of 14 mm and 20 mm respectively at 300 mg/ml (Table 6), and 15 mm and 8 mm respectively at 300 mg/ml (Table 7).

The hot water extracts of *A. muricata* also exhibited antimicrobial effects recorded in Tables 8, 9, and 10. They show diameters of inhibition of 10 mm at 150 mg/ml and 18 mm at 300 mg/ml against *E. coli*. *Candida albicans* and *Candida tropicalis* displayed 5 mm and 8 mm respectively at 300 mg/ml. (Table 8). *E. coli* and *S. aureus* showed zones of inhibition of 10 mm and 22 mm respectively at 300 mg/ml (Table 9), and 2 mm each at 300 mg/ml (Table 10).

Table 1. Phytochemical constituents of leaf, stem, and fruit extracts of sour sop

Phytochemical constituents	Leaf	Stem	Fruit
Tannins	+	+	+
Flavonoids	+	+	+
Glycosides	+	–	–
Saponins	+	+	+
Phlobatannins	–	–	–
Reducing sugar	+	+	+
Carbohydrate	+	+	+
Alkaloids	+	+	+
Steroids	+	+	+
Protein	+	+	+
Nitrate ion	+	+	+
Starch	+	+	+
Anthraquinone	–	–	–

+ present; – absent

Table 2. Antimicrobial activities of n-hexane leaf extract of *Annona muricata* (mm)

Clinical Isolates	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	18	20
<i>Staphylococcus aureus</i>	0	0	2	15	21
<i>Salmonella typhi</i>	0	0	0	2	5
<i>Candida albicans</i>	0	0	0	8	10
<i>Candida tropicalis</i>	0	0	5	8	15

Table 3. Antimicrobial activities of n-hexane stem extract of *Annona muricata*

Clinical Isolates	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	10	15
<i>Staphylococcus aureus</i>	0	0	0	6	22
<i>Salmonella typhi</i>	0	0	0	0	4
<i>Candida albicans</i>	0	0	0	0	0
<i>Candida tropicalis</i>	0	0	0	0	0

Table 4. Antimicrobial activities of n-hexane fruit extract of *Annona muricata*

Microorganism	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	10	15
<i>Staphylococcus aureus</i>	0	0	0	6	22
<i>Salmonella typhi</i>	0	0	0	0	4
<i>Candida albicans</i>	0	0	0	0	0
<i>Candida tropicalis</i>	0	0	0	0	0

Table 5. Antimicrobial activities of Ethyl acetate leaf extract of *Annona muricata*

Microorganism	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	8	12
<i>Staphylococcus aureus</i>	0	0	4	8	13
<i>Salmonella typhi</i>	0	0	0	0	5
<i>Candida albicans</i>	0	0	0	4	8
<i>Candida tropicalis</i>	0	0	3	6	10

Table 6. Antimicrobial activities of Ethyl acetate extract stem extract of *Annona muricata*

Clinical Isolate	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	5	8	14
<i>Staphylococcus aureus</i>	0	2	8	15	20
<i>Salmonella typhi</i>	0	0	0	0	0
<i>Candida albicans</i>	0	0	0	0	4
<i>Candida tropicalis</i>	0	0	0	0	5

Table 7. Antimicrobial activities of Ethyl acetate extract fruit extract of *Annona muricata*

Clinical Isolate	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	10	15
<i>Staphylococcus aureus</i>	0	0	0	0	8
<i>Salmonella typhi</i>	0	0	0	0	0
<i>Candida albicans</i>	0	0	0	0	0
<i>Candida tropicalis</i>	0	0	0	0	0

Table 8. Antimicrobial activities of hot water leaf extract of *Annona muricata*

Clinical Isolates	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	10	18
<i>Staphylococcus aureus</i>	0	0	0	5	20
<i>Salmonella typhi</i>	0	0	0	2	4
<i>Candida albicans</i>	0	0	0	0	5
<i>Candida tropicalis</i>	0	0	0	4	8

Table 9. Antimicrobial activities of hot water stem extract of *Annona muricata*

Clinical Isolates	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	0	10
<i>Staphylococcus aureus</i>	0	0	0	6	22
<i>Salmonella typhi</i>	0	0	0	0	0
<i>Candida albicans</i>	0	0	0	0	0
<i>Candida tropicalis</i>	0	0	0	0	0

Table 10. Antimicrobial activities of hot water fruit extract of *Annona muricata*

Clinical Isolates	5 mg/ml	10 mg/ml	50 mg/ml	150 mg/ml	300 mg/ml
<i>Escherichia coli</i>	0	0	0	0	2
<i>Staphylococcus aureus</i>	0	0	0	0	2
<i>Salmonella typhi</i>	0	0	0	0	0
<i>Candida albicans</i>	0	0	0	0	0
<i>Candida tropicalis</i>	0	0	0	0	0

Discussion

The phytochemical constituents of leaf, stem, and fruit extracts of *Annona muricata* revealed tannins, flavonoids, saponins, reducing sugars, carbohydrates, alkaloids, steroids, proteins, and starch. Previous studies have shown that the antimicrobial

properties of plants are due to tannins, alkaloids, saponins, flavonoids, sterol, triterpenes, and reducing sugars (Pathak et al., 2010; Ogu & Amiebenomo, 2012; Ogu et al., 2012; Ogu, Ezeadila & Ehiobu, 2013). Thus, the antibacterial activities of the leaf, stem, and bark extracts observed in this study are most likely due to the presence of one or more of these bioactive principles in the extract. The leaves possess more phytochemical components than the stem or fruits. This suggests that the leaves may be utilized for the strongest beneficial effects on human health. This finding agrees with studies conducted by Edeoga et al. (Edeoga, Okwu & Mbaebie, 2005) and Usunobum and Paulinus (Usunobum & Paulinus, 2015), who report that *Annona muricata* are reservoirs of free radical scavenging molecules, rich in antioxidant activity.

This study tested for and observed antimicrobial activities of n-hexane, ethyl acetate, and aqueous extracts of the leaves, stems, and fruits of soursop on selected clinical isolates. It showed that n-hexane, ethyl acetate, and aqueous extracts of soursop leaves inhibited *E. coli*, *S. aureus*, *S. typhi*, *C. albicans* and *C. tropicalis* at concentrations of 300 mg/ml and 150 mg/ml. There was no sensitivity recorded at lower concentrations against the tested isolates except at the concentration of 50 mg against *S. aureus* and *C. tropicalis*. This corroborates the earlier report of Sarah et al. (Sarah, Mustafa, & Rehab, 2015), of the antibacterial effect of methanolic and aqueous extracts of the leaves of *Annona muricata* against various bacterial strains: *Staphylococcus aureus* ATCC29213, *Escherichia coli* ATCC8739, *Proteus vulgaris* ATCC13315, *Streptococcus pyogenes* ATCC8668, *Bacillus subtilis* ATCC12432, *Salmonella typhi* ATCC23564, and *Klebsiella pneumonia*. This is supported by the previous reports of Lans (2006) who demonstrated that the leaf, bark, root, stem, fruit and seed extracts of *Annona muricata* possess anti-bacterial, antifungal, and anti-malarial properties. Similarly, the n-hexane, ethyl acetate, and aqueous extracts of soursop stems in this study demonstrated antibacterial and antifungal effects against *E. coli*, *S. aureus*, *S. typhi*, *C. albicans*, and *C. tropicalis* at concentrations of 300 mg/ml and 150 mg/ml. Thus, *Annona muricata* extract contains a wide spectrum of activity against a group of bacteria responsible for the most common bacterial diseases. Pathak et al. (2010) also reported that leaf extract of *Annona muricata* is used in the treatment of various bacterial infectious diseases. Thus, the plant possesses an abundance of antibacterial compounds as reported earlier (Moghadamtousi et al., 2015).

Nevertheless, in this study, although the n-hexane extract of the fruit showed antibacterial effects on all the selected bacteria at 300 mg/ml and 150 mg/ml, the *Candida* species were resistant at the same concentrations. This suggests that more of the antibacterial bioactive ingredients were soluble in n-hexane than the antifungal components. The slightly greater antimicrobial activities recorded in this study for leaf extract over stem or bark extracts, suggests that more of the bioactive ingredients are lodged in the leaves, as reported by Ogu et al. (Ogu et al., 2012). This is probably one of the reasons herbal practitioners have almost always recommended using leaf extracts over those of stems or barks in native herbal medicine. This submission is in consonance with the submissions of previous studies (Adeshina, Onujagbe & Onaolapo, 2010; Ogu et al., 2012). The aqueous extract of the stem and leaves showed that hot water leaf extraction resulted in better antibacterial effects than cold extraction, indicating that most of the active agents were expressed by hot rather than cold maceration.

Studies in the past have reported similar finding (Matsushige, Kotake & Takeda, 2012). The findings in this study further support earlier claims that medicinal plants can be used for effective treatments of infectious diseases caused by a variety of microorganisms, and thus should be exploited.

Conclusions

Many common plant-based foods contain powerful antimicrobial phytochemical substances that can improve human health. The antimicrobial properties demonstrated for different parts and fractions of *Annona muricata* might provide a good alternative to antibiotic drugs in the treatment of some infections. The phytochemicals found in this study could also offer significant protections to consumers against many diet related diseases, including cancer, because of the presence of antioxidants. Therefore this study suggests that every part of the *Annona muricata* can be used for numerous health benefits and should be prepared and consumed in an appropriate manner in order to confer the most health benefits possible.

Annona muricata (soursop) is an essential medicinal plant which has been reported to promote the general health of human beings. Its potential as a source of new drugs cannot be over-emphasized. Therefore, proper and adequate use of the plant will be a welcome development. Also, it would probably be beneficial to incorporate some of the active

substances into foods and drinks, and finally, the molecular study of the plant will provide more vital information about its potential as a good drug alternative.

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Education along the Belt and Road

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Abstract

The Belt and Road Initiative (BRI) is focused on extending the cooperation between China and the countries of Central Asia, the Middle East, Africa, and Europe. The five goals laid out by the Chinese government, along with unimpeded trade and financial integration, include people-to-people bonds. This last goal is to be achieved by education and international academic cooperation. In 2016, China's Ministry of Education provided a detailed framework that stated which educational projects may be implemented within the BRI. The aim of this research is to analyze, based on the official documents proposed by Chinese ministries, the variety of educational programs offered by the Chinese government to the BRI countries. Furthermore, their strengths and weaknesses will be shown, and the article will also focus on the opportunities available for Polish higher education institutions that may profit from well-led projects.

Introduction

Most academic studies of the Belt Road Initiative (BRI) have focused on the purely economic possibilities of the BRI, while this research is devoted to educational solutions offered by the New Silk Road. Education is one of the most important elements that determine the innovation of the Chinese economy. A number of studies confirm that investing in education has a greater impact on the economic growth of a country than building new infrastructure. Beginning with Deng Xiaoping's reforms of 1978, education in China has undergone constant changes that have allowed it to successfully building its human capital. However, the low levels of teaching at Chinese universities still remain a problem. The Chinese government is looking for new ideas and schemes for improvement; through the BRI, they wish to achieve bilateral and multilateral transfer of knowledge through interdisciplinary and multicultural cooperation (Bieliński, 2016, Bizon, 2019). In this article, based on the documents published by the Chinese government, the main ideas for developing education

through the BRI will be presented. Moreover, Polish educational opportunities that can be achieved with the support from China will be discussed.

The Belt and Road Initiative

The concept of the New Silk Road, which would "forge closer economic ties, deepen cooperation and expand development space in the Eurasian region," was presented by the President of the People's Republic of China (PRC), Xi Jinping, during his visit to Kazakhstan in 2013 (MoFA, 2013). Before 2016, it was known under the name *One Belt One Road* (OBOR, Chinese: 一带一路, pinyin: Yídài yílù); however, its name was changed to the *Belt and Road Initiative* (BRI) as the Chinese government noticed that the emphasis on the word 'one' lead to misunderstandings that there would be only one route within the OBOR. The BRI should be perceived more as an international cooperation strategy between countries, rather than geographically-defined tracks (Bērziņa-Čerenkova, 2016). For China, the BRI is an opportunity to further develop, expand

its sphere of influence, and strengthen its position in the international arena. In times of widespread globalization, the New Silk Road also aims to reinforce economic cooperation between countries along the route. Initially, the initiative involved 65 countries located along the historic Silk Road from China to Western Europe (Hübner, 2014), but it has now spread around the globe, even to countries in the Americas or Southern Africa. Although a number of these countries did not sign onto the Initiative, the investments made by the Chinese government in their region are perceived as an agreement to take part in the BRI. On the official BRI webpage, hosted by the Office of the Leading Group for the Belt and Road Initiative and the State Information Center, 137 countries are listed on the 'international cooperation' page, including Poland. The site also includes a total of 187 cooperation documents that have been signed with both national governments and international organizations (Belt and Road Portal, 2019a; 2019b).

In 2015, the Chinese government issued *Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*. In this document, five cooperation priorities were listed: a) policy coordination, b) facilities connectivity, c) unimpeded trade, d) financial integration, and e) people-to-people bonds (NDRC, 2015). Realizing these goals would stimulate the global economy and promote dialogue between the countries along the BRI. However, the whole world noticed the opportunities of this project only in 2017, and its importance for China, and also for the BRI region. Leaders from 29 countries and over 1,600 representatives from 140 other countries attended the *Belt and Road Forum for International Cooperation* (BRFIC) organized in Beijing in May 2017. Since then, under the idea of the New Silk Road, the policy of *soft expansion* has developed, which includes expanding cultural influences, financial aid for selected projects, and supporting regional integration. The BRI has grown in scope and should be perceived as an international collaboration strategy for common development. Whether a given country will benefit from this initiative or not depends only on the governments' decisions (Wang, 2019).

Polish-Chinese relations

Although Polish-Chinese relations have never been a priority for previous Polish governments, along with the growing importance of Beijing in the international arena, Poland has begun to pay more

attention to closer relations with China in the political and economic spheres. However, the results of these efforts remain limited, and controversies related to the nature of China's foreign policy and international expansion are growing. In order to understand the current dynamics of the relations between Warsaw and Beijing at the bilateral and multilateral levels, one should first understand the historical conditions for the development of these relations.

Polish-Chinese relations in the last few decades were to a large extent conditioned by wider political and economic context in the international arena. Given both geographical and cultural distance between the countries, the People's Republic of China (PRC) has never been a leading international partner for the Polish government. Poland established official diplomatic relations with the PRC in October 1949, the second country after the USSR. Initially, these relations developed relatively dynamically; the PRC Prime Minister Zhou Enlai visited Poland in 1954 and 1957, and a Polish delegation of the Central Committee of Polish United Worker's Party (Polish: Polska Zjednoczona Partia Robotnicza – PZPR) visited China to attend the 8th Congress of the Chinese Communist Party (CCP). In connection with the split between the USSR and the PRC, the relations between Poland and China also weakened (Gawlikowski, 2009).

This situation changed only after the death of Mao Zedong. An era of reforms initiated in the late 1970s under the leadership of Deng Xiaoping became an opportunity for creating new relations between Poland and China. However, internal problems of both countries prevented the strengthening of dialogue. The year 1989 turned out to be a breakthrough for both Poland and the PRC, but for extremely different reasons, which once again hindered cooperation. Even after 1989, Poland's diplomatic relations with China can only be described as correct, apart from the PRC government's disapproval after the Dalai Lama visited Poland in 2008. The diplomatic situation only changed in 2010. First, during the 2010 EXPO in Shanghai, Poland received a very prominent exhibition space, which was well received by the Polish government. Then in 2011, the President of Poland, Bronisław Komorowski, visited China, where he signed a strategic partnership agreement between Poland and China. In 2012, the Prime Minister of China, Wen Jiabao, visited Poland. During his stay in Warsaw, the first summit of the heads of governments of the countries of Central and Eastern Europe and China took place. In practice, this meeting turned out to

be the inauguration of the so-called platform 16+1, a mechanism for multilateral cooperation between the PRC and the 16 countries of the region. This event symbolically assigned Poland the role of leader of Central and Eastern Europe in relations with China. Since then, the Polish government has continued to strengthen its relations with the PRC. Poland sees opportunities that go hand-in-hand with cooperation with China; however, despite the signing of many bilateral contracts and agreements, most of their assumptions have not been implemented yet (Tuszyński, 2014; Habowski, 2016).

Prior to the establishment of the People's Republic of China, Poland and China maintained scientific relations. Even though these relations may seem more fruitful than diplomatic ones, China has never been an important field of study for Polish scholars. However, two Polish travelers, a missionary and a scientist, are historically significant. The first documented contact with the Chinese was made by Benedict of Poland (Polish: Benedykt Polak, Latin: Benedictus Polonus), a Franciscan, who entered the court of the Great Khan of the Mongol Empire in 1246 with Giovanni da Pian del Carpine. He was the author of the chronicle *De Itinere Fratrum Minorum ad Tartaros* (English: *On the travel of Franciscan friars to the Tatars*), and another work *Historia Tartarorum* (English: *The history of the Tatars*), both published centuries after his death. In the 17th century, other Poles visited China, the Jesuit missionaries Michał Boym (Chinese: 卜彌格, pinyin: Bǔ Mígé) and Jan Mikołaj Smogulecki. Apart from his missionary work, Michał Boym was involved in collecting scientific materials. From this, he developed a series of works about China, including Chinese medicine, local fauna and flora, descriptions of the country, and most importantly, maps and atlases of China. Unfortunately, many of his works were not published (Olszewicz, 1953, Miazek-Męczyńska, 2014).

In the 21st century, China became the world's second-largest economy by nominal GDP and until 2015, it was the world's fastest-growing major economy. Poland should seek cooperation, especially since China offers a number of proposals that Poland can benefit from (IMF, 2013; The World Bank, 2019). Assumptions of economic agreements signed between Poland and China have so far not been implemented due to numerous formal barriers and bureaucratic problems. Due to these setbacks, Poland should consider becoming involved in other branches of cooperation, one of which may be education.

Education on the Belt and Road

Education has always played an important role in China. The imperial examination system was in force until the early 20th century and served as a tool for the direct selection of government officials. The biggest changes in the country's education system occurred at the end of the 20th century when Maoist attachment to ideology was replaced by skills and knowledge. This was followed by the appreciation of practical sciences, especially technical ones. Currently, the Chinese government faces many challenges regarding its education system, ranging from elementary schools to higher education. Some of the concerns are similar to those of their Western counterparts, as no education system is perfect. To improve its education system, China seeks solutions, further reforms, and support from foreign governments (Yong, 2014). One of the ways to find allies in the search for better education is the *Belt and Road Initiative*.

One of the five major goals for the BRI is 'people-to-people bonds.' Even though this term may describe a variety of actions, the Chinese government has stated that the main way to achieve this goal is education. In July 2016, the Ministry of Education released *Education Action Plan for the Belt and Road Initiative*, a document that has since served as a guidebook to the ideas and visions proposed by the Chinese government (MoE, 2018a). According to the document, "education is vital to the strength of a country, the prosperity of a nation, and the happiness of a people" and it should be used to develop the remaining goals of the BRI. For China, it is important to integrate with global educational trends and to also promote common educational prosperity among nations along the BRI. China is also open to cooperation in as many educational projects that will contribute to further development of the BRI region as possible (Belt and Road Portal, 2017).

The *Education Action Plan* includes three visions for cooperation for countries along the BRI to "work together to build a Belt and Road educational community," and to promote the improvement and development of education in order to educate a wide range of specialists whose knowledge may support the BRI. To accomplish these goals, the BRI countries should endeavor to complete the proposed visions: a) "**promote closer people-to-people ties**" – meaning the improvement of the relations between the nations of the BRI countries and deepening the understanding between the people; b) "**cultivate supporting talent**" – meaning the promotion of

talents that may be supportive for realizing the BRI goals; c) **“achieve common development”** – meaning common co-actions of BRI countries to improve the level of education in the region (Belt and Road Portal, 2017).

A set of four principles for cooperation has also been prepared to achieve these visions: a) “focusing on nurturing of the people, prioritizing people-to-people exchanges” i.e. promoting the growth of competences of the population within the region and encouraging people to create bonds to exchange knowledge and qualifications; b) “combining government guidance with social involvement” i.e. governments should cooperate together with schools, universities, and entrepreneurs to promote changes and educational development; c) “realizing shared growth through consultation and collaboration, and fostering greater openness and cooperation” i.e. countries of the BRI region should start reforming their systems of education to be more open to international cooperation and integration; d) “promoting harmony, inclusiveness, mutual benefit, and win-win outcomes” i.e. the BRI countries descend from culturally different civilizations and there is a need for mutual understanding to sustain cooperation (Belt and Road Portal, 2017).

To fulfill the first vision, i.e. **“promote closer people-to-people ties”**, the Chinese government wants to boost student exchanges. Many different scholarships are available both for students and scholars from the BRI region; among the most recognizable aids is the *Silk Road Scholarship* which supports up to 10,000 students from the BRI countries each year. In 2017, 66,100 Chinese students, 3,679 of them on government scholarship, studied in 37 BRI countries. Moreover, in 2017, 317,200 students from the BRI countries studied in China, accounting for 64.85% of all international students (MoE, 2018a). Having so many students obtaining their degrees abroad, there was a need to sign agreements on the mutual recognition of academic qualifications with foreign governments. According to the PRC Ministry of Education, a total of 47 agreements have been signed, including 24 agreements with the BRI countries, including Poland in 2016. China also promoted the implementation of UNESCO’s *Asia-Pacific Regional Convention on the Recognition of Qualifications in Higher Education*, proposed in 2011 and enforced in February 2018. A further step is to pursue efforts at creating a global system for the mutual recognition of qualifications (UNESCO, 2011; Belt and Road Portal, 2017; MoE, 2018b).

Another step to promote people-to-people ties are Chinese language and cultural education, which is particularly supported by the Confucius Institutes (CI), a project established in 2004 which serves to advocate the BRI goals. CIs are non-profit educational organizations with the assistance of the Ministry of Education of PRC, overseen by the Confucius Institute Headquarters (Hanban), operating at universities, colleges, schools, and other educational institutions around the world. Their goal is to promote Chinese language and culture to local society through, e.g., language courses, cultural events, academic lectures, or summer camps (Chen, Wang & Cai, 2010). CIs have an existing initiative that supports the BRI. According to the Ministry of Education, in June 2018 51 of the BRI countries established 135 CI and 129 Confucius Classrooms (MoE, 2018b). Among the activities held by CIs to promote the BRI are the organization of academic lectures and conferences along the BRI, carrying out research on various branches of the BRI, teaching Chinese to students and scholars willing to deepen their academic knowledge of China, or CI scholarships and a Chinese Bridge Competition which allow students to study in China. The Ministry of Education has noted the importance of learning languages and thus promotes studying foreign languages within China, especially those from countries across the BRI region. One of the key universities in China – Beijing Foreign Studies University (BFSU, Chinese: 北京外国语大学, pinyin: Běijīng Wàiguóyǔ Dàxué) has been obliged to increase the number of languages it teaches. In 2019, it offered 101 different languages used as official languages in 176 countries with diplomatic relations with China, and 45 of these languages are offered exclusively at BFSU (BFSU, 2019).

The second vision, **“cultivating supporting talent,”** can be developed by the aforementioned scholarship programs, but the Chinese government has also proposed additional solutions. To prepare future students to study abroad, they must first learn foreign languages and be open-minded to different cultures, especially Western ones. More and more international kindergartens and schools have been opened in China to prepare young Chinese for becoming overseas students. Additionally, the Ministry of Education also promotes technical and vocational education and training (TVET). The importance of TVET lays in the variety of technical projects to be accomplished through the BRI. Although TVET is in a way contrary to the Confucian tradition which promoted theoretical knowledge instead of skills,

the Chinese government is aware that it must educate skillful engineers to continuously develop local industry (Xiong, 2011; UNEVOC, 2018).

In China, skilled workers have been undervalued for decades, even though an enormous number of people are employed in blue-collar jobs. In 2006, 270 million people were employed in the workforce, but only 87.2 million (32%) were qualified skilled workers, and only 3.6 million were high-level skilled workers (Xiong, 2011). The situation did not change much, leading to a great shortage of skills. In 2018, the number of employed rose to 776 million, but only 20% (155.2 million) were qualified, and only 6% of those were high-level skilled workers (Xinhua Net, 2018). One idea is to encourage the operation of foreign industries in China to provide vocational skills training along with local TVET institutions to educate specific qualifications needed by those companies. Another project is named Luban Workshops, after Lu Ban (Chinese: 鲁班, pinyin: Lǔ Bān), an ancient Chinese architect. The idea of this project is in a way similar to the Confucius Institutes but for technical and vocational training. Teachers are to provide up-to-date knowledge on technology, promote collaboration between vocational schools in the BRI region, and encouraged to implement vocational education reforms. Luban Workshops operate in African countries, Thailand, Cambodia, Pakistan, and even Great Britain, and are planned to spread to other European countries (MoE, 2018c; China Daily, 2019).

The last vision, “**achieving common development**,” seems more open to all the countries of the BRI region and means enhancing the quality of education through the *Silk Road Education Assistance Program*. However, this program is in fact aimed mostly at the Least Developed Countries (LDCs), which can receive support from China. Starting with the aforementioned Luban Workshops to educate skillful workers, the Chinese government has prepared a set of aids to improve the level of education. First, China will educate staff with different specializations to support those countries to convey their knowledge to local teachers and scholars. Moreover, apart from teacher training, the Chinese government will equip educational institutions with teaching materials and schemes and high-quality technologies. They will also encourage each country to develop new mechanisms of educational fundraising to accumulate more resources, increase the scope of educational assistance, and receive support from external investors. This will achieve shared educational development with support from both the local

government and institutions which will benefit from an educated labor force (King, 2014; Belt and Road Portal, 2017; Ehizuelen et al., 2017).

Since 2013, the Chinese government has supported many educational institutions (31 projects until 2016) in LDCs to show their commitment to the development of the region. Mutual development can be also achieved by increased connectivity between higher education institutions (HEIs). Multiple scholarships for students and scholars, many signed cooperation agreements with governments and HEIs, and a thriving desire to conduct research to go down in history, have propelled collaborative research. Chinese HEIs have established research alliances not only with universities along the BRI, but also with corporations and governments to conduct innovative research in fields such as economics, medicine, and new technologies or science. These alliances allow staff exchanges, resource sharing, division of research costs, and facilitate access to research subjects. Moreover, the Chinese government will establish research centers that focus on understanding the perspective of the BRI countries through their culture and language and also through education, economics, politics, and social development. The centers are expected to evolve into think tanks supporting Chinese decision-makers (MoE, 2018b).

Opportunities for Poland

In the *Education Action Plan for the Belt and Road Initiative*, the Chinese government proposed many suggestions for boosting education using the idea of the BRI. Some ideas are not applicable to Poland; however, Polish HEIs should seek ideas that may be implemented in Poland and may develop our native educational system. This section will discuss several opportunities proposed in the BRI that Polish academics, students, and scholars may benefit from.

According to the Chinese Ministry of Education, in 2017, 608,400 Chinese students left their home country to study abroad, and 1,454,100 students were enrolled in foreign higher education institutions, making China the largest source of international students in the world. The majority of these students are self-funded (89%), which should be important to Polish HEIs (MoE, 2018a). Studying in Poland is much cheaper than Western European countries, due to lower tuition fees, cheaper educational materials, and lower overall costs of living. Moreover, the level of education at Polish academics is comparable to that offered in the West. These factors should incentivize Chinese students willing to

obtain an education abroad; however, the curricula offered by Polish HEIs provide a limited number of degree courses in English, making it almost impossible for Chinese to study in Poland. Polish HEIs should seek opportunities to establish more majors taught in English, encouraging Chinese youth to study in Poland. Gaining these overseas students will increase the internationalization of Polish academies and grant additional income from tuition fees.

Another opportunity for Polish students and young scholars are the *Confucius Institute Scholarships* (CIS). There are currently five CIs in Poland – in Cracow, Wrocław, Poznań, Opole, and Gdańsk – and all offer annual scholarships for those willing to study in China. Students may choose from a variety of types of stays, from a four-week study during summer, up to doctoral degree. Depending on the length of the stay, candidates must meet different sets of requirements; however, a common requirement is that an applicant must know the Chinese language to receive financial aid from Hanban. Nonetheless, CIS degree courses are dedicated only to sinologists and future Chinese language teachers. The Chinese government offers its own scholarship, open to everyone, allowing a student to take degree courses in any major, even those conducted in English. Both of the aforementioned scholarships cover tuition fees, accommodation, insurance, and even pocket money (from 2500 RMB to 3500 RMB per month). The only expenditure for a scholarship holder is the cost of international flights and obtaining a visa (CSC, 2018; Confucius Institute, 2019).

Educational cooperation with China is visible not only at the level of universities but also at the governmental level. In 2018, the National Science Centre (Polish: Narodowe Centrum Nauki), a governmental grant-making agency that provides financial support to Polish scholars conducting research, opened a grant competition called SHENG for research projects carried out by Polish-Chinese teams. SHENG is a competition carried out in cooperation between the National Science Center and the National Natural Science Foundation of China (NSFC). The evaluation included joint Polish-Chinese applications for financing research projects, and experts assessed the scientific value of the projects, the qualifications of the research team, the possibility of project implementation, and the cost estimate. The awarded grants totaled almost 36.4 million PLN, divided amongst thirty projects from 250 applications (NCN, 2019). Even though the next edition of SHENG has not been announced, it is possible that future releases will appear and once again draw the interest of scholars.

These are only a few of the opportunities provided to Polish academia that may be realized through the Belt and Road Initiative. More are likely to come, along with the development of the BRI, with more openness from the Polish government, HEI authorities, and scholars and students themselves.

Conclusions

The number of different projects to be completed using the influence of the BRI is enormous, ranging from scholarships and scholar exchanges to cultural education served by Confucius Institutes, as well as technical and vocational education and training initiatives in the Least Developed Countries. Many other ideas not mentioned in the article may also fall within the vision the Chinese government laid out in the *Education Action Plan for the Belt and Road Initiative*. Cooperation with Chinese partners may be profitable for Poland, not only from a financial perspective but also for the transfer of knowledge. However, there is a need to set a coherent vision of this partnership in order to realize a high number of projects and avoid the recurrence of activities which have already been carried out or completed.

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Relationship between intellectual property and economic competitiveness

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Abstract

Various economic theories indicate that many factors determine the competitive position of national economies. In addition to classical factors such as natural resources, technology, and capital (including human capital), other elements include openness and readiness to generate and implement innovation. An important role is played by institutional and legal systems, which provide economic liberty, free competition, and protection against monopolies, corruption, and crime. According to some research, an important role is also played by issues related to intellectual property (and more precisely, industrial property). The purpose of this article is to verify the importance of intellectual property on economic development. For this purpose, literary studies and patent research were primarily used, including an analysis of the relative specialization index (RSI). The analysis results indicated that the effect of IPP on GNP was not explicit and, depending on the starting position of an economy, and an increase in IPP outlays may have various effects. Another important finding is the extraordinarily dynamic growth of the Chinese economy, as measured by patent indices.

Introduction

The question of economic competitiveness has been of central interest to many economists for decades, and it is often analysed together with the concept of innovation, which is perceived as one of the main factors that determines competitiveness. One of the foundations of innovation are R&D outlays, which in turn are related to intellectual property protection (IPP). Although researchers and policy-makers often explicitly present theses concerning the positive impact that intellectual property rights have on various economies, the empirical literature is much less explicit in this respect.

Theoretic Analysis of relations between IP and competitiveness

Intellectual property is defined within the Convention Establishing the World Intellectual Property

Organization (WIPO), as the collection of rights that refer primarily to (Treaty, 1967):

- literary, artistic, and scientific works;
- interpretations of artist-interpreters and artistic performances;
- inventions in all areas of human activity;
- scientific discoveries;
- industrial models;
- trademarks and service marks, tradenames, and logos;
- protection against unfair competition;
- other types of rights concerning intellectual activity in industrial, scientific, literary, and artistic activity.

The analysis in this study will focus on industrial property. The incredibly diverse definitions of intellectual property rights in specific countries slightly hinders analysing the influence of IPP on the competitiveness of economies. Intellectual property is the object of numerous legal acts, and the sources of

such rights include both domestic and international acts. However, most intellectual property rights are established by domestic laws; hence, their scope is limited to the territory in which regulations apply. The principle of territoriality makes it necessary to apply for the IPP rights in several states simultaneously. The principle of territoriality refers to the right to industrial property – exclusive rights that primarily encompass a territory of a single country where protection is granted.

Issues concerning intellectual property rights can be analysed from either a micro- or macroeconomic point of view. When deciding to start a new innovative project, an entrepreneur must take into account uncertainty related to future income. Therefore, in order to decide which innovation to implement, the expected monopolistic rent from the introduction of an innovative product must compensate for an incurred risk. The less probable it is to obtain a monopolistic rent from an innovation, the greater the benefits may be from innovation for other market players. In this context, other economic entities may also benefit from the effects of technology or knowledge transfer. The launch of an innovative product in the market may lead to its imitation by a market competitor, which will also be a source of additional income. The most popular measure that secures an innovator's rent is the protection of intellectual property (NBP, 2016, p. 42).

From a microeconomic point of view (i.e., the point of view of an innovator), IPP plays a positive role because they give an innovator a chance to gain profit (innovator's rent) from the introduction of an innovation. An entrepreneur who has patented solutions may produce/offer a product they have created or gain benefits from issuing a license.

While trying to transfer microeconomic questions to a macro scale, one may begin with a traditional opinion that assumes a linear dependence between the strength of intellectual property protection and innovation. Stronger IP protection results in a longer period of maintaining a monopoly and the possibility of gaining benefits from the introduced innovation, which in turn stimulates further innovations and should lead to the growth in their number (NBP, 2016, p. 42). The above assumption, however, is not reflected in empirical data.

(Bochańczyk-Kupka, 2017) discusses issues relating to mutual dependencies between a state and its significance and IPP. The author claims that intellectual property is immensely important for contemporary enterprises and national economies, and also cites OECD reports that indicate changing trends

in the structure of GNP generation. They highlight the fact that knowledge-, technology-, and innovation-based sectors currently produce more than 50% value-added. In addition, they are increasingly responsible for employment – in 2013, in EU member states, 1/3 of employees worked in enterprises that significantly used intellectual property (EUIPO, 2016).

Studies that concern the dependence between the pace of economic growth and the strength of intellectual property protection indicate the existence of two different approaches. According to one, the dependence between the pace of economic growth and the strength of an IPP system is directly proportional; therefore, enacting stricter IP protection accelerates economic growth. It is assumed that only the certainty of long-term and strong protection may encourage a potential creator to search for innovation.

In contrast, advocates of the second approach indicate that making the property protection stricter negatively impacts a growth rate because it facilitates the establishment and development of monopolies. Patent protection blocks the flow of knowledge, which may slow innovation processes in an economy (Boldrin & Levine, 2004).

One of the first detailed studies on the dependence between IPP and the level of economic growth was the work by (Falvey, Foster & Greenaway, 2006) which analysed data concerning 80 countries over 5 years. The findings of the study indicated the occurrence of a positive and significant dependence between the level of intellectual property protection and the economic growth rate. According to the authors, in the case of both high- and low-income countries, IPP reinforcement positively affects the growth rate. For rich countries, the provision of security and guarantee of profit for innovators plays an important role. In countries with low income, the strong IPP welcomes the inflow of direct foreign investments and positively affects imports. In the case of countries with an average development rate, the above-mentioned dependencies were not confirmed.

An attempt to combine the above-mentioned approaches is an eclectic model. According to proponents of this approach, the dependence between the level of intellectual property protection and innovation of economies has a U-shaped curve (Bessen & Maskin, 2009). Consequently, both insufficient and extreme IP protection is unfavourable from the point of view of economic competitiveness. Insufficient protection may adversely affect inventions because it does not provide innovator's rent. On the other hand, if protection is too strong, it increases the

share of monopolised sectors and negatively impacts production dynamics by, among other things, limiting the accumulation of experiences during the process of acquiring skills through practice (Furukawa, 2010).

In their research, Bessen and Maskin (Bessen & Maskin, 2009) adopted the assumption of the sequence and complementarity of innovation (a subsequent innovation is based on a previous one; every potential innovator adopts a different research path). In this view of innovation processes, patent protection will not stimulate innovation; therefore, the whole economy may perform better if there was no protection at all. Murray and Stern were also opposed to protection that is too strong. As a part of their analysis concerning relationships between patents and scientific publications, they concluded that the number of article citations significantly decreases after patent protection is granted to inventions described therein. This implies an active influence of obtaining a patent on knowledge diffusion and innovation (Murray & Stern, 2007).

Research into the relationship between intellectual property and economic growth was carried out by Gold et al. (Gold, Morin & Shadeed, 2019), who analysed data from 124 countries from 1995–2011 and used it to create an index that assessed the strength of IPP. The authors indicate the value of this index for economic research and presented initial evidence indicating that intellectual property leads to faster economic growth. Their results coincide with cause-effect relations shown in the literature, namely that IP leads to greater levels of technology transfer and increased domestic innovation. However, this simple picture is hard to match with other aspects that result from their research. An in-depth analysis of the obtained results leads to the conclusion that IP may have little direct influence on growth, and the causal relation stems more from beliefs and opinions rather than from the actual application of IP. This inexplicit situation may result from differences in the methodology, scope, and purposes of research (Lopez, 2009).

One should consider a complementary theory that explains the positive relationship between higher levels of IP protection and growth, i.e. that beliefs may play a greater role than has been previously recognised economic policy literature. More precisely, research suggests that a strong conviction that IP potential increases wealth may be sufficient in itself to obtain growth, despite the lack of a direct foundation in IP regulations in a target country. In this scenario, investors – mostly foreign – react

to the increased level of IP not to obtain IP rights in such a place, but because the greater IPP reinforces their conviction that the economy will likely develop. According to this theory, such political convictions, as suggested by (Briggs, 2010) and detailed by (Morin & Gold, 2014), rather than the direct economic consequences of IP by themselves, lead to growth. This does not mean that IP has no direct impact. The presented evidence is in accordance with the argument that domestic IP systems directly affect the level of domestic innovation, which in turn contributes to economic growth; however, such an influence is at best limited.

While it is possible to ‘prove’ a negative statement – namely that IP has no direct economic influence, despite frequent assurances – a number of factors that have been analysed below suggest that an indirect placebo effect not only exists, but may provide a useful supplement (or substitute) for the direct IP impact on investments and imports (Park & Ginarte, 1997). Research carried out by Gold et al. (Gold, Morin & Shadeed, 2019) has shown that the placebo effect was approximately 5 times stronger than the direct IP impact.

As previously mentioned, the analysis of literature concerning IP, innovation, and growth suggests the existence of different opinions on the impact of IP on innovation. Hall and Harhoff explain that although patent rights stimulate research and development and their diffusion, they also hinder the combination of new ideas and inventions and raise transactional costs (Hall & Harhoff, 2012). Due to such mutually balancing tendencies, the authors concluded that theoretic literature does not contain an explicit result with respect to the stimuli provided by patents. Similar findings were given for other forms of IPP (Landes & Posner, 2003).

In the case of developing countries, this suggests that a direct impact of IP on the growth is affected by a number of factors, including the research and development potential of a country, wealth per capita, the character and efficiency of domestic institutions, and the phase of development (Chu, Cozzi & Galli, 2014). Therefore, there is no one optimum IPP level for all countries. Instead, the literature suggests that countries should modify their IPP depending on the comprehensive and liquid innovation ecosystem that encompasses the abovementioned factors. According to the conclusion of Hudson and Minea (Hudson & Minea, 2013), as a result of this situation, ‘we do not observe any more an unchangeable single optimum IP level for every country, but rather an evolving level.

The recognition that an optimum domestic IPP level changes depending on circumstances does not explain which elements in the ecosystem are most important in determining domestic IP protection. Maskus suggested that developing countries can take greater advantage of increased IPP levels when they have 'adequate complementary advantages,' such as greater investments in human capital and more open economies and policies, such as strong antimonopoly regulations (Maskus, 2000). Hudson and Minea discovered that the initial IPP levels and GNP jointly affected the optimum IP levels of a country (Hudson & Minea, 2013). Sweet and Magio indicated that such optima depend both on the level of development and the complexity of an economy (Sweet & Magio, 2015). Ivus et al. indicated that the most important aspect is not the level of IPP but the form of such protection (Ivus, Park & Saggi, 2016).

Researchers have also suggested that IP likely contributes to growth through at least two separate processes: by encouraging foreign rights owners to export hi-tech goods to domestic economies, and by creating incentives for domestic innovation (Ivus, Park and Saggi, 2016).

Table 1 presents the latest leading research into the effectiveness of an IP system in stimulating economic growth, both directly and indirectly. The comparison of such research reveals deep contradictions between studies, which cannot be simply explained.

Table 1. Effects of intellectual property protection (IPP) (Gold, Morin & Shaded, 2019)

Effect of IP on...	Results
Innovation	Positive – Kanwar, Everson (2003) – Chen, Puttitanun (2005) – Schneider (2005) Negative – Hudson, Minea (2013) – Lerner (2009) U-shaped, according to level of development – Kanwar, Everson (2003) – Hudson, Minea (2013) – Chu, Cozzi, Galli (2014)
GDP per capita (middle-income countries)	Negative – Kim et al. (2012) No relationship – Falvey, Foster & Greenaway (2006)
GDP per capita (low-income countries)	Positive – Falvey, Foster & Greenaway (2006) Negative – Kim et al. (2012)

It can be assumed that the discrepancies between the results of research presented in Table 1 may result from differences between models and applied

methods. In addition, it can be concluded that economies constitute multi-dimensional systems and are subject to complex interactions and variables, which may be difficult to capture in a statistical model.

Nevertheless, even if one takes such differences into account, it is also necessary to explain extreme divergences between the obtained results, and one could propose several explanations of the above-mentioned discrepancies. First, some research may be simply incorrect or incomplete. This may result from the applied models, used theories, selected indices, or collected data, which are incorrect or obsolete. Second, related to the first explanation, there may simply be an insufficient number of studies conducted, which would prevent the confirmation of an explicit pattern to explain the situation. Third, since the theory predicts that the impact of IPP on growth depends on other factors, we may observe the effects of an unknown and fundamental cause.

Despite the merit of such explanations, it seems that a fourth theory provides a more interesting clarification, which may be a starting point for future research. According to this theory, the current research has examined the wrong object, i.e., the direct impact of IP on growth, rather than the indirect influence of 'environmental (atmospheric) conditions,' especially the convictions that higher IPP levels lead to growth (Intarakumnerd & Charoenporn, 2015). The contradictory results in the above-mentioned research stem, according to this theory, from including indices that are not related to convictions, and from not taking into account those that are related to them. If this theory proves right, the main obstacle to improving patent systems may lie not in obtaining new in-depth research findings, but in the economic policy of patent systems and particular interests owned by a number of stakeholders in the present system.

Analysis of Patents and their Relationship with the Competitiveness of Economies

Data from EPO and WIPO databases were used to determine which countries play a key role in the race of using knowledge and innovation to build a competitive advantage, and also to indicate which countries best use their potential in several selected sectors. Based on data from the European Patent Office databases (Table 2), it can be concluded that the number of patents is growing systematically. The only exception was the year 2011.

When analysing EPO data from 2009–2018 (Table 3), the European Union showed the most

Table 2. Number of patent applications to EPO (based on data from (EPO, 2019))

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of applications	134 511	151 015	142 822	148 562	148 027	152 703	160 004	159 087	166 594	174 317

Table 3. Total applications – split by main countries (based on data from (EPO, 2019))

Geographic origin	2009	2018	Share 2018	% change 2009–2018
EPO states	68 679	81 468	47%	18.6
United States	32 846	43 612	25%	32.8
Japan	19 863	22 615	13%	13.9
China, People's Republic of	1 629	9 401	5%	477.1
Korea, Republic of	4 189	7 296	4%	74.2
Others	7 305	9 925	6%	35.9
Total applications	134 511	174 317	100%	

applications, followed by the US, Japan, and China, the latter of which saw the highest growth rate.

To determine which technological areas featured the highest number of patent applications, data from 2018 were also analysed, and the list of the most frequently patented sectors is given in Table 4.

Table 4. European patent applications filed with the EPO (based on data from (EPO, 2019))

Technology field	Applications filed (2018)	% change 2009–2018
Medical technology	13 795	38.2
Digital communication	11 940	84.3
Computer technology	11 718	50.6
Electrical machinery, apparatus, Energy	10 722	40.0
Transportation	9 039	47.9
Measurement	8 744	45.2
Pharmaceuticals	7 441	33.5
Biotechnology	6 742	30.8

According to Table 4, objects of patent applications submitted to the European Patent Office are most

Table 5. Patents applications (WIPO) (based on data from (WIPO, 2019))

Country	Number of patent applications
China	1 381 594
USA	606 956
Japan	318 479
Republic of Korea	204 775
Germany	67 712
India	46 582
Russian Federation	36 883
Canada	35 022
Australia	28 906

often medical and digital technologies. An important role is also played by electronic and measuring devices, as well as transport solutions. This indicates which sectors are the greatest field of struggle among enterprises that use IPP in their businesses.

The data concerning patent applications within the WIPO shows a different picture. The list of states with the highest number of patent applications (2017) is presented in Table 5.

Table 6. Universities with the highest number of patents granted in 2016–2018 (based on data from (WIPO, 2019))

University	Country	Number of patents (2016–2018)	% change (2016/2018)	Number of patents (2018)
University of California	USA	1417	15.40	501
MIT	USA	731	–8.47	216
Shenzhen University	China	396	131.00	201
South China University of Technology	China	290	240.00	170
Harvard University	USA	511	3.68	169
University of Texas System	USA	474	1.94	158
Seoul National University	Korea	378	12.30	137
Tsinghua University	China	311	63.10	137
Stanford	USA	338	16.35	121
China University of Mining and Technology	China	297	35.71	114

The undisputed leader in this case is China, which far exceeds the US and Korea. The growing importance of China is further confirmed by the list of universities (Table 6) that are granted the highest number of patents, as well as enterprises that are patent application leaders (Table 7).

Table 7. Enterprises with the highest number of patent applications (2018) (based on data from (WIPO, 2019))

Company name (country)	Number of patents application
Huawei Technologies (China)	4 024
ZTE (China)	2 965
Intel (USA)	2 637
Mitsubishi Electric (Japan)	2 521
Qualcomm (USA)	2 163
LG Electronics (Republic of Korea)	1 945
BOE Technology (China)	1 818
Samsung Electronics (Republic of Korea)	1 757
Sony (Japan)	1 735

As a part of the analysis, the relative specialization index (RSI) was also used. When analysing patents, an additional value indicates that the country has a relatively high share of patents in the total number of applications concerning a technology area. The higher the value, the greater the country's advantage over other countries.

$$RSI = \log \left(\frac{F_{C,T} / \sum_C F_{C,T}}{\sum_T F_{C,T} / \sum_{C,T} F_{C,T}} \right) \quad (1)$$

F_{CT} – patent applications from country C and in the technology area T ,

F_C – patent applications from country C ,

F_T – patent applications within the technology T .

Data included in the following analysis came from the WIPO database from 2010–2014 and 2017–2018 for comparison. Considering another timeframe may result in significantly different results because the number of patent applications from a country within a technology area is not necessarily stable.

The diagrams in Figures 1–8 graphically present the results of the conducted analysis and indicate which countries have a relative international advantage in selected industry areas (technology). In addition, comparing data from 2010–2014 and 2017–2018 shows that in the case of this analysis, we also face the growing importance of the Chinese economy, which became a global IT leader in several sectors.

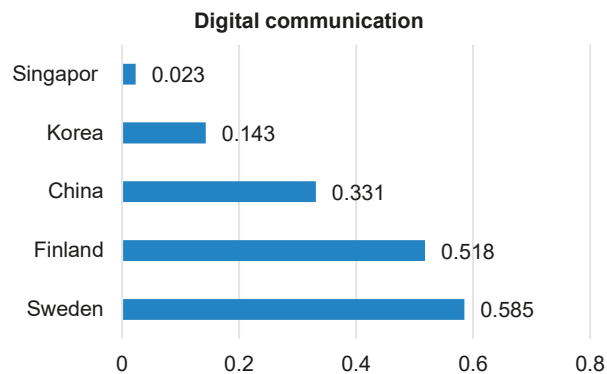


Figure 1. RSI index (2017–2018) for patents in digital communication (based on data from (WIPO, 2019))

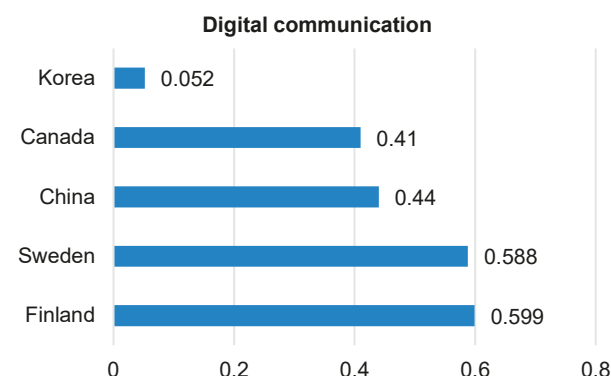


Figure 2. RSI index (2010–2014) for patents in digital communication (based on data from (WIPO, 2019))

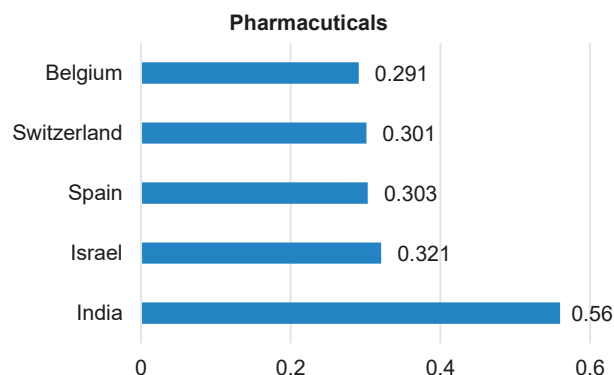


Figure 3. RSI index (2017–2018) for patents in pharmaceuticals (based on data from (WIPO, 2019))

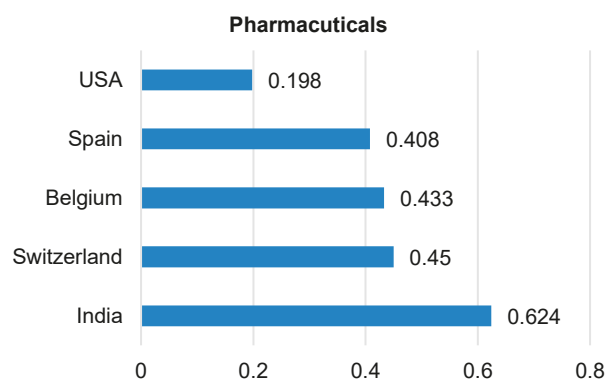


Figure 4. RSI index (2010–2014) for patents in pharmaceuticals (based on data from (WIPO, 2019))

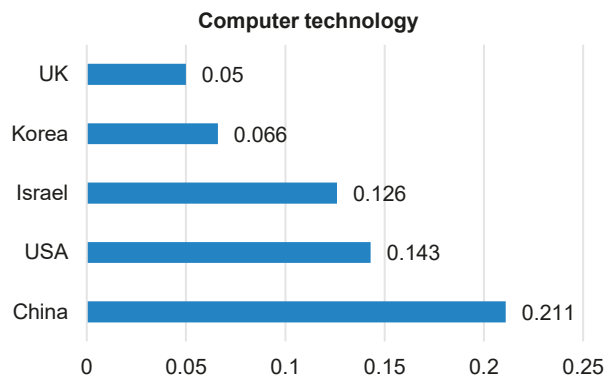


Figure 5. RSI index (2017–2018) for patents in computer technology (based on data from (WIPO, 2019))

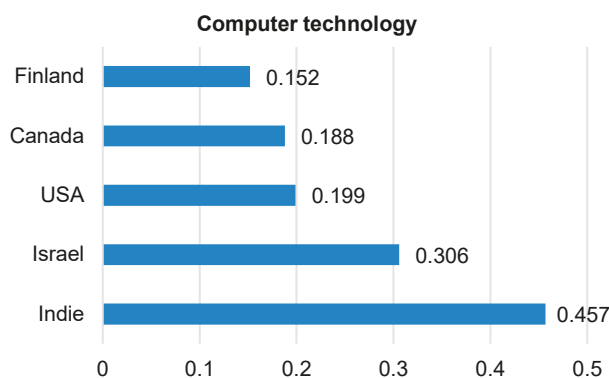


Figure 6. RSI index (2010–2014) for patents in computer technology (based on data from (WIPO, 2019))

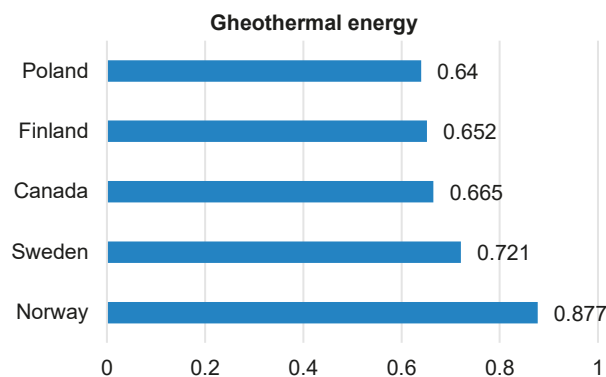


Figure 7. RSI index (2017–2018) for patents in geothermal energy (based on data from (WIPO, 2019))

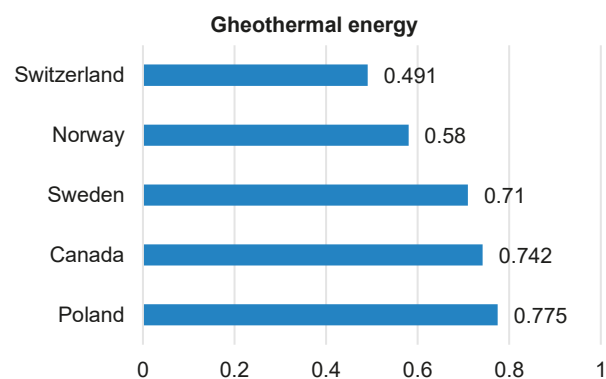


Figure 8. RSI index (2010–2014) for patents in geothermal energy (based on data from (WIPO, 2019))

The analysis shows that countries can play a major role in several technologies. It also reveals the growing importance of China. In addition, Switzerland plays a major role, which may be related to the fact that many international concerns (including pharmaceutical ones) have their registered offices in that country. Poland, on the other hand, is featured as a country with the largest number of patents in geothermal energy.

Conclusions

The conducted analysis leads to the conclusion that the dependence between competitiveness and IPP laws is stronger and noticeable on the micro-level. Enterprises with interesting solutions that are protected with patents, can be turned into a significant competitive advantage. However, with respect to macroeconomic analysis, this dependence is no longer so explicit, and one can quote a number of studies indicating that the strong IPP system negatively influences innovation and domestic GNP. Intellectual property rights can have both stimulating and hindering effects, and it is difficult to isolate the nature of such an influence, which depends on a variety of conditions.

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Maritime University of Szczecin

The Maritime University of Szczecin (MUS) continues the tradition of marine-related education at Szczecin's maritime schools that was established in 1947. Since then, it has developed dynamically and maintained the highest standards in all areas of research and education.

MUS is recognized by the maritime industry as an important research centre developing marine engineering, navigation, transportation engineering and many other fields. MUS provide research services by **Green Energy – laboratory of wind power plants**, **Marine Fuel and Lubricating Oils Laboratory**, **Maritime Risk Analysis Center** and **Marine Power Plants Laboratory**.

Experts at the University develop innovative concepts like the LNG terminal in Świnoujście. The **European LNG Training Centre** (at MUS) provides the necessary training and awards the required qualifications for operating the terminal LNG equipment and LNG tankers.

The **Baltic Fishing Training Centre in Kołobrzeg** is a new MUS unit, established in June 2013. There are plans to set up a European Maritime Education Centre in co-operation with other universities of the Baltic states. This project involves two MUS training units, the Marine Traffic Engineering Centre and the Marine Rescue Centre. These units, equipped with several state-of-the-art simulators, will be run a broad training courses for Polish and foreign seafarers of all ranks.

The **Marine Rescue Training Centre**, one of the largest and best equipped centers of its type in Poland, offers training courses covering areas such as safety, life rescue, health security and environment protection. Participants are trained to respond in extreme emergency situations.

The **Training Centre for Marine Officers** runs training qualifications and specialized courses for merchant and fishing fleets officers.

The education of mariners calls for thorough onboard seamanship training. Part of this training takes place aboard the modern research-training vessel **Navigator XXI**.

MUS graduates, with an excellent academic background of theoretical knowledge and practical skills, become specialists recognized in Europe and internationally. At present, students can choose a program at one of our five faculties, all conferring bachelor, master in Polish, or in English (selected programs). Doctoral studies are possible at two faculties: Faculty of Marine Engineering and Faculty of Navigation.

There are five faculties at the Maritime University of Szczecin:

1. Faculty of Computer Science and Telecommunication

The following field of study is available:

- Computer Science

2. Faculty of Engineering and Economics of Transport Engineering

The Faculty of Engineering and Economics of Transport Engineering offers courses in four major fields:

- Management and Production Engineering
- Transport
- Logistics
- Management

3. Faculty of Marine Engineering

The following field of study is available:

- Mechanical Engineering

4. Faculty of Mechatronics and Electrical Engineering

The following field of study is available:

- Mechatronics

5. Faculty of Navigation

The Faculty of Navigation offers courses in four major fields:

- Navigation
- Transport
- Geodesy and Cartography
- Naval Architecture

Maritime University of Szczecin provides education to professionals who succeed in finding jobs on the sea and in land. Our graduates are well prepared to meet the requirements of the employment market – English-speaking and equipped with modern knowledge.

Our education programmes comply with requirements of STCW Convention. Our training centres provide continuing education on safety and professional development.



Maritime University of Szczecin

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The **MUS Innovation Centre** is a company established by the **Maritime University of Szczecin** and it was founded in August 2013. We were established in response to growing interest in solutions that arise at the Maritime University of Szczecin – one of leading maritime universities in the world.

Our main goal is to provide these solutions to the market. As an independent company, but working closely with the University, we are your first and last stop on the way to use the knowledge and skills of the university faculty.

Our main task is to commercialize the **results of scientific research and inventions**. We also offer the opportunity to benefit from our **modern laboratories, research facilities and highly qualified staff (R&D)**.

We are especially interested in collaborations in the following areas:

- **Research, expertise, analysis, opinions, training**
- **Sale of licenses (exclusive and non-exclusive)**
- **Establishing a new company with or without VC/seed involved (spin off, spin out)**
- **Other kinds of IPR sale**
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If you have any questions please do not hesitate to contact us. More information about our services can be found on www.innoam.pl.

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We got a ministry grant for our quarterly development

We hereby inform, that the quarterly *Zeszyty Naukowe Akademii Morskiej w Szczecinie*, *Scientific Journals of the Maritime University of Szczecin* following Decision No. 583/P-DUN /2019 of 21 May 2019 received funding for the years from 2019 to 2020 from the Ministry of Science and Higher Education of Poland for the activities of promoting science. The project includes the tasks: translations and proofreading.



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