ISSN (online) 2543-912X ISSN 2543-6597

Ekonomia i Zarządzanie
Economics and Management

Engineering Management in Production and Services

Volume 10 Issue 4 2018

Bialystok University of Technology

International Society for Manufacturing, Service and Management Engineering

ISSN 2543-6597

Bialystok University of Technology
Faculty of Engineering Management

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ISMSME
International Society for Manufacturing, Service and Management Engineering

Engineering Management in Production and Services

Volume 10 • Issue 4 • 2018

www.empas.pb.edu.pl

Frequency

ECONOMICS AND MANAGEMENT
is published quarterly since 1998

As of the beginning of 2017 the journal
is published under a new name:
ENGINEERING MANAGEMENT
IN PRODUCTION AND SERVICES

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Publisher

Bialystok University of Technology
Wiejska 45A, 15-351 Bialystok, Poland

The International Society
for Manufacturing Service
and Management Engeneering (ISMSME)

Submission

Papers for submission should be prepared according to the *Authors Instructions* available at www.empas.pb.edu.pl

All papers should be submitted through the electronic submission system

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Indexation

Journal is indexed in SCOPUS, EBSCO Business Source Ultimate (Complete), Norwegian Register for Scientific Journals, Series and Publishers, Index Copernicus, ERIH PLUS, Google Scholar, Central European Journal of Social Sciences and Humanities, Research Papers in Economics (RePEc), BazTech and BazEkon databases

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Improving the mechanism of securing the originality of texts published in "Engineering Management in Production and Services" – tasks financed in the framework of the contract no. 735/P-DUN/2018 by the Ministry of Science and Higher Education from the funds earmarked for the public understanding of science initiatives.

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ISMSME International Society for Manufacturing, Service and Management Engineering

received: 30 August 2018
accepted: 1 December 2018

pages: 7-20

Relations between risk attitudes, culture and the endowment effect

Anita Kolnhofer Derecskei

ABSTRACT

The main purpose of this research was to examine whether systematic cross-national differences existed in risk preferences. As a part of the survey, it was also tested how the subjects decided on behalf of their friends. Considering the type of risk-taking and the role of endowment plus relevant cultural backgrounds, the answerers were grouped, and each segment could be identified. Finally, this segmentation could be correlated with behaviour in risk decisions. Here, the Allais situation was used testing respondent behaviour in risky decision-making on behalf of others. This paper used the validated DOSPERT Scale, measuring risk perceptions and risk preferences of international students (n=244). The used survey contained different risk attitudes depending on decision making and involved the following criteria: Ethical, Financial, Health or Safety, Recreational, and Social Risks. Applying the DOSPERT Scale, differences were also found between 'Risk-Taking', 'Risk-Perceptions', and 'Expected Benefits'. This result can be explained by different risk attitudes particular to people making decisions involving measured risks. At the same time, thanks to the worldwide sample, this paper focused on cultural differences and observed the impact of different cultural backgrounds on risk-taking. Comparing personal traits with Hofstede's cultural UAI (Uncertainty Avoidance Index) helped us understand deeper cultural influences. The sample was widely heterogeneous, which led to some changes in the original research question and provided a new method in the conceptual model. Based on the state of the art, a conceptual model was deduced, three hypotheses were tested, and three various segments were identified regarding the personal DOSPERT (Domain-Specific Risk-Taking Scale) Risk Preferences. In the second part of the paper, Personal Risk Preferences were connected and tested not only using the national culture background but also attitudes towards the endowment. Although there was no significant correlation between the distribution of risk perception, the styles of each role might show how the cultural heritage impacts various decisions and risk levels.

KEY WORDS

risk, management, cultural differences, principal-agent problem, ownership

DOI: 10.2478/emj-2018-0019

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Introduction

Risk is a relevant part of the life of a business and society. Furthermore, it forms an integral part of a business as risk is attached to every choice between various alternatives and final decisions. Almost every important economic decision involves some risk and uncertainty. But in mainstream economics, where a subject allocates resources in order to satisfy his or her needs, risk is explained by utility theories. Seemingly, "risk attitude is nothing more than a descriptive label for the shape of the utility function presumed to underlie a person's choice. A person's risk attitude describes the shape of his or her utility function (derived from a series of risky choices) for the outcomes in question" (Weber et al., 2002, p. 264). Nowadays, it is insufficient to use a lonely model or

inductive theories to determine the business behaviour of actors and estimate their final decisions. As a major approach, the Homo economicus model demands an interdisciplinary view. Therefore, psychology and economics need each other, and this phenomenon appears in findings of the field of economic psychology (e.g. Palmer et al., 2013 studied cognitive neuroscience and moral philosophy revelations of risk in hypothetical financial options).

Risky problems are mainly encountered in financial or gambling situations. The DOSPERT Scale serves as one of the validated solutions measuring risk in three dimensions and six different aspects. According to this method, 'risk' as an expression refers to uncertainty as a synonym. "People differ in the way they resolve decisions involving risk and uncertainty, and these differences are often described as differences in risk attitude" (Blais & Weber, 2006, p. 33). These results were assumed in H2. Based on individual DOSPERT scores, the respondents can be grouped into no more than three clusters, and each cluster can be characterised.

Although risk can be characterised using personal differences, our personalities are affected by culture and society. Our perceptions are driven by the living environment, values, common experiences, exhibited habits and used languages. Therefore, this paper aims to produce a wide study of risk measurement using the validated DOSPERT scales as well as to make a comparison using the Hofstede's Uncertainty Avoid Index.

According to Bakacsi (2015), who referred to Eisenhardt's work, the premises of the Homo economicus model are based on ideas of 'selfish or self-authored' agents, bounded rationality and risk avoidance. The tendency for risk avoidance leads to problems in contracts and agreements. So, there is a closed circle where the principal–agent relationship and the endowment effect impact the political and legal background that forms our culture while culture influences our risk perception. Hopes that Homo economicus is not only self-oriented can be substantiated using the study by Chang et al. (2016) maintaining that economists are also concerned about the well-being of others and have other-regarding preferences. Dawes and Thaler (1988) detailed the effect of altruism. According to them, altruism is the reason behind cooperation, and it results in "doing the right (good, honourable, …) things", which clearly motivates many people. Indeed, all of these interconnections form the fabric of culture and trigger ethical concern. Moreover, all these soft factors impact decisions made by Homo economicus because usually people decide differently on behalf of others than on behalf of themselves, which is indicated in H3. Characteristics particular to respondent clusters can be connected with roles of the endowment. Therefore, this research focused on risk perceptions (personal level) depending on the cultural background and the outcome of a risky situation encountered by a recipient. Most of these factors mentioned above were tested using game experiments similar to those described in this study. This paper aims to fill the research gap regarding the dependence of risk perceptions (personal level) on the cultural background. Consequently, the paper follows the classical IMRAD structure (i.e. introduction of detailed methods and results is followed by a conclusion and discussion). The remaining part of the article consists of several sections, starting with the Introduction, which reviews the importance and relevance of the topic. Next, literature review focuses on risk, its cultural differences and their relevance as well as the endowment effect. Based on the endowment effect, the subjects were divided into four groups. Besides, the literature review served as a basis for the formulation of hypotheses and the theoretical model presented in the section named research questions and hypotheses. Next, there is a section detailing the methodology and samples, which is followed by results. Final sections are discussion followed by Conclusions and a brief overview of research limitations explaining implications for future research efforts.

1. Literature Review

According to Kahneman (2013), risk is not objective; so, it is not possible to give its clear definition because it depends on the way a subject judges each risky situation. After all, the Nobel Prize-winning authors Kahneman and Tversky firstly considered risk a notable economic factor (Tversky & Kahneman, 1974). In their earliest work, risk was identified with the probability of an outcome and the uncertainty of a situation. In economics, risk is addressed using expected utility theories. The authors called the attention of economists to the need for understanding psychology.

Dohmen et al. (2009) collected and tested individual risk attitudes. The authors focused on the

measurement, determinants and behavioural consequences of risk. An etic approach was suggested because risk measurement and recommendations focused on those possibilities that were considered unrelated to cultural differences. An etic account attempts to be "culturally neutral", limiting any ethnocentric, political, and/or cultural biases. This paper aims to find cultural differences among risk perception styles. Therefore, as an emic account comes from a person within the culture (Morris et al., 1988), the so-called emic approach was chosen. Using this approach, cultural variables fit into general causal models of a particular behaviour. This approach offers a methodology that focuses on external and measurable features that can be assessed by parallel procedures at different cultural sites. That is why the use of a multi-setting survey makes a cross-sectional comparison possible. This part assumed H1. Namely, Individual DOSPERT scores and the Hofstede's cultural UA dimension index had significant relationships.

Risk is judged depending on its definition. Blais and Weber (2006) marked out that everybody would have different attitudes when making decisions that involve Ethical, Financial, Health/Safety, Recreational, and/or Social risk. Moreover, differences exist between "Risk-Taking", "Risk-Perceptions", and "Expected Benefits". It can be stated that they followed an etic approach as well. They suggested a validated (i.e. scientifically approved) scale for risk measurement. Only one dimension was used from these branches and it is detailed further. Although in Hungary, Radnóti (2010) translated and tailored the survey to Hungarian specifications, this study preferred the original English version. That means that although the emic approach is also implemented, this study used the original version and was compared with the Hofstede indices which are absolutely emic-approach related.

According to Faragó and Kiss (2005), the level of uncertainty and the level of stakes impact on the outcome of hypothetical bet situations. While entrepreneurs focused on the level of stakes, students were more influenced by the probability factor. There is an absolute agreement with the statement because profit-making and loss-avoiding situations motivate business-sector participants to choose higher stakes that sometimes entail higher risk. Consequently, greater emotional value is attached to profit and loss. This can lead to further investments in loss-making projects and such situations can be explained by the endowment effect. Faragó (2008) found that the type and amount of resources (reference points) also impact on risk-taking behaviour. Approaching the extinction point, people take greater risks. The abundance of resources also means the tendency to take big risks, but mainly in the opposite direction (a negative frame). Finally, having a medium amount of resources indicates the avoidance of risk.

At the same time, most cultural differences have to be taken into account. Birnbaum (2008) summarised the state of the art and completed the individual level with a group level. Before Weber et al. designed the DOSPERT Scale, they also focused on a cultural comparison in the field of risk.

In their study (Weber & Hsee, 1998), they divided the reasons for differences in risk perception into three levels: (1) individual, (2) situational, and (3) cultural. They found that reliable cultural differences in the pricing of risky options exist among American, Chinese, German and Polish respondents. They thought that these differences were caused by the individualism–collectivism factor, which is also used in Hofstede's work. Among others, Vasvári (2015) also handled the impact of different cultural backgrounds. However, the earliest studies focusing on cultural differences can be traced back to Hofstede. Based on Hofstede's research (1980), attitudes to uncertainty avoidance, and consequently judgments of risk, can be assumed to differ by culture. Hofstede defines uncertainty avoidance as the following: "the way that a society deals with the fact that the future can never be known: should we try to control the future or just let it happen. This ambiguity brings with it anxiety and different cultures have learnt to deal with this anxiety in different ways. The extent to which the members of a culture feel threatened by ambiguous or unknown situations and have created beliefs and institutions that try to avoid is reflected in the score on Uncertainty Avoidance" (Hofstede Centre, 2018). It has to be underlined that Hofstede focused on uncertainty (i.e. "The Uncertainty Avoidance dimension expresses the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity") and not on risk, because in their opinion, risk is mainly a personal trait involving how the probability of an event's positive or negative outcome can be managed. Vasvári (2015) drafted the concept of risk and referred to Hofstede's dimensions; the author underlined that where uncertainty, measurability and decision are familiar concepts, the joined areas result in risk.

Faragó (2008) also used Hofstede's dimensions and demonstrated "some specific tendency

characterising Hungarian organisational culture: both proactive and aggressive competition are practised in successful organisations while competitive aggression is found to be a risk-aversive strategy in other countries. Further, dynamic and friendly environment attracts aggressive competition, and a dynamic and hostile environment provokes proactivity. The opposite relation was found in western organisations. The decreasing risk-taking propensity of unsuccessful and worsening organisations might prevent them to use adaptive strategies to become more successful" (p. 29).

According to Camerer (1998), some studies concentrated on fitting theories to individuals. As mentioned earlier, risk-taking preferences might be taken into account. Palmer (Palmer et al., 2013) detailed how individual differences could be measured, also mentioning cross-cultural differences. However, it is not only separate individuals that are affected by culture as sometimes a decision has to be made on behalf of friends (partners) and this challenges individuals' risk perceptions and risk-taking attitudes (Kolnhofer-Derecskei, 2017). The other side of the coin is that altruistic behaviour can be motivated.

Making a decision on behalf of somebody else (i.e. a decision is made by one person, but the outcome is enjoyed by somebody else) can be described using the following theories: indifferentists, agents against principal, the braves or the double Risk-Takers, good friends (Tab. 1).

Information included in Tab. 1 helps to clarify each group facing them with decision alternatives.

The paper by Andreoni and Sprenger (2010) is absolutely relevant because the Allais problem might be connected with an uncertain and certain effect. The management of uncertainty among different cultures was measured by Hofstede (2017). However, a more in-depth study is available in an early work by Kolnhofer-Derecskei (2017) relating ethnicity to different roles. In this paper, subjects were grouped into types mentioned before (Tab. 2). Further and wider evaluations were investigated because individual-based roles were connected with cultural impacts.

Individual levels should be connected with the cultural level, and the transition could be the level of regulation (e.g. the national legal system). Fehr and Fischbacher (2003) highlighted the interaction between altruists and selfish subjects in human cooperation. A minor group of altruists can affect the majority of selfish subjects. The authors tested the effect of punishment and reward in the case of altruism. Calabuig et al. (2016) found that the endowment effect disappeared with punishment. So, punishment has an opposite psychological effect on intrinsic motivation. Friendship and subjective positive feelings between owners and decision makers improve rationality through shared responsibility (e.g. unwritten businessmen agreement). Previous findings by Kolnhofer-Derecskei's (2017) assumed that people decided systematically differently about their own property rather than that of others. People tended to be more risk-averse when the outcome was theirs but would risk on behalf of others. At the same time, this verified the Agent–Principal Theory and the endowment effect. However, it should be underlined that in the second situation, the safe wins were more attractive for the subjects than the feeling of risk (like in the original Allais paradox situation) if no punishment was applied. On the other hand, Allais followed the between subjects methodology with no replications nor feedback.

Tab. 1. Ownership effects

Theory	Researchers and Theories	Definition
Indifferentists	Endowment effect (Kahnenan et al., 1991)	those who neither risk themselves nor on behalf of a friend. They select the same safe choices two times, i.e. in both cases
Agents against principal	Principal and Agent (Bakacsi, 2015)	those who avoid risk when they have to decide about their money, but take risk on behalf of their friends
The braves or the double Risk-Takers	Fairness (Falk et al., 2008)	those who take risk in both situations (they are not influenced by the identity of the owner)
Good friends	Altruism (Dawes & Thaler, 1988)	those who play risky for themselves but avoid risk in place of a good friend (protect their gains)

Tab. 2. Response variations

Owner	Self		Good friend	
Situation	Certain	Uncertain	Certain	Uncertain
Same safe choices INDIFFERENTIST	X		X	
Good friends FRIEND		X	X	
Double Risk taker BRAVE		X		X
Principal agent AGENT	X			X

2. Research Questions and Hypotheses

The original plan — by which it means discovering the connection between individual risk perception and the level of cultural heritage — was not successful; the main reason was on account of a widely heterogeneous sample. The original idea was expanded and required a larger conceptual model (Fig. 1) where, based on DOSPERT, firstly respondent scores can be segmented and characterised. Later, this segmentation was studied in relation to ownership roles. Finally, three hypotheses were formulated.

Following hypotheses were formulated:

H1. Individual DOSPERT scores and Hofstede's cultural UA dimension index have significant relationships.

Weber and Hsee (1998) divided the reasons for differences in risk perception into three levels, namely, (1) individual, (2) situational, and (3) cultural. Blais et al. (Blais & Weber, 2006) prepared DOSPERT as a tool that measures risk perceptions on the individual level. One of Hofstede's dimensions focuses on uncertainty which can be considered as the cultural level of risk. Faragó (2008) and Vasvári (2015) found the interaction between the two levels. In this study, this relationship was measured by both indexes. Focusing on the individual level, the following hypothesis was formulated:

H2. Based on individual DOSPERT scores, the respondents can be grouped into no more than three clusters, and each cluster can be characterised.

DOSPERT as a possible indicator of individual risk level relies on various dimensions. These results help us identify and understand different clusters of subjects. Because of the number of respondents, these clusters are no more than three. Characteristics of these clusters are based on the original DOSPERT's groups (Blais & Weber, 2006). Making a decision on behalf of somebody else is a risky situation, which also causes ownership problems. This gave rise to the following hypothesis:

H3. Characteristics of the clusters can be connected with endowment roles.

Due to the state of the art (Tab. 1) ownership applies to four different types of behaviour. Kolnhofer-Derecskei (2017) underlined that the subjects respond differently when deciding about their own interests

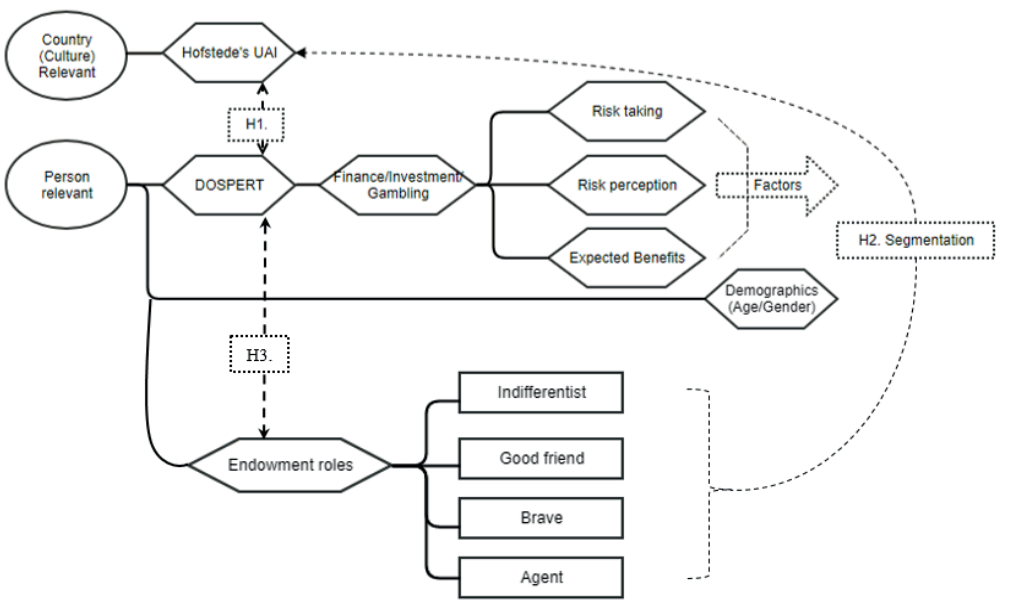

Fig. 1. Conceptual Model

and the interests of their friends. The actors can be identified using the aforementioned types. However, these behaviour types are influenced by a risk level particular to each actor.

3. Methodology and Samples

Data collection process was based on empirical primer survey where the text originated from the original DOSPERT Survey detailed in Tab. 3. In each part, semantic differential scales with 7 items were used, according to the original work.

Investment and Gambling statements were the following:

- Investing 10% of your annual income in a moderate growth diversified fund. (I_1)
- Investing 5% of your annual income in a very speculative stock. (I_2)
- Investing 10% of your annual income in a new business venture. (I_3)
- Betting a day's income at the horse races. (G_1)
- Betting a day's income at a high-stakes poker game. (G_2)
- Betting a day's income on the outcome of a sporting event. (G_3)

Ownership roles were identified earlier (Kolnhofer-Derecskei, 2017). The whole survey was used worldwide in 2017. However, these results can be caused by non-representative sample selection methods. Nevertheless, descriptive histograms (Fig. 2) show some differences among participants' cultural backgrounds.

The participants were contacted via email, requesting to fill-out a survey presented as a Google Survey Form. The respondents came from different home countries (Fig. 2). The statements were offered randomly.

The methodological background was observed after wider descriptive statistics, each factor was summarised and grouped into three main clusters using principal component analysis methods with standardised values (predefined factors reasoned that); in the frame of hypothesis testing (comparison Hofstede's UAI with clustered DOSPERT RT, RP and EB), the nonparametric testing and crosstabs analysis were used. Finally, in the case of segmentation, descriptive statistics and average linkage cluster analysis were preferred again. All the techniques used SPSS (anywhere with p = 0.95) and Excel.

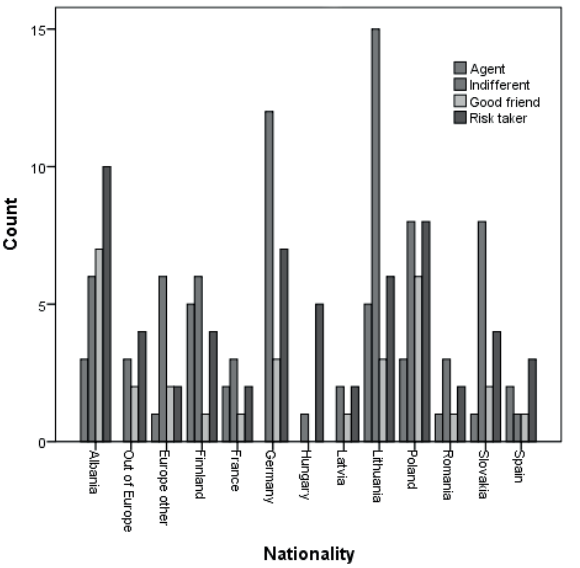

Fig. 2. Distributions depending on respondent roles

Source: author elaboration on the basis of (Kolnhofer-Derecskei, 2017).

Hanoch (Hanoch et al., 2006) highlighted how the interests of subsamples could take a domain-

Tab. 3. DOSPERT Survey

Domain subscales or life domains	Items number	Risk-taking (How respondents engage in risky activities)	Risk perception (How respondents assess the level of risk in each activity)	Expected Benefits of risk (what kind of benefit respondents obtain in each risky situations)
Ethical	6 statements	Instruction: "For each of the following statements, please indicate the likelihood that you would engage in the described activity or behaviour if you were to find yourself in that situation." 7 point ranking scale	Instruction: "we are interested in your gut-level assessment of how risky each situation or behaviour is." 7 point ranking scale	Instruction: "For each of the following statements, please indicate the benefits you would obtain from each situation." 7 point ranking scale
Financial (Investment/ Gambling)	6 statements			
Health/Safety	6 statements			
Recreational	6 statements			
Social	6 statements			
5 categories	30 items	30 items (from 5 categories) have to be evaluated 3 times = 90 scales		

specific approach, hereby influencing the final results of the DOSPERT test. In this study, the major population was foreign university students from partner institutes of the Obuda University. Finally, n=244 valid respondents formed the sample from 28 countries; they were born between 1960 and 1998 (average age of 25.68); 107 males and 137 females filled the survey, mainly students from the fields of Engineering and Business.

4. Results

Mean scores of each measured DOSPERT statement can be found in Tab. 4. The whole sample estimated gambling situations as riskier with a lower evaluated income/benefit (i.e. gambling statements were scored higher in risk perception and lower in the willingness of participation or risk-taking with no significant difference made). However, in the case where participants wanted to take part in financial or investment situations, gambling was less preferred.

All the aforementioned endowment roles (types of subjects) can be identified among the subjects with the following frequencies (Tab. 5). Around 70 percent of the subjects chose the same options for themselves and on behalf of their friends, half of them voted for the risky (certain) and another half for the uncertain (not risky) outcomes.

Unfortunately, none of the separated DOSPERT statements showed significant relationships with Hofstede's UAI (Using Crosstabs analysis Pearson Correlation assymp. sig. were $p>0.05$ in all cases). The main problem was rooted in the small members of each subpopulation. Finally, only the most successful members across the nationalities were selected. Even then, there were no more stochastically significant connections but the results can be seen in Fig. 3. Hofstede's scores are between 0–100; here, these results were divided by 10, so histograms offer a better overview of data (numbers of members are mentioned).

Tab. 4. Descriptive statistics

Descriptive Statistics	N	Min.	Max.	Mean	Std. Deviation
Risk-taking (willing to take part) scores 1–7					
Investing 10% of your annual income in a moderate growth diversified fund. (F/I)	244	1.00	7.00	3.62	1.78
Investing 5% of your annual income in a very speculative stock. (F/I)	244	1.00	7.00	4.19	1.81
Investing 10% of your annual income in a new business venture. (F/I)	244	1.00	7.00	4.20	1.73
Betting a day's income at the horse races. (F/G)	244	1.00	7.00	2.44	1.71
Betting a day's income at a high-stakes poker game. (F/G)	244	1.00	7.00	3.11	1.92
Betting a day's income on the outcome of a sporting event. (F/G)	244	1.00	7.00	2.52	1.71
Risk perception (evaluation of risk level) scores 1–7					
Investing 10% of your annual income in a moderate growth diversified fund. (F/I)	244	1.00	7.00	4.41	1.64
Investing 5% of your annual income in a very speculative stock. (F/I)	244	1.00	7.00	3.82	1.55
Investing 10% of your annual income in a new business venture. (F/I)	244	1.00	7.00	4.24	1.45
Betting a day's income at the horse races. (F/G)	244	1.00	7.00	4.66	1.78
Betting a day's income at a high-stakes poker game. (F/G)	244	1.00	7.00	4.40	1.77
Betting a day's income on the outcome of a sporting event. (F/G)	244	1.00	7.00	4.79	1.82
Expected Benefit (outcome) scores 1–7					
Investing 10% of your annual income in a moderate growth diversified fund. (F/I)	222	1.00	7.00	4.09	1.71
Investing 5% of your annual income in a very speculative stock. (F/I)	232	0.00	7.00	4.27	1.82
Investing 10% of your annual income in a new business venture. (F/I)	233	0.00	7.00	4.30	1.84
Betting a day's income at the horse races. (F/G)	223	1.00	7.00	3.19	1.71
Betting a day's income at a high-stakes poker game. (F/G)	220	1.00	7.00	3.39	1.72
Betting a day's income on the outcome of a sporting event. (F/G)	220	1.00	7.00	3.28	1.85
Valid N (listwise) 0.00 missing value	206				

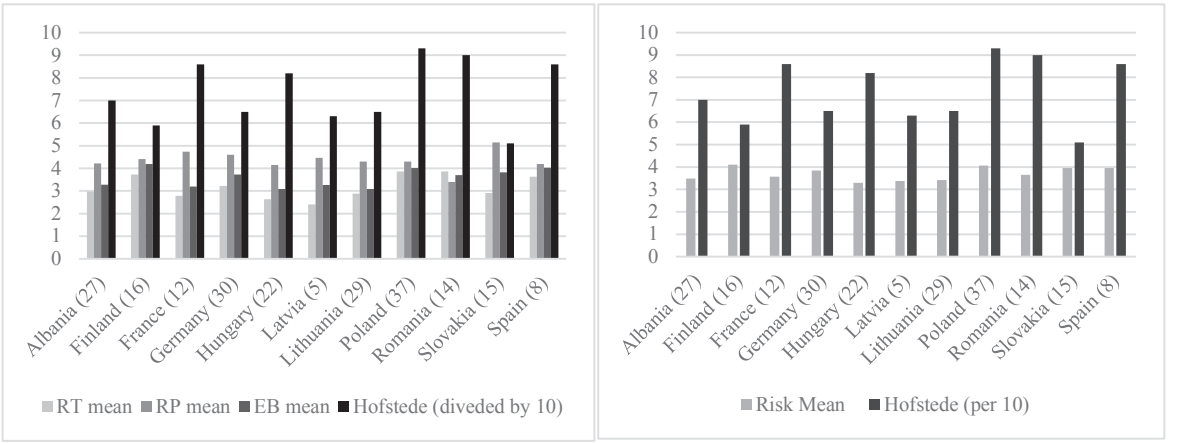

Fig. 3. DOSPERT Survey

Because of heterogeneity, the national differences did not allow a satisfying segmentation. In order to understand the differences between respondents, the cluster analysis was used but beforehand, the high number of factors from a previous grouping (18 statements were grouped into 3 factors) proved meaningful. The MDS Scale draws a stable relationship among statements (Tucker's Coefficient of Congruence = 0.969) in Fig. 4.

After a more in-depth data selection and cleaning, n=204 full filled answers were taken into account. Although in each dimension an average value also could be used, the reliability test (Cronbach's Alfa 0.739) reasoned the usage of three determined factors (based on standardised values). With these three factors the respondents were clustered into three segments (two segment variation was also tested). The three segments are described in Tab. 6.

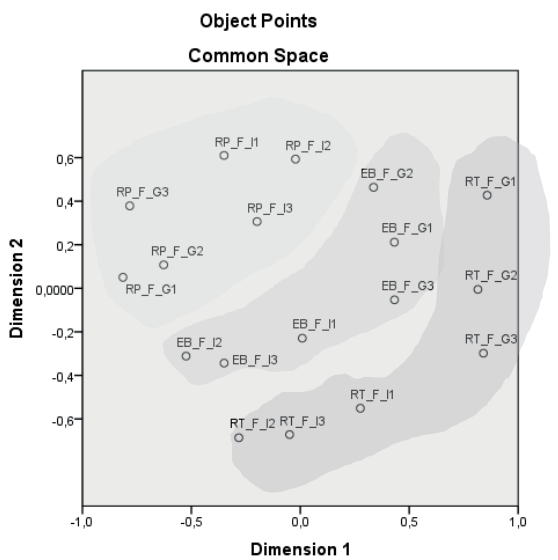

Fig. 4. MDS Scale of the DOSPERT Survey statements

Tab. 5. Crosstabs according to roles (capita)

Roles	Frequency	Percent (distribution)
Agent	23	12.4
Indifferent	74	39.8
Good friend	30	16.1
Risk taker	59	37.7
Total	186	100

Tab. 6. Final Cluster Centres

	Cluster		
	1	2	3
Risk Taking	-.45410	.86199	-.70572
Risk Perception	-1.30375	-.10001	.69505
Expected Benefits	-.62056	.61586	-.37929
Number of Cases	35	87	84

Missing 38 (not answered)

The results show that a minus value means non-typical characteristics and a plus value means typical characteristics in each cluster. Results of segmentation and wider implications can be realised in the next chapter.

5. Discussion

In real life of a business, actors are subjects who are not able to be fully rational and, as Simon (1978) suggested, have bounded rationality with predictable mistakes (biases). Knowing these heuristics as a human side of actors helps us understand and tell the truth sometimes to influence rationality. In this paper, financial and gambling risk-taking situations were examined in hypothetical bet situations presented in the form of the DOSPERT Survey. The

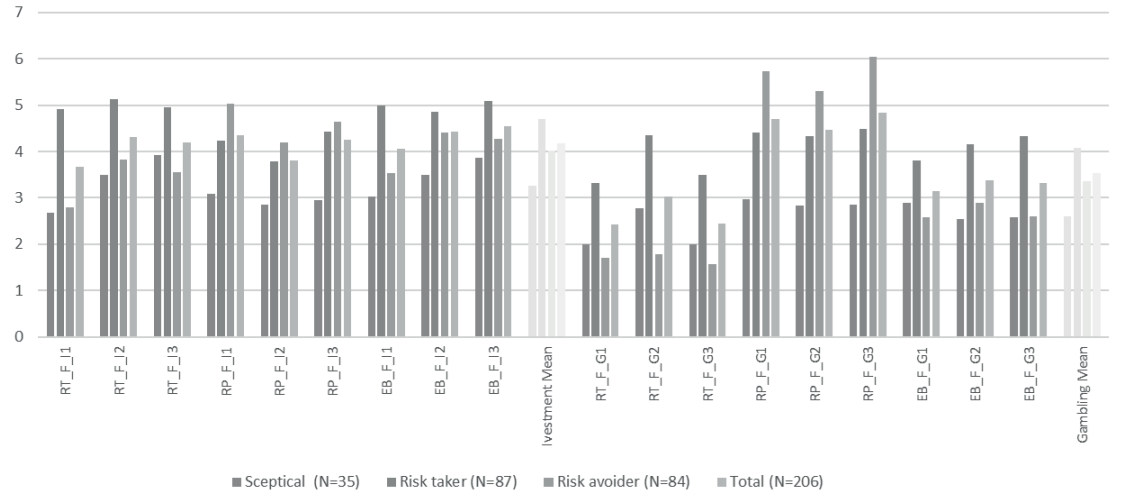

Fig. 5. Comparison of segments

subjects had to value each situation using seven ranking scales in three dimensions: (1) risk-taking willingness or how respondents engage in risky activities, (2) risk perceptions or how respondents assess the level of risk in each activity, and (3) expected benefits or what kind of benefit respondents obtain in each risky situation. At the same time, cultural differences were also taken into consideration measuring by Hofstede's Uncertainty Avoid Index, which expresses the degree, to which members of a society feel uncomfortable with uncertainty and ambiguity (in other words, in risky situations). People as members of society regularly face decision challenges. In business, this challenge is making a decision on behalf of another person. Finally, three hypotheses were formed and tested.

H1. Individual DOSPERT scores and Hofstede's cultural UA dimension index have significant relationships. REJECTED

H2. Based on individual DOSPERT scores, the respondents can be grouped into no more than 3 clusters, and each cluster can be characterised. ACCEPTED

H3. Characteristics of the clusters can be connected with endowment roles. REJECTED

According to Tab. 6 and Fig. 5, the respondents can be divided into three segments. Where the values are positive, those characteristics are typical; negative ones are non-characteristic. The segments are stable and (with 0.05 sig level in each case p=0.00) differ significantly from each other.

Segmentation characteristics are the following:

Sceptical Segment 1: respondents do not like risk. In addition, they do not search for risk either in gambling or in investment situations. (The eldest being on average 26.051 yrs.) Hofstede's UAI mean is 74.91 with std. deviation of 12.45.

Risk Taker Segment 2: respondents do not perceive risk, which explains their enjoyment of risky situations; besides, they anticipate a higher outcome benefit, mainly in investment situations. (The youngest being on average 24.95 yrs.) Hofstede's UAI mean is 77.84 with std. deviation of 15.46.

Risk Avoider Segment 3: respondents avoid risk because they perceive it at the highest level in each situation. They do not want much in return (average age of 25.54 yrs.). They mostly reject gambling situations because of high risk. Hofstede's UAI mean is 68.93 with std. deviation of 14.04

Tab. 7 shows the statistical differences between each segments . To figure out how the aforementioned countries can be characterised with each segment, Fig. 6 shows the distributions of segments in various countries.

This research attempts to explore whether there are systematic cross-national differences in choice-inferred risk preferences between nations. Unfortunately, this study was not able to verify cultural influences on risk attitudes, but Hsee and Weber (1999) found that Chinese were significantly more risk-seeking than Americans, although they found significant differences only in the investment domain and not in others (medical and academic decisions). Baillon (Baillon et al., 2016) investigated the rationality of group decisions versus individual decisions under risk. They found that communication led to more rational choices, but on the other hand, groups violated stochastic dominance less often than

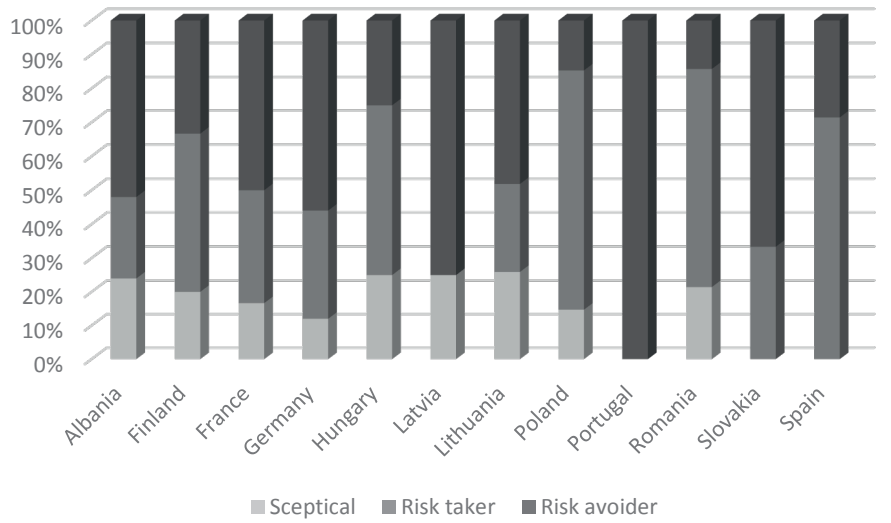

Fig. 6. Distribution of segments in countries

Tab. 7. Cluster Report

Scores		Risk taking	Risk Perception	Expected Benefit	Eta	ANOVA Sig.
Sceptical	Mean	2.8286	3.2097	3.1054	0.645	0.00
	N	35	35	35		
	Std. Deviation	.94628	1.02209	1.04268		
	Grouped Median	2.9150	3.2767	3.4660		
Risk taker	Mean	4.1469	4.2806	4.3405	0.539	0.00
	N	85	85	84		
	Std. Deviation	.92751	.92475	.95274		
	Grouped Median	4.1177	4.3100	4.1623		
Risk avoider	Mean	2.5993	4.9462	3.3407	0.456	0.00
	N	84	84	84		
	Std. Deviation	.78879	.96700	1.15359		
	Grouped Median	2.5400	4.9773	3.3300		
Total	Mean	3.2835	4.3709	3.7138		
	N	204	204	203		
	Std. Deviation	1.14101	1.13314	1.17817		
	Grouped Median	3.2623	4.5378	3.8678		

Tab. 8. Crosstabs analysis

Ownership roles * Segmentation Crosstabulation					
Count		Risk types segmentation (3 clusters)			Total
		Sceptical	Risk taker	Risk avoider	
Ownership roles (4 types)	Indifferent	14	32	42	88
	Good friends	8	12	12	32
	Double Risk taker	8	29	22	59
	Agent	4	14	7	25
Total		**34**	**87**	**83**	**204**

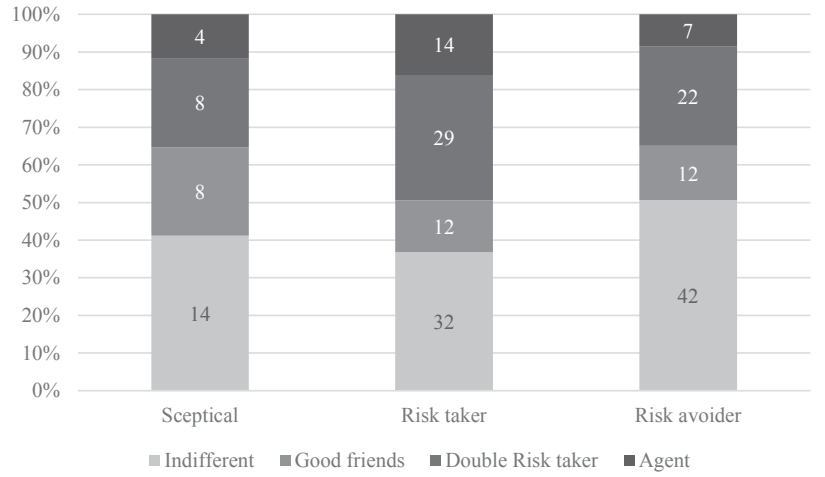

Fig. 7. Distribution (number of respondents) of endowment roles and risk-taking clusters

individuals did. Here, just the individual situation was investigated, but later it would be interesting to observe the impact of group decisions (e.g. conformity).

In Hungary, Faragó (2005), widely studied risk-taking behaviour presented in field experiments. She found that subjects took much smaller risks in real situations where they had to face real consequences, so people did not engage in extreme risk-taking strategies. She also built the famous framing effect into the design and demonstrated the prospect theory (i.e. in a positive frame, we gain risk-taking behaviour, and in a negative frame, we lose risk-avoidance behaviour). These decisions affect the success of a business; the author (Faragó, 2008) found that successful organisations were more willing to take risks than unsuccessful ones. The direction of change had a strong influence on risk-taking as well: organisations which were getting better took more risks and the ones that were getting worse refrained from risk-taking.

Finally, the two clusters (a type of segmentation) were studied. Here, ownership roles and segmentation are evaluated using the crosstabs analysis (in Tab. 8).

Unfortunately, no significant correlation was found, Cramer's V (0.128) showed a weak connection and was not significant (approx. sig. 0.353). Due to the result, H3 was rejected. Tab. 9 helps to describe risk perceptions crossed with the ownership roles.

Although there was no significant correlation, the distribution of risk perception styles in each role might be interesting (Fig. 7) and show how the

Tab. 9. Crosstabs analysis

REPORT				
		RT_ MEAN	RP_ MEAN	EB_ MEAN
Indifferent	Mean	3.0485	4.4241	3.5319
	N	97	97	94
	Std. Deviation	.99738	1.05535	1.17857
	Minimum	1.00	1.17	1.00
	Maximum	5.33	6.67	6.83
Good friends	Mean	3.5046	4.1963	3.5194
	N	35	35	35
	Std. Deviation	1.26124	1.27092	1.11040
	Minimum	1.33	1.67	1.00
	Maximum	7.00	6.67	5.67
Double Risk taker	Mean	3.2661	4.6687	4.0297
	N	67	67	66
	Std. Deviation	1.14643	1.12973	1.18302
	Minimum	1.33	1.83	1.00
	Maximum	6.33	7.00	7.00
Agent	Mean	3.5859	4.0066	3.7739
	N	29	29	28
	Std. Deviation	1.19340	1.16232	1.28361
	Minimum	1.00	1.67	1.00
	Maximum	5.83	6.00	6.67
Total	Mean	3.2508	4.4079	3.7077
	N	228	228	223
	Std. Deviation	1.12187	1.13944	1.19622
	Minimum	1.00	1.17	1.00
	Maximum	7.00	7.00	7.00

cultural heritage impacts our decisions and risk levels. Matching these two cases of segmentation, the following can be provided. It is obvious that a Risk Avoider will not take any risk on their behalf or behalf of others, or a part of Risk Takers are more likely to take any risk on behalf of others. But it is interesting that in the Sceptical group, the biggest share of Good Friends could be found.

Conclusions

Wang (Wang et al., 2017) highlighted how cross-cultural dimensions mattered more than macroeconomic variables in explaining loss aversion. Wang, Rieger and Hens (2017) conducted a standardised survey in 53 countries worldwide that included questions from the Hofstede survey on cultural dimensions as well as lottery questions on loss aversion. They found that Hofstede's individualism, power distance, and masculinity increased loss aversion, whereas the impact of uncertainty avoidance was less significant. Such findings could explain the results of this research as well. Moreover, the authors also found a relation between the distribution of major religions in a country and loss aversion. In comparison, the connection of loss aversion to macroeconomic variables seemed to be much smaller. Chang (Chang et al., 2016) highlighted that the political implication could encourage people to help strangers by lowering the associated costs e.g. "Good Samaritan" laws (protect this group of people) would be necessary nowadays when the countries are going through a rapid urbanisation process. So, it seems that the cultural background greatly increases the likelihood of how people would deal with strangers in their daily life.

Guiso and Paiella (2008) used household survey data to construct a direct measure of absolute risk aversion and they related this measure to consumer's endowments and attributes and to measures of background risk. They also received an interesting result. The risk aversion was a decreasing function of the endowment, and they also showed that the consumer's environment affects risk aversion.

Ferreira (2018) used a method similar to that applied in this research; however, she found an attitude of risk-aversion across the entire sample of 12,500 (approx.) supported by the ING. She also used the DOSPERT Scale but changed the topic or the target of risk to financial markets' products (i.e. shares, mutual funds, and bonds). According to her, people in Germany, Poland and Austria appeared to associate riskier investments with lower expected benefits. She found significant differences in risk aversion between the 15 countries studied. Germany, Austria and the Netherlands were most risk averse while the US, Turkey, Australia and the UK were more accepting of risk. All of this must be taken in consideration in the case of investment sector. More interestingly, significant differences between countries were found in terms of institutional, cultural and geographical factors. They seemed to have a substantial influence on the formation of individual risk-benefit perceptions associated with financial investment. significant heterogeneity in the strength of such relationships became evident from country-specific correlations between financial risk and benefit perceptions. In the Netherlands, Belgium, the Czech Republic, and Turkey, no significant pattern was found in the way people constructed their perceptions of financial risks and benefits. Moreover, people living in Germany, Austria and Poland seemed to believe that the riskier the investment, the lower the expected benefits. In contrast, people of France, Spain, the UK and the USA perceived (standardised) risk and the expected benefit level (also standardised) showed a positive rising correlation. A somewhat weaker but ascendant connection was found in the case of Luxemburg, Italy, Romania and Australia.

The author of this article underlined that risk attitudes were not uniform across or within countries. She found that the overall negative association between the perceived financial risks and the risk-taking propensity held for all countries but three clear groups were identified. She measured the country-specific correlations between the financial risk propensity and the perceived risk level. Finally, countries in the first group were relatively more risk-prone (Turkey, the USA, Poland, Italy and the UK), moderated risk connection was found (Austria, Belgium, the Czech Republic, Spain and Austria), at the end countries in group C were the most risk-averse (Germany, France, Luxemburg, the Netherlands, Romania). Her paper verified that the use of a bigger representative sample could show cultural differences. Unfortunately, this paper faced massive unexplained heterogeneity.

Research Limitations

The main problem of this survey is rooted in the methodological background; branches of effect impact on main final findings but the problem can be corrected using a high number of representative samples. The limitation of this study was related to hypothetical situations that were verbally described rather than represented visually or numerically. Typically, such situations are new to subjects, so their judgements could be based on simple guessing or misinterpretation. It also must be underlined that the majority of subjects were students with none or limited financial experience, and according to Camerer (1998), the past actually affects our risk perception.

In summary, this study verified various types of risk attitudes and can be a good basis for future efforts. Hopefully, this paper helps to understand how risk perceptions can help businesses improve decision making in relation to financial problems. The behavioural economics agenda should focus on the remaining most interesting questions and further research on the institutional and cultural determinants of risk perceptions and attitudes.

Acknowledgements

The research was supported by the New National Excellence Program ÚNKP-17-4/I of the Ministry of Human Capacities. Some parts of the paper were based on the oral presentation of the author, given at the International Scientific Conference Emerging Trends in Economics, Culture and Humanities (ETECH2018) in Riga, Latvia.

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sciendo

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 15 May 2018
accepted: 15 October 2018

pages: 21-33

Leadership versus customer orientation in an innovative enterprise — a contribution to further exploration

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ABSTRACT
The consideration of the multidimensionality and multidirectionality of management science within the research process is currently a very important challenge. The search for dependencies and connections between leadership and customer orientation falls fully into the desired research trend. Both leadership and customer orientation are widely described within management science; however, the connections and dependencies which occur between them still require further, in-depth exploration and knowledge concerning leadership and customer orientation needs to be systematised. This article aims to identify further directions of study into leadership and customer orientation in an innovative company. Additional goals include the systematisation of knowledge regarding customer-oriented leadership and the formulation of research hypotheses which will become the starting point for future studies. The conclusions are supported by the results of a quantitative study which applied the CAWI method to a group of 204 business leaders from North-East Poland. The article presents the results of the preliminary research realized as part of a research grant from the National Science Centre entitled "Leadership and customer orientation in an innovative enterprise". The results of the conducted research show that customer orientation among business leaders is not uniform and depends on the size of their company, the style of management and the type of innovation implemented by their enterprise.

KEY WORDS
Leadership, customer orientation, innovative company

DOI: 10.2478/emj-2018-0020

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Introduction

Both leadership and customer orientation are widely described in management science. As individual cognitive categories, they are a common subject of study with customer orientation continually evolving mainly due to the dynamic changes within the business environment. Assuming the perspective of an organisation, customer orientation is a part of market orientation (Ejdys, 2015). It consists of a company treating a customer as a source of inspiration as well as the final judge in the process of the market offer development, which results in a favourable attitude of the customer towards the company and enables the company to retain the customer, thus benefiting both parties (Mazurek-Lopacinska, 2011).

Being at the beginning and the end of the value chain, customers are placed at the centre of interest of a company. Acceptance of the point of view of a customer forms the basis for the operation of an enterprise and occurs not only at the operational but mainly at the strategic level. Keeping all that in mind, it is a gross simplification to claim that successful customer relationships are secured by personnel directly involved in providing a service and arise from their direct contact with the customer. Customer value and benefits result from well-established relationships, the responsibility for which rests on the shoulders of a person overseeing the enterprise as a system. This person is a visionary, a strategist and a decision maker at the same time, who can also influence supervised workers. In business, this role is assumed by leaders. The justification of this opinion stems from marketing orientation, where the company's mission is based on values important to the customer, who is also engaged in the process of value creation, the growth of which is facilitated by all employees (Mazurek-Lopacinska, 2011). A leader and leadership are notions which are commonly defined in science; however, most approaches and concepts leave these terms unclear and ambiguous. For the purpose of the present work, it has been accepted that a leader is a manager occupying the top level management position, able to organise people and available resources to effectively realise established goals and lead the organisation towards long-term successes (Karaszewski, 2006). The study presented in this article focused on leaders managing innovative enterprises. It falls within the relevant and fast-advancing area of research investigating directions and determinants related to the development of the broadly understood innovation. It has been assumed that such enterprises were more customer-oriented as the market conceptualisation of innovation is impossible without the approval of target markets.

The aim of this article is to identify further directions of study into leadership and customer orientation in an innovative company. Additional goals include the systematisation of knowledge regarding customer-oriented leadership and the formulation of research hypotheses, which will become the starting point for future studies.

The remainder of the article consists of the following sections: Section 1 presents the cognitive theoretical analysis and the synthesis of scientifically recognised connections and relationships that possibly exist between the leadership and customer orientation in an innovative company. Results of the literature review formed the basis for the empirical part and indicated the conclusions given in Section 3, which describes the methodology. Results of research are described in Section 4. Finally, Section 5 summarises the findings and, the conclusions briefly explain the limitations of the research and implications for future research efforts.

1. Customer orientation and leadership in management science — conceptions, connections and dependencies

The fast-changing business environment and the growing demands of various stakeholder groups pose challenges not only to modern enterprises but also to researchers. Currently, one of the main goals of management science is to eliminate disproportions between practical needs and scientific achievement. It is, therefore, important to keep under consideration the multidimensional and multidirectional character of management science during the process of research. The search for dependencies and connections between leadership and customer orientation falls fully into this field of study. Both concepts — leadership and customer orientation — have been broadly described in management science; however, the connections and dependencies between them require further, in-depth exploration. Leadership and customer orientation form the foundation for the operation of an enterprise. As available research results indicate, their shared interactions may impact the development and the competitive position of a company (Day, 1999; Kennedy et al., 2003; Kirca et al., 2005; Narver, 1998). As no business can exist without customers and direct interaction with them, customer orientation remains a basic and integral competence of a modern organisation. Customer needs determine business development directions. In the end, it is up to customers to decide whether to accept an offer and make a purchase (Sheth et al., 2000). In an attempt to systematise knowledge concerning customer orientation, it is possible to identify three basic fields of research: customer orientation as a business philosophy, customer orientation as an area of organisational activity and customer orientation as a concept of value creation. Each of these trends displays a different concept of leadership.

As a business philosophy, marketing orientation perceives benefits as a result of the focus customers and their needs. The implementation of this approach by managers can determine their company's competitive advantage (Kohli & Jaworski, 1990; Ganesan, 1994), become an element of its success (Hall 1992) or affect its profitability (Donaldson, 1993; Naver & Slater, 1990). In accordance with this approach, the fulfilment of customer needs and their satisfaction are better than competition and deemed essential by researchers; however, they are very difficult to implement organisationally (Capon et al., 1991). Besides, it is stressed that gathering knowledge regarding the market and customers is an imperative condition of market success not only in the context of better identification of target market needs (Kibelling et al., 2013; Sousa, 2018) but also in the sense of building relationships between the partners of the exchange process (Julian & O'Cass, 2002) and being oriented towards innovation (Park et al., 2017). The evolution of the conception in this area depends on refocusing from current target market needs to the search and fulfilment of future, secret customer demands (Autachene-Gima, 2005). As a business philosophy, market orientation means directing all of the company's efforts at current and future needs of target markets. This requires upper management to display a high level of market awareness supported with the conviction that the enterprise's success starts and ends with the customer. Marketing orientation as a business philosophy not only poses a challenge to managers directly engaged in the process of acquiring and serving customers but also demands full acceptance of the fact that the customer is the source of the company's success.

In the opinion of some researchers, the executive perspective on customer orientation has been, inadequately explored in management science (Saarijavi et al., 2014). As a business (executive) activity, marketing orientation requires the enterprise to develop processes and procedures for the implementation of goals that emerge as a result of established customer relations. This activity includes customer service systems, communication with customers, market research, decision-making processes and managing tasks resulting from the interaction with target markets. Market orientation perceived as a certain set of processes and tasks can offer many benefits which include not only satisfied customers but also happy employees (Jaworski & Kohli, 1993), effective sales systems (e.g. Siguaw et al., 1998) and lasting competitive advantage (Dwyer & Tanner, 2002). Operations resulting from customer orientation should not be implemented incidentally but rather planned in the long term (Strandvik et al., 2014; Van Raaij, 2008). Therefore, strategic knowledge is essential and the leader, who is the top manager with a long-term vision for the enterprise, should be its source and its administrator (Gebhardt et al., 2006; Folley & Fahy, 2014).

The realisation of benefits resulting from establishing long-term relationships with customers requires the company to perceive the customer as a source of value (Gallarza & Gil-Saura, 2011). The worth of customers is defined through the value they add to the organisation (Khalifa, 2004). In terms of value creation, relationships with customers can only be maintained by providing them with the expected value and assuring that that the same level of value would be maintained in the future (Gordon, 2001). In a modern organisation, customer value can be seen, among others, in the following areas: placing customers in the centre of and their engagement in the value creation process; co-planning of products with simultaneous characterisation of the buyer's level of engagement, inclusion in problem diagnosis and in the real process of production (Rogozinski, 2006). Research into customer value also shows that it can significantly impact the enterprise's process of strategic decision making (Sanchez-Fernandez & Iniesta-Bonillo, 2007). A customer-oriented company bases its cooperation with the customer on the exchange of value — the customer becomes a valuable asset only when they decide that the offer presented by the enterprise will provide them with economic, functional, symbolic and emotional value (Rintamaki, 2007). The type of value which customers bring to the company, as well as the value which they receive, is a key, strategic decision of the enterprise made at the highest level of management.

Customer orientation falls into the concept of the value chain, therefore, exceeding the buyer–seller relations. Having a customer-oriented approach in the value chain consists of fulfilling and recognising customer needs through the cooperation with all partners in the chain (Nahm, 2004). This approach requires appropriate support for management and maintenance of customer relationships. It is also important to stress the company's flexibility in adapting every element of the value chain to changing needs and, from the perspective of building and maintaining customer relationships, the improvement of the information system (Jeong & Hong, 2007). It should be stressed that a customer-oriented enterprise

has a customer management system — a business strategy consisting of building long-term relationships with customers aimed at maximising the level of customer satisfaction and, at the same time, minimising their departure from the company (Tracey & Tran, 2001). Being oriented at the needs of customers means establishing cooperation at the interorganisational level contributing to the creation of cooperative connections (Park et al., 2017).

The scientific exploration of customer orientation also confirms the existence of connections which occur between the company's focus on customer needs and the level of its innovativeness (Esty & Porter, 2005; Roswening & Grinstein, 2015). Continued fulfilment of new and rapidly changing needs requires the enterprise to react quickly offering innovative products as well as using innovative methods of communication with target markets. Studies confirm that enterprises which are more focused on customers are also more open to innovation (Ford & Paolio, 2013).

As a subject of research, descriptions of customer orientation are most often declarative in character. They justify and explain benefits resulting from the company being customer oriented and satisfying its customers. Customer orientation is presented as a superior orientation whose implementation has a great impact on establishing a competitive advantage. All of the company's efforts should focus on the profitable fulfilment of customer needs. This means that it is necessary to find factors that determine a company's customer orientation. The same understanding is confirmed by available research (Kennedy et al., 2003; Kirca et al., 2004). The leader — top manager — is directly involved in the implementation of the selected approach. Regardless of the company's organisational structure or its model of management, customer-related decisions are taken at the top level of management. Customer value creation is an activity based on strategic decisions which are the domain of top managers and not solely the personnel directly engaged in the service process (Saraijavi et al., 2014). Study results also show that the manner, in which a company is managed, can be a barrier to the development of its market competencies (Harris & Ogbonna, 2001). Additionally, research demonstrates that leaders oriented at fulfilling the needs of their employees are also more aware of customer needs (Pekovic, 2016; Boddy & Croft, 2016). When leadership favours creativity, it advocates the growth of innovation and the level of being attuned to customer needs (e.g. Harris & Ogbonna, 2001; Lichtarski & Trenkner, 2018).

Studies into the relationship between leadership and customer orientation also pose some questions in regard to their merit and conceptual character. In business, both leadership and customer orientation are the subjects of numerous studies, but their definitions and the way they are perceived varies, which often makes these scientific categories ambiguous and discordant (Alio, 2012; Hunitie, 2018). However, despite a large number of definitions, many studies maintain that a business leader plays a significant role in determining the company's value chain, starting with the acceptance of the idea (concept) for a new product (service) and all the way to its market introduction (Deschamps, 2005). From the perspective of customer orientation, the building of customer relationships is not solely the domain of middle management and personnel directly involved in the service process. The complexity of the problem addressed within the article encourages a further, broader study into the leadership perspective. A leader who runs the entire organisation is not only the decision maker but also the creator of strategy responsible for all types of assets including human resources. A leader is not only a person who inspires workers to work toward the good of the enterprise (Antoni, 2005) and is responsible for their motivation (e.g. Loke & Lantham, 2002) but also someone who influences employees and through that impacts the level of the organisation's innovativeness (Carneiro, 2008; Zuraik & Kelly, 2018) and, in consequence, affects customers.

The diversity of various leadership concepts and the multidimensional character of customer orientation indicate that research into the relationship between these two categories requires further exploration. It is important to find factors which determine this relationship. The systematisation of knowledge concerning leadership and customer orientation in the broad perspective is also very important. Business leaders present different styles of management, and owners running companies of different size and type have different ideas for the success of their organisations.

2. Research methods

The following research questions were formulated to achieve the research goal:

1. Which areas of customer orientation are the most significant to leaders?
2. Are there dependencies between the company size and the leader having a customer-oriented approach?
3. Does the leader's customer-oriented approach depend on their position?
4. Does the enterprise's field of operation determine the leader's customer orientation?
5. Are there dependencies between the style of management and customer orientation?
6. Which areas of customer orientation are the most important to the leaders considered in the study?
7. Is there a connection between the type of innovations being implemented by the company and the leader's customer orientation?

The conclusions were drawn on the basis of results of a quantitative study carried out using Computer Assisted Web Interviewing (CAWI) conducted with 204 business leaders from Podlaskie Voivodeship. The research entitled "Leadership and customer orientation in an innovative enterprise" was carried out in 2018 as a part of the grant from the National Science Centre. According to the concept accepted by the study, a leader was deemed to be a person who:

1. Is a manager from the top management level or is the owner of the business or, on account of being the founder of a company (first owner) still influences its development and has a part in making key decisions.
2. Runs an enterprise employing at least 3 workers.
3. Manages an innovative company which is implementing at least one type of innovations, including product, process, technological or informational.

These conditions determined the conceptual character of leadership. As mentioned before, leadership is a multidimensional category which functions within numerous concepts and theories (Kraszewski & Skrzypczynska, 2016). This statement functions as a certain limitation. The selection of the study respondents was a compromise, and the accepted criteria did not fully define respondents as leaders. It is certainly disputable whether the occupied position always makes someone a leader. Hence, the approach which fully identifies a leader as a manager able to manage people and available resources to effectively achieve established goals and lead the organisation towards the long-term success was established as the starting point (Karaszewski, 2006). This perspective allowed a preliminary identification of relationships which occur between leadership and customer orientation. Top managers in charge of innovative enterprises were included in the study intentionally. An initial review of up-to-date research concerning leadership and customer orientation showed that innovations are an integral part of both of these concepts. The focus on innovations can be interpreted as being customer oriented. The introduction of innovations results from a reaction to the changing market conditions. On the other hand, leaders are the main drivers of the improvement and success in an organisation.

The study included 204 leaders among whom 16.67% were directors, 27.45% were chairpersons of the board, 6.37% were company owners and 40.2% were heads of the branch (Fig. 1).

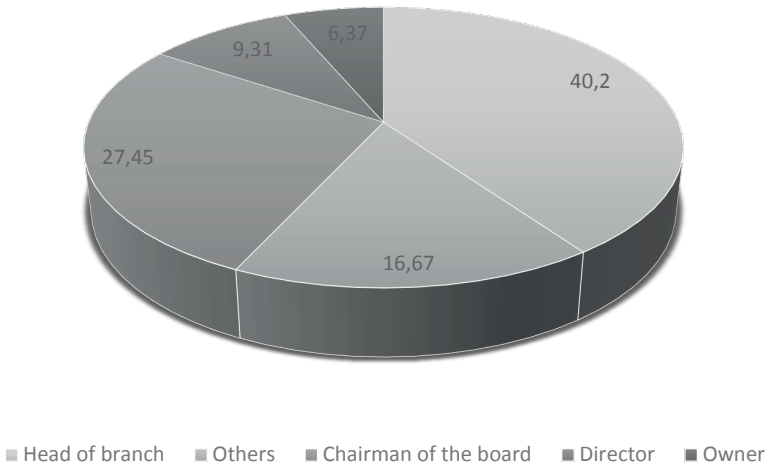


Fig. 1. Distribution of participants in relation to their position

The greatest number of respondents (46.6%) ran companies with 10 to 49 employees, and 43.1% of participants managed businesses with 3 to 9 employees . Very large companies with more than 250 people had the smallest representation in the study. The distribution of respondents according to industry was also the same as the distribution within the Voivodeship. The greatest number of respondents managed trading and services companies (74.5%), 15.2% ran construction companies, and 10.3% oversaw production companies (Fig. 2).

In relation to the scope of implemented innovations, most study participants introduced product innovations (82.8%). Improvement of communication methods was carried out by 76.5% of respondents. Technological innovations were chosen by 66.7% of participants while process innovations were used by 68.1%. The type of implemented innovations depended on the company's field of operation (Tab. 1).

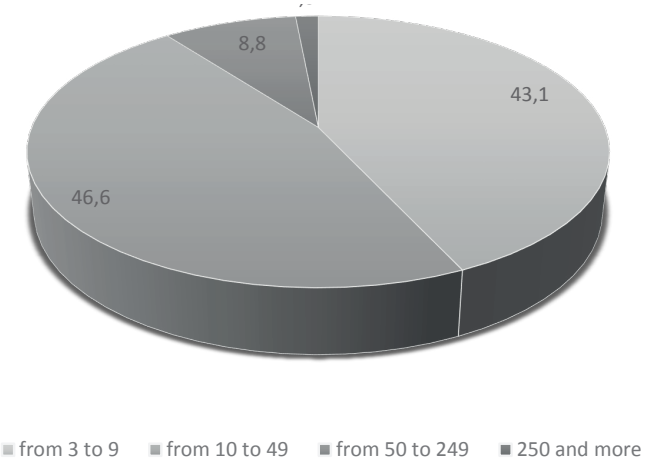


Fig. 2. Structure of enterprises according to the number of employees

Tab. 1. Structure of respondents according to the type of introduced innovations

No	Innovation type	Answer	
		Yes	No
1	A new or a significantly improved product has been introduced into the company's offer	82.8%	17.2%
2	The company's machinery has been expanded or modernised, new machines or devices have been purchased, the production process has been improved	68.1%	31.9%
3	The company has purchased and installed new software or IT solutions such as CRM	66.7%	33.3%
4	The company has implemented new methods of marketing communication or modern promotion tools, for example, social networks (FACEBOOK) or remarketing	76.5%	23.5%

3. Research results

On a scale of 1 to 5 where 1 was full denial and 5 meant full approval, entrepreneurs (leaders) were asked to assess, the veracity of statements relating to a market-oriented company (Tab. 2). The table below presents average values of the assessment of single statements indicated by all survey respondents. According to the leaders, the development directions of a company are determined by customers, while a rapid reaction to market needs determines its success. Such perception of the success of an organisation falls fully within the concept of customer orientation. Respondents agreed that an enterprise could create new needs and shape new trends (average score of 3.83).

This is an example of strategic thinking and proves that the majority of leaders are aware of changing customer needs and expectations and want to address them. On the other hand, there is the operational approach. The leaders strongly believe, every product can be sold, and everything depends

Tab. 2. Leader-provided assessment of statements arising from customer orientation

No	Variable	Average
P05_01	Rapid reaction to the needs of the market determines the success of an enterprise	3.95
P05_02	Customers determine the development direction of an enterprise	3.69
P05_03	The customer is the most important stakeholder of the organisation	3.78
P05_04	The customer is not only a stakeholder but also a resource of the enterprise	3.76
P05_05	Systematic monitoring of needs and expectations of customers is essential	3.98
P05_06	Maintaining relationships with returning customers is more difficult than gaining new customers	3.54
P05_07	The ability to maintain relationships with returning customers is more important than the ability to gain new customers	3.68
P05_08	An enterprise should create new needs and shape new trends	3.86
P05_09	A leader (top manager, company owner) should be in direct control of the marketing department	3.66
P05_10	The marketing department (sales department) is the most responsible unit for building relationships with customers	3.59
P05_11	It is the customers and their needs who are the main source of inspiration in the creation of new products and services	3.87
P05_12	The customers are most of all partners and not a source of profit	3.47
P05_13	A leader should concentrate on building close relationships only with key customers	3.12
P05_14	Standards for customer service are a factor which determines successful sales	3.70
P05_15	Every product can be sold, and everything depends on the skills of the salesperson	3.82
P05_16	The customer is the co-creator of product value	3.68
P05_17	An enterprise should aspire to expand internationally	3.57

on the skills of the salesperson received high scores (average score of 3.82). It can be concluded that in the opinions of leaders, marketing and thus customer orientation are the result of good work of the sales department, not a strategy. Relatively low average values were attained by statements which were the foundations of customer orientation. It can be concluded that the customers are most of all partners and not a source of profit (average score of 3.47). Fig. 3 presents the ranges of responses within individual statements contained in Tab. 1. It shows a high rating for P05_05 (systematic monitoring of needs and expectations of customers is essential). This is a manifestation of the market awareness of respondents. However, in-depth inference requires finding out about actions undertaken by enterprises to monitor the market. The results of the research could be interpreted in two ways, namely, according to the leaders, the clients could not be differentiated and each client, irrespective of the turnover achieved, should be treated in the same way. On the other hand, it can be presumed that the strategic dimension of competences attributed to the leader decreases.

On the basis of a preliminary analysis of the study results, it is also possible to see the existing dependence between the size of the enterprise and the leader's customer orientation (Fig. 3). The values were calculated based on the assessment of 17 statements (P5_01 – P5_17) made by respondents (Tab. 2) and present the average of the responses. Research results demonstrate that the most customer-oriented leaders ran companies with 10 to 49 employees, and the least customer-oriented managers were those who managed large enterprises. How could this result be explained? In smaller companies, top managers were more engaged in the achievement of company goals and had greater control over this process. The organisational structure of such entities was flatter. The managers had to have greater knowledge regarding the market, and mainly carried the full responsibility for the company's success. This required a greater awareness of the market and, frequently, direct relationships with customers. When it came to large companies, leaders assumed the role of a strategist, a visionary or the delegator of tasks. The expanded organisational structure of such companies permitted the designation of people responsible for particular areas of operation including that of building customer relations. A large part of the responsibility for the achievement of market goals was passed on to lower management.

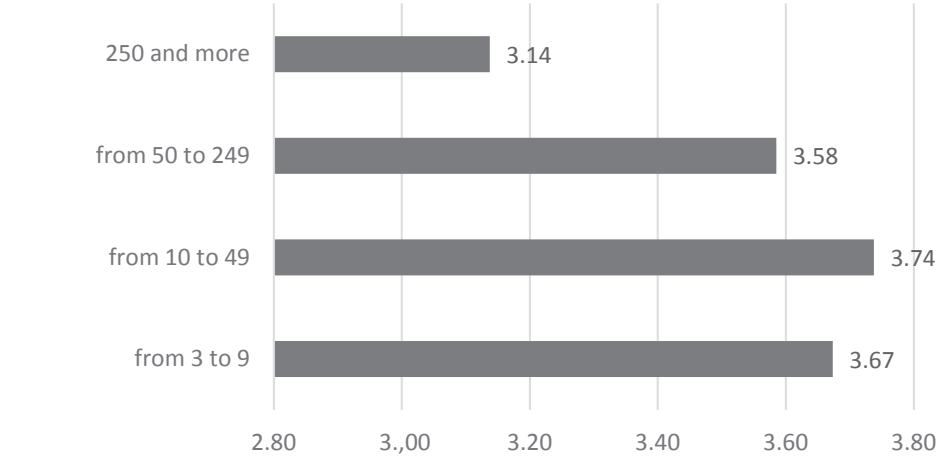


Fig. 3. Number of employees and level of customer orientation

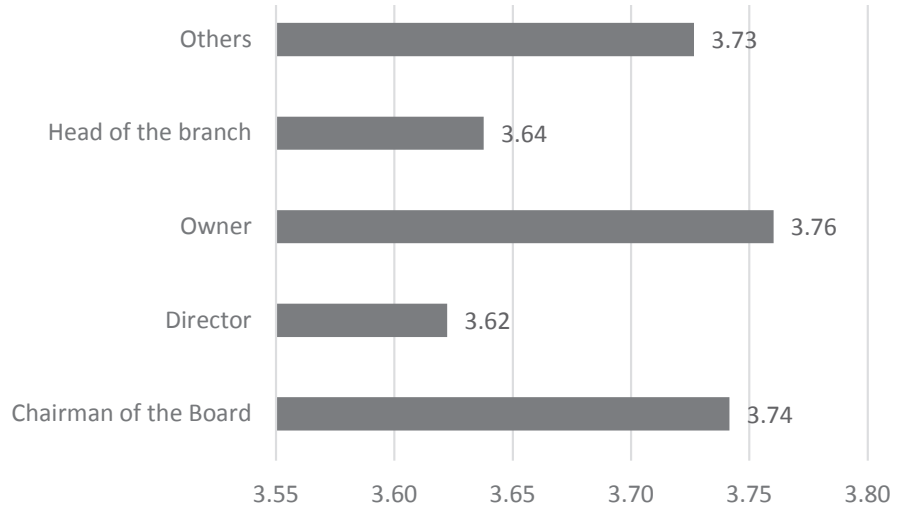
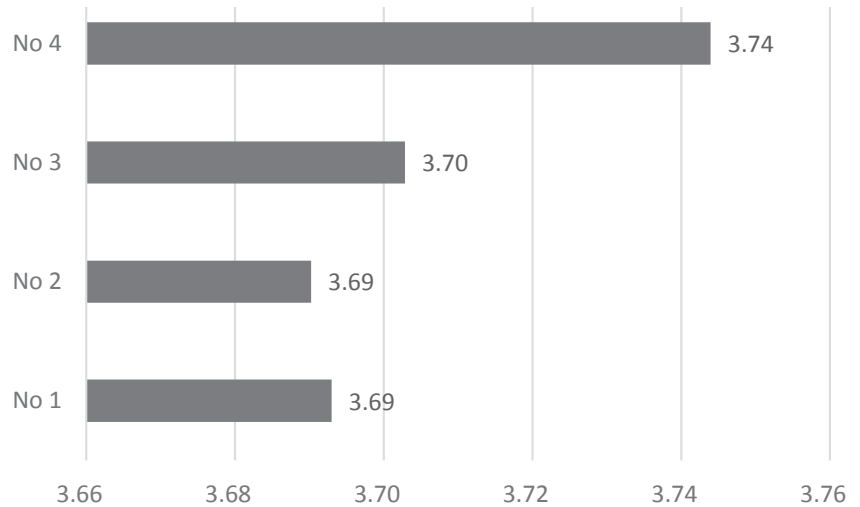


Fig. 4. Position of the leader and level of customer orientation



No 1 — product innovations; No 2 — technological innovations; No 3 — process innovations; No 4 — marketing innovations

Fig. 5. Innovation type and level of customer orientation

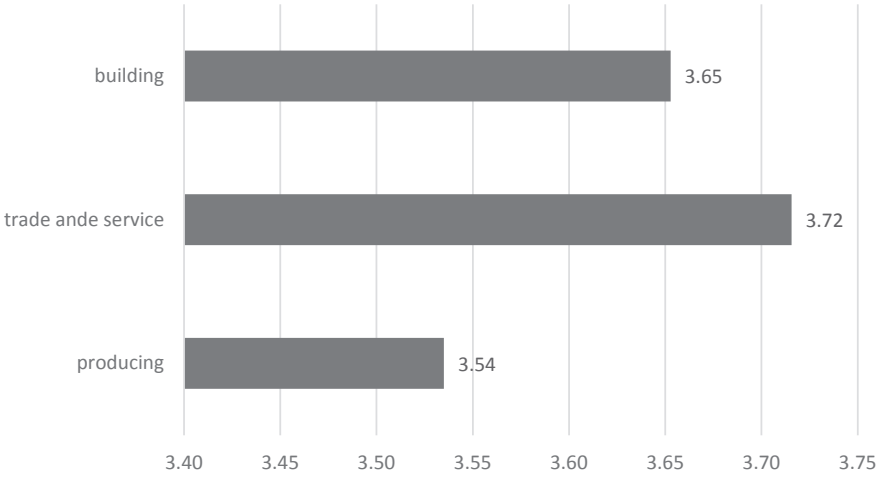


Fig. 6. Company's profile and customer level of orientation

Tab. 3. Leadership styles with statements

Leadership style	Statements
Democratic (DEM)	Before making a decision, I listen to the opinions of employees and colleagues. I am willing and personally engaged in interviewing employees. In my company, employees have a lot of freedom in their activities.
Autocratic (AUT)	In my opinion, every employee needs control. Employees cannot be trusted. Every employee should have precise guidelines; otherwise, they will not perform the task assigned to them.
Training (TRA)	I know the strengths and weaknesses of each of my employees. In my company, I know exactly how to allocate tasks between employees. I know my employees and thanks to that I know how to motivate them.
Affiliate (AFF)	In my opinion, the atmosphere is the most important thing at work. Employees are best motivated by praise. I always try to be empathic.
Process (PRO)	Every time I explain exactly how the task is accomplished. The employee task must follow the prescribed procedure. I like it if the employee performs tasks in a designated way.
Liberal (LIB)	I have very good employees, and I do not have to control them. My only task is the organisation of workplaces. In the work of subordinates, I interfere only upon their request.

The study results show (Fig. 4) that the occupied position can determine the level of customer orientation (the used method of calculation was the same as for Fig. 3). Leaders who were the most customer-oriented were also the company owners (including company founders, the average score of 3.76). These leaders viewed their organisations as more than just a place of work and a source of income. They were often emotionally invested in their company and perceived its success as their personal success, hence the greater awareness of customers and the market. Branch managers were less customer oriented. This may be explained by the fact that their goals and tasks were established for them and their role was more aimed at meeting the strategic goals rather than creating them. This also concerned the market goals. Directors also usually acted in the name of others and their connection with their enterprise was less emotional.

Preliminary research results also showed possible relationships between the type of introduced innovations and the leader's customer orientation (Fig. 6). Top managers introducing marketing innovations (average score of 3.74, the used method of calculation was the same as in Figs. 3 and 4) were the most customer oriented. Obviously, the goal of such innovations is the direct impact on the customer in the communication and sales process. Lower

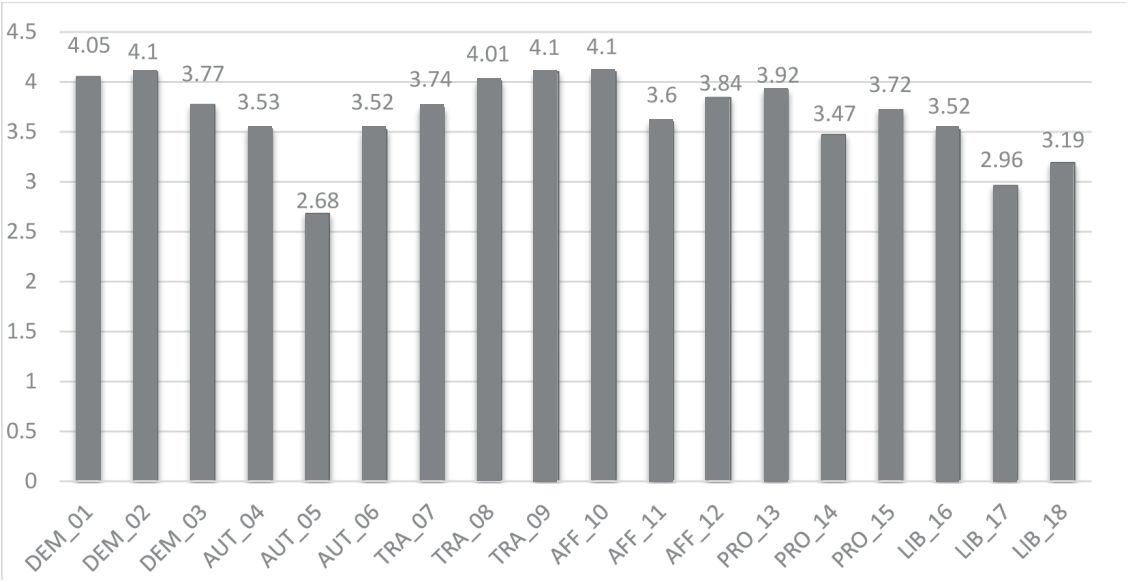


Fig. 7. Distribution of responses within 18 statements about the leadership styles (from Tab. 3)

average values assigned to product and technological innovations (the average score of 3.70) were probably the result of the concentration on manufacturing processes and not sales. It should be emphasised that this is not always a consequence of the smaller market awareness but comes from the specificity of activity or functioning as an indirect link in the supply chain.

The companies in the trade and services sector were the most customer oriented (the average score of 3.72, the used method of calculation was the same as in Figs. 3, 4 and 5) in contrast to manufacturing and construction companies (Fig. 6, the average scores of 3.54 and 3.65). This may be due to the fact that the customer satisfaction in these enterprises depends on the high quality of products and services.

The preliminary analysis of the test results confirms the connections between the leadership style and customer orientation. This is illustrated by Fig. 6. The presented values were the result of counted responses for each style (respondents rated the correctness of statements assigned for particular styles on a scale of 1 to 5, Tab. 3). The relevant question contained claims regarding the assessment of the level of customer orientation. The preliminary research results showed that clients who preferred autocratic and liberal leadership styles were less customer oriented. Democrats were the most customer-oriented. Therefore, it can be presumed that the management style adopted by top managers of the company impacts on the customer policy.

The aim of this article was to identify further directions of study into leadership and customer orientation in an innovative company. Interviews conducted with the help of CAWI were preliminary and carried out among leaders managing enterprises operating within the Podlaskie Voivodeship. The regional scope of the study seems to be a limitation for the conclusion process, but it is not a barrier for the identification of connections and relations between the two categories considered in the research.

4. Discussion and conclusions

On the basis of the conducted research, it can be concluded that an innovative enterprise demonstrates dependencies between leadership and customer orientation. It can be generally ascertained that the manner and scope of customer orientation results from the leadership style of the company's management and size. It is also possible to connect the type of implemented innovations with the level of customer orientation. The ambiguity of customer orientation is not only suggested by theory but can also be seen in practice. The preliminary analysis of the study results points toward the need for further exploration. The categories of leadership, marketing orientation and innovativeness complement each other (Fig. 8).

The study of leadership within this context shows that it influences not only external resources but also

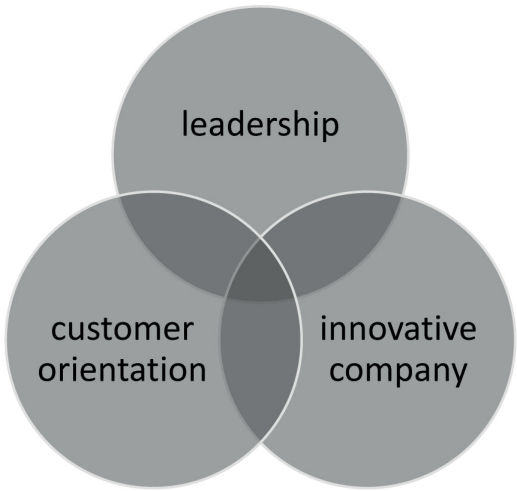


Fig. 8. Connection between leadership, marketing orientation and innovations

other stakeholders, especially customers. Given below are directions for studying leadership in the context of customer orientation as well as the organisation's innovativeness:

1. Identification of factors determining customer orientation in various types of enterprises. The identification of factors which determine customer orientation of leaders managing production companies seems to be especially important (Nazarko et al., 2015; Gudanowska, 2018). When it comes to companies providing services, the relationships are direct, which decidedly decreases the distance between the company and the customer.
2. The preliminary study results show that the type of position held by the leader can determine their level of customer orientation. It must be assumed that the market engagement of the leader is the result of their emotional relationship with the company. It is important, therefore, to determine whether a position indicates interpersonal abilities of the leader and experience resulting from the occupied top management position impacts on customer orientation.
3. The preliminary analysis of the study results demonstrates that the leader's customer orientation is determined by their style of management. However, it remains unclear whether the effectiveness of the leader's influence on external resources translates to their level of customer orientation.
4. The ambiguity and the multidimensional character of the notion of leadership point towards the need to introduce the term of customer-oriented leadership as a type of business leadership in management science. This will allow the systematisation of knowledge concerning leadership and customer orientation.
5. It is also important to identify barriers and drivers behind the customer orientation depending on the type of business and implemented innovation.
6. The preliminary epistemological analysis shows that in management science, there is a lack of tools for the measurement of the level of customer orientation of top managers. Up-to-date measurement attempts concern the effectiveness of activities of employees directly involved in customer service or the effectiveness of individual marketing tools, sales results or market share.
7. There is a need to create a model of customer-oriented leadership. In this part of the paper, the analysis of the research results should be carried out.

It should be emphasised that the presented analysis of the research results is only preliminary. It was an attempt to show probable dependencies, used to identify potential directions of research in the area of leadership and marketing orientation in an innovative enterprise. Despite the limitations and the necessity to focus on selected areas, it can be clearly stated that the problem is multidimensional, and its cognition is important from the point of view of science and practice. The exploration of the indicated research areas requires the use of statistical analysis methods.

As theoretical and empirical analysis shows, a leader influences the company's marketing activities, including relationships with customers (e.g. Carneiro, 2008; Park & Kasim, 2017). However, the aim of the

research is to refine these relationships and indicate the drivers behind and barriers to relationships. It is important to investigate mutual interactions considering the evolution of customer orientation as a scientific concept. There is a clear shift of focus from long-term customer relationships (Kohli & Jaworski, 1990) to the delivery of new values, and this is directly related to development and innovation (e.g. Deschamps, 2008; Ejdys, 2015; Foley, 2004; Gallarza & Gil- Saura, 2011, Saarijarvi et al., 2015; Pomffyova et al., 2016). Thus, discussions regarding customer orientation are impossible without innovation, and these categories depend on the decision of the leader (e.g. Rosenzweig & Grinstein, 2015).

It should also be emphasised that business leadership, which is the subject of many scientific studies, has not been fully understood in the management sciences. Relationships between leaders and stakeholders, their determinants and consequences require further exploration.

Acknowledgements

The studies have been carried out as part of a project No. 2017/01/X/HS4/01009 financed by the National Science Centre).

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Volume 10 • Issue 4 • 2018

sciendo

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 5 August 2018
accepted: 15 December 2018

pages: 34-54

Information-decision model for self-controlling enterprise processes

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ABSTRACT

This study demonstrates that integrated management and direct control systems may be organised as integrated enterprise process control (EntPC) systems, which are composed of self-controlling enterprise business processes. A business process has been defined as a control system for business activities, which are considered to be business processes of the lower level, or as base processes that are control systems for control plants in the form of infrastructure operations. An enterprise process also influences its delivery. This definition has been generally compared with definitions used in approaches of BPMN, YAWL, ARIS, DEMO and MERODE. Each enterprise process has its own controlling unit that contains one information unit and one decision unit, as well as memory places of the information-decision state variables that are processed by the business transitions that belong to these units. The i-d state variables are attributes of business objects, i.e. business units, business roles, business activities, business accounts and business products. Their values are transferred between business transitions that belong to the same or different controlling units. Relationships between business objects, business transitions and i-d state variables, as well as the other most important concepts of the EntPC system framework (EntPCF), are presented in this paper as the class diagrams of the enterprise process control language (EntPCL).

KEY WORDS

enterprise integration, complex control systems, enterprise modelling, enterpriseprocess control, industry 4.0, enterprise architectures

10.2478/emj-2018-0021

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Introduction

Integrated management and process control systems

From a technical perspective, any activity of an enterprise consists in performing business processes. Therefore, business process management that answers the questions "What should be done?" and "Where, when and how should it be done?" encompasses all areas of enterprise operations management. It includes production management, sales management, accounting, human resource management, and all other functions that correspond to modules of well-known enterprise resource planning (ERP) systems (Langenwalter, 2000). In manufacturing enterprises, according to the ISA-95 standard, an ERP system

operates on the highest level of integrated management and process control systems (Sholten, 2007). The IMPC systems also include manufacturing execution systems (MES), supervisory control and data acquisition (SCADA) systems and programmable logic controllers (PLC) that belong to control levels of their functional hierarchy.

Control is generally defined as a goal-oriented action of an object, named a controlling unit, upon another object, named a control plant (Bubnicki, 2005). In the case of MES and SCADA systems, each of these objects is a system with a complex internal structure. Management, which essentially means the influence exerted over somebody to do something, is a special case of control. Thus, for every enterprise, its IMPC system may be regarded as a complex structure with one big controlling system and a control plant being a set of infrastructure processes, which are control plants of the base direct control systems at the PLC level. A controlling system may be perceived as a central controlling unit of the entire IMPC system.

Information-decision state of IMPC controlling systems

IMPC systems are multilevel discrete-time control systems. This means that information processing is allowed only at discrete-time instants that are separated by discrete-time periods, whose length depends on the organisational level. Discrete-time periods and their end instants are identified by pairs

$$(l,t) \in Tl \subset L \times T,$$

in which the identification numbers of time instants, $t \in T$, obtain integer values from the sets assigned to their time scale numbers, $l \in L$. In management subsystems, discrete-time periods are often referred to as planning periods.

Every IMPC system is an IT system. Thus, information flow in an IMPC system consists in recording data to the memory of its controlling system and reading it at the same discrete-time instant or at a later moment in time. The information-decision state of an IMPC system at a given discrete-time period

$$x_{l,t} = [v_{l,t}, u_{l,t}], \qquad for\ (l,t) \in Tl, \qquad (1)$$

is a set of values of the i-d state variables, $x_{ih}(l,t)$, that are assigned not only to the instants (l,t), but also to the instants $(l, t+h)$, shifted in time, back or forward, by a definite number h of discrete-time periods. The i-d state represents all current and past information as well as forecasts and decisions concerning the future, that are recorded in the memory of the controlling system and are needed to make new decisions. They are introduced to the controlling system from outside by its users and by measurement devices as external input variables

$$u_{l,t} = f^{ext}(l,t), \qquad for\ (l,t) \in Tl, \qquad (2)$$

or they are calculated in the controlling system at the beginning of the discrete-time period, as internal i-d state variables

$$v_{l,t} = f((l,t), x_{l,t-1}, u_{l,t}), \qquad for\ (l,t) \in Tl \quad (3)$$

Inputs to the procedures performed in the controlling system are external input variables $u_{l,t}$ and preceding i-d state variables $x_{l,t-1}$.

One should note that external input variables are the output variables of procedures that introduce data to the controlling system. Thus, all i-d state variables are output variables of procedures performed in the controlling system.

The model (1)(2)(3) is correct under the assumption that introducing and processing data durations at the beginning of discrete-time periods may be neglected in comparison with the duration of these periods. Therefore, one should show how to organise those data processing procedures that do not satisfy this assumption (Zaborowski, 2018).

From an IT point of view, equation (3) is a static model of the cause-result dependencies between the input and output variables of procedures that are performed at settled discrete-time instants (l, t). However, from the control theory perspective, it is also a dynamic model of the IMPC controlling systems because the coordinates of the i-d state vector $x_{l,t}$, which are not visible in vector equations (1)(2) and (3), are i-d state variables $x_{ih}(l, t)$ that are assigned not only to the instants (l,t) but also to the instants shifted in time $(l, t + h)$.

Enterprise reference architectures

The general mathematical model of IMPC controlling systems in the form of difference equations may facilitate transferring the results of the classical control theory to the systems of enterprise management, e.g., to analyse enterprise stability and controllability or to assess management quality using criteria and methods applied to the control systems. However, practical conclusions from such an analysis always concern i-d state variables perceived as

attributes of enterprise processes or attributes of structural objects that belong to these processes. Therefore, any theory describing the structure and operation of all IMPC systems must include a universal model of the structure of the enterprise processes as well as the structure and functioning of their control systems and interactions between them. The author's theory of Enterprise Process Control (EntPC theory) (Zaborowski, 2016a) satisfies these requirements.

Specific IMPC systems, whose structure conforms with the EntPC reference model, have been named Integrated Enterprise Process Control (EntPC) systems. In an EntPC system, control is decentralised in the hierarchical organisational structure, where control plants may be subordinate control systems (Mesarović, Macko & Takahara, 1970), and in the multistage structure of transactions (Dietz, 2006a,b) between delivery and receiving processes (Fig. 1). Such a decentralised system includes production, preparatory and managerial processes that interact on all organisational levels of an enterprise.

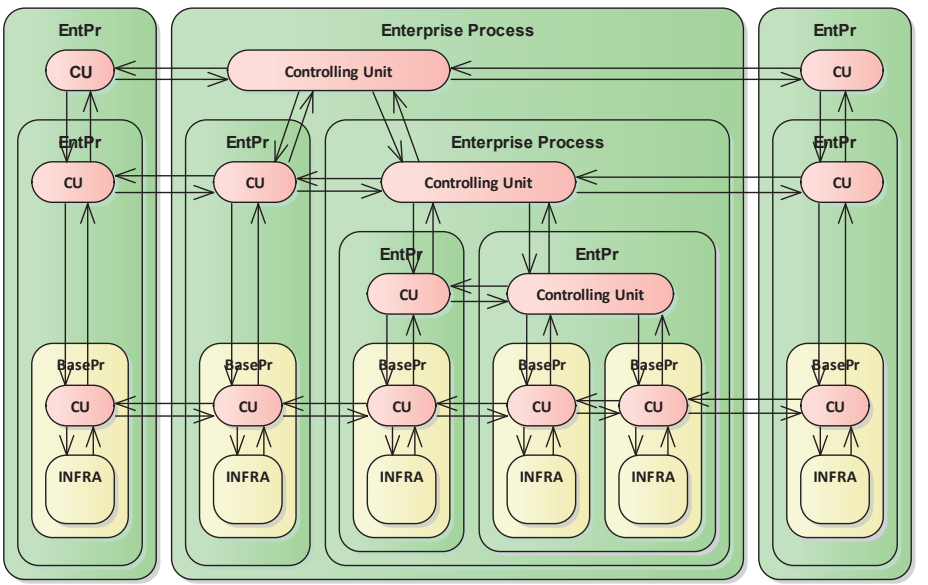

Fig. 1. Sketch of hierarchical and transactional couplings between control systems of business and base processes

Process control on the MES and SCADA levels, just as business process management on the ERP level, answers the questions "What should be done?" (what products and how many/ much of them) as well as "When and how should it be done?" (at which discrete-time periods and with what values of quality parameters). The question "where" (in which organisational units) is relevant on the ERP and MES levels. Therefore, in the case of the EntPC theory, the common model of enterprise processes on the ERP, MES and SCADA levels was inspired by standards for modelling business processes (van der Aalst & van Hee, 2002; Reijers, 2003; Dietz, 2006a; Davis & Brabander, 2007; Hofstede et al., 2010; Weske, 2012; BPMN, 2013; WFMC, 1999). Furthermore, it was assumed that the feedback structure should be adopted not only to individual process control systems on the PLC level but also to all individual control systems of enterprise business processes.

I-d state variables are not only attributes of enterprise processes but also attributes of other structural objects that belong to IMPC systems. Specifications of those structural enterprise objects that are relevant to the construction and functioning of IMPC systems, as well as their relationships, are accessible as parts of different "enterprise reference architectures", also called "enterprise architecture frameworks" (EAF), (Bernus, Noran & Molina, 2015; Kosanke, Vernadat & Zelm, 1999; Noran, 2003; Panetto, 2007; Saha, 2004; Vernadat, 2002; Williams, 1994). Similar specifications are the content of class diagrams for enterprise conceptual models, which are metamodels of graphical languages for modelling enterprise architectures, e.g. ArchiMate (Iacob et al., 2012) and UEML (Vernadat, 2002; Panetto, 2007). The EAF's are the fundamentals of standards for IMPC systems. For example, the ISA-95 standard is based on the Purdue Enterprise Reference Architecture (PERA) (Williams, 1994).

In the case of EntPC systems, the metamodel of the Enterprise Process Control Language (EntPCL) is a part of the Enterprise Process Control Framework (EntPCF). The EntPCF defines how to create and use specific EntPC systems. The thesis on the generality of the EntPC theory (Zaborowski, 2016a) says that every IMPC system, irrespective of the enterprise, in which it is implemented, may be replaced, retaining all its functions and data, with a corresponding EntPC system, whose structure is conformable with the EntPCL metamodel. The EntPC theory includes the EntPCF itself and the thesis on its generality, as well as arguments and case studies, demonstrating that the thesis is true. The abbreviation "EntPC" is used instead of "EPC" to avoid confusion with the acronym of Event-driven Process Chain (Davis & Brabander, 2007).

The concepts of the EntPC theory are defined deductively, beginning with the most general concepts and moving forward, step by step, to those related to the structural details of the EntPC systems. The first part of the EntPC theory includes the information-decision model of enterprise business processes, which is presented in this paper.

1. Business processes

1.1. Definitions

Based on the APICS dictionary (Blackstone & Cox, 2005), a "business process" is a set of logically related tasks or activities performed to achieve a defined business outcome. According to van der Aalst & van Hee (2002), "a business process is one focused upon the production of particular products. These may be physical products. The 'product' can also be a service.". Thus, business processes are divided into manufacturing processes, service processes and administrative processes. Administrative processes, whose products are documents, may be listed among service processes (Reijers, 2003).

In the previous versions of the EntPC theory, that is in the ERC and EPC2 theory (Zaborowski, 2009, 2011), the business process was defined as an ordered set of activities and related resources. Resources are used, consumed or produced by these activities. In the EntPC theory, product places, which are found among "business accounts", as well as business products themselves, are components of business activities.

Resources, both consumable and reusable, are the means needed to perform business processes (Reijers, 2003). In the EntPC theory (and in its previous versions) resources are passive objects, although in the YAWL standard (Hofstede et al., 2010) and in all cases when business processes are administrative, they are regarded as actors performing business tasks or activities (Tab. 1).

For every modelling standard, a business process includes not only business activities but also certain elements that are designed to control their execution (Badura, 2014). They are events and gateways for BPMN; events and rules for ARIS; events, conditions and task decorators for YAWL; and selected business transitions (e.g., Boolean transitions) and guard conditions for EntPCL (Tab. 1).

The terms "business process" and "business activity" may be understood, depending on the context and on the accepted convention, as a model or as an instance of a given process or activity (Weske, 2012). According to the EntPC theory, these terms are assumed to refer to the models, whereas the specific realisations of business processes and activities are referred to, respectively, as business works or cases and business tasks (Tab. 1). A business task is a single or serial execution of a business activity. The duration of business tasks is usually equal to or greater than one discrete-time period, whereas durations of business events, which are business transition executions, formally are equal to zero.

In the EntPC theory, business processes are subdivided into production, preparatory and managerial processes. They are analogous to the primary, secondary and tertiary processes that have been described by van der Aalst & van Hee (2002). Production-oriented processes are defined as production processes (including manufacturing and service processes) and preparatory processes (repairs, overhauls, tooling setups and the like).

Different approaches to modelling enterprise business processes (Tab. 1) provide different meanings of the term "business process". In the DEMO (Design and Methodology for Organisations) (Dietz, 2006a,b) and EntPCL approaches, business processes are production-oriented. In the MERODE method of enterprise modelling for enterprise information system engineering (Snoeck, 2014), business processes are managerial workflow processes, which influence business objects through information system services and business events. In this approach, all production-oriented processes are

counted among business objects, not among business processes. In the BPMN (BPMN, 2013), YAWL (Hofstede et al., 2010) and ArchiMate (Iacob et al., 2012) approaches, business processes are described as administrative processes. Manufacturing activities may belong to them as "waiting" activities or "manual" activities that are performed outside the modelling system.

Tab. 1. Selected concepts of the EntPCL and similar concepts used in the well-known approaches to business process modelling

EntPCL	DEMO	ArchiMate	YAWL	BPMN	ARIS	MERODE
business process	business process					
managerial business process			YAWL net	process	process	business process
business activity	P-act type					
managerial activity		business process	task	activity	function	service task
business object	fact type	business object	data element	data object (model)	entity	business object type
business product	P-fact type	product / business service	document type	document (model)	product/ service	
business transition	transition C-act type	business event application component	event	event (model)		event type
guard condition			condition		event	
variable		data object	variable	property	attribute	attribute
Boolean transition			task decorator	gateway	rule	
business unit	actor	business actor	resource	participant	organisational unit	
business role	actor role	business role/ business function	resource role	partner role	position	
business work	process performance					
managerial work			case	process (instance)	process occurrence	
business task	P-act					
managerial task			work item	activity (instance)	function occurrence	
realisation object	fact		case data element	data object (instance)	entity occurrence	business object
business task product	P-fact		case document	document	product/ service occurrence	
business event	event		event log	event	event occurrence	event
variable record			data value	property (instance)	entity occur. attribute	

1.2. Production-oriented business processes

The first axiom of the PSI theory (Performance in Social Interaction), which underlies the DEMO methodology (Design and Engineering Methodology for Organisations), states that "the operation of an enterprise is constituted by the activities of actor roles: … production acts (P-acts) and coordination acts (C-acts). These acts have definite results: production facts (P-facts) and coordination facts (C-facts)" (Dietz, 2006b). Therefore, the active and passive objects listed in Tab. 1 may be regarded correspondingly as acts and facts or as their types.

Based on the PSI theory, a business process called herein a multi-transactional business process, is "a process that consists of an ordered collection of transaction types" (Dietz, 2006b). A transaction is a sequence of acts that includes one P-act and several C-acts, which are the activities of the two actor roles: initiator and executor of the transaction. Thus, all C-acts of a transaction are assigned to the P-act performed by its executor.

According to the EntPC theory, a business process is a self-controlling business process defined as a system of control for a finite, partially ordered set of business activities that transform material resources, documents and services into products to fulfil the requirements of other business processes, that belong to a given enterprise or to its environment. Output products, just as input products, may be material resources, services or documents. A service is an outcome of a service process. Business activities, $a \in A$, are stages of business processes, $p \in Pa$. Conversely, every business process observed from the outside is a business activity. For example, the process F is an activity in the process X (Fig. 2). Therefore, the set of business processes is a subset of the set of business activities, $Pa \in A$. A business activity is a business process of a lower level or a base process that has no subordinate activities. A base process,

$$p \in Pb = Ab \subset A,$$

is a system that controls an infrastructure process.

Strictly speaking, the equal sign in the above formula does not concern the sets of base processes and activities. It relates to the sets of their identification numbers, but in practice (and in all formulas of the EntPC theory), software objects (representing real objects) are equated with their identifiers.

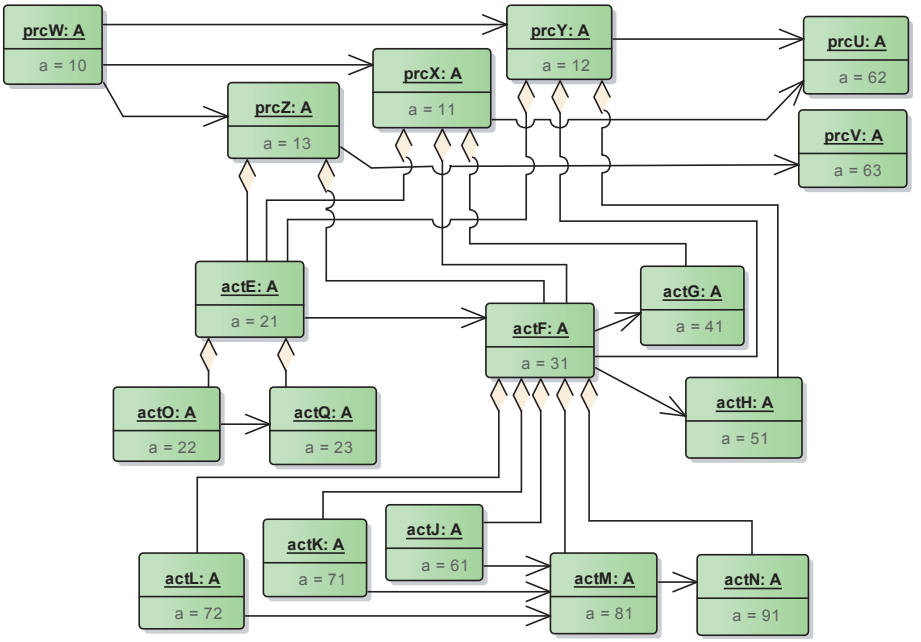

Fig. 2. Example of an EntPCL object diagram for activities in business processes

Unlike activities and processes, which are active objects, all business products, including services, are passive objects. The output products of business activities, after withdrawal to other business activities, formally become their input products, which are other structural objects (Fig. 3).

Each self-controlling business or base process has exactly one controlling unit that performs all its C-acts. If it is a base process, then it has only one stage consisting of only one P-act type that is an infrastructural process. If it is a business process, then

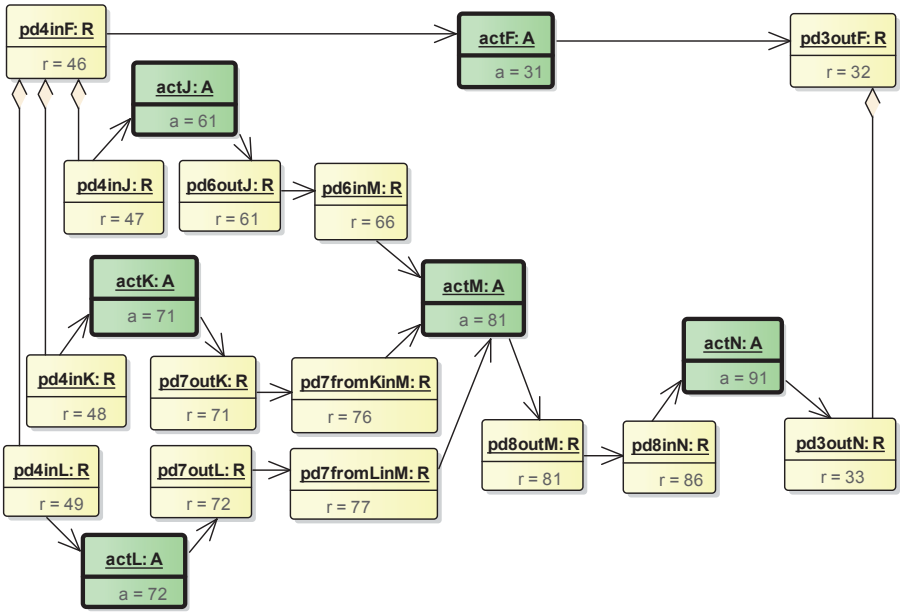

Fig. 3. Example of an EntPCL object diagram for the flow of products in business processes

its stages are business activities, which are P-act types whose components are C-act types belonging to the controlling units of the corresponding subordinate processes.

It is easy to notice that all business processes, irrespective of their definitions, are ordered sets of act types, whose common purpose is making products. However, in the case of administrative processes, which are often equated with business processes (because of the popularity of the BPMN standard), P-acts have no special role in the process structure. In contrast, in the case of self-controlling business processes, as well as for multi-transactional business processes, all C-acts are assigned to definite P-acts.

The structure of self-controlling business processes determines the following:

- hierarchical relationships between business activities and business processes,
- order relationships of performing business process activities,
- relationships between business activities and their input and output products,
- relationships between output activity products and input products of the following activities.

All these relationships may be shown in tabular form or in EntPCL diagrams (Zaborowski 2015, 2016a). They are patterned on UML object diagrams (Booch, Rumbaugh & Jacobson, 1999), but they are simpler because the only relationships between the presented objects are associations. Among associations, just as for the UML standard, one can separate the composition and weak aggregation. Additionally, the order relationships, represented by arrows, are distinguished. These relationships present the sequence of a performed activity (Fig. 2), the flow of products between activities (Fig. 3), the sequence of events, the information flow between software objects and the like. Therefore, just as for ArchiMate (Iacob et al., 2012), other diagrams illustrating a sequence of events or activities, e.g. UML activity diagrams, are not needed.

In the EntPCL diagrams, only those object attributes are visible that are useful for describing relationships between objects. Object identifiers are presented as the first of these attributes. Furthermore, they are the identification numbers of rows in the tables of enterprise objects belonging to their classes.

Sometimes, the same activity is a stage in different business processes. In other words, the same business activity may be an element of different business processes. For example, activity E belongs not only to process X but also to processes Y and Z (Fig. 2). Such relationships are presented as elements of a weak aggregation relation.

Every self-controlling business process has its own controlling unit that controls its subordinate and delivery activities. In the illustrative object diagram (Fig. 2), the unit that controls activities E, F and G and belongs to the process X is hidden in the activity denoted by 'prcX'. Similarly, the controlling unit that

controls activities J, K, L, M, and N of the process F is hidden in the activity 'actF'. The controlling unit of a specific activity determines its decisions based not only on superordinate decisions but also on requirements that are submitted by the controlling units of the receiving activities (e.g., the controlling unit of the activity F reacts to decisions from the controlling units of processes X, Y and Z as well as to orders from the controlling units of activities G and H). One should remember that the concepts "activities" and "processes" do not denote their concrete realisations (Tab. 1). They are understood as models that concern all feasible instances of their structural relationships.

1.3. Business units

Each specific business activity, $a \in A$, is performed by only one business unit, $u \in U$. This fact is formally modelled by a composition relationship, in which the business activity is a component of a specific business unit (Fig. 4). Similarly, each business process, $p \in Pa$, is a component of a definite business system, $s \in S$. These relationships are function dependencies:

$$u = u(a) \in U, for\ \ a \in A$$

$$s = s(p) \in S, for\ \ p \in Pa$$

On the other hand, there is exactly one generic activity, $a^n(a) \in An$, that is attributed to each business activity.

Business systems and business units are defined as systems of control, correspondingly for all the business processes and business activities that are performed by these systems and units. If a business system is not an elementary one, its controlling unit also controls business units that belong to it. Conversely, business systems, if observed from the outside, are business units of a higher level, $S \subseteq U$. In the structure tree of business units, the enterprise as a whole is the root. Business units, except the ones from the highest level, are components of business systems (Fig. 4) $s = s(u) \in S$.

The hierarchical structures of business systems correspond to analogous structures of business processes (Figs. 2, 3). The difference between these structures is that relationships between business systems and units are composition relationships, whereas, between business processes and activities, they are weak aggregation relationships.

Among all business systems of an enterprise, organisational systems, $s \in Sorg \subset S$, are particularly notable. Typical examples of organisational systems that belong to different organisational levels include the following:

- the enterprise as a whole,
- a work site,
- a workshop, and
- a workstation.

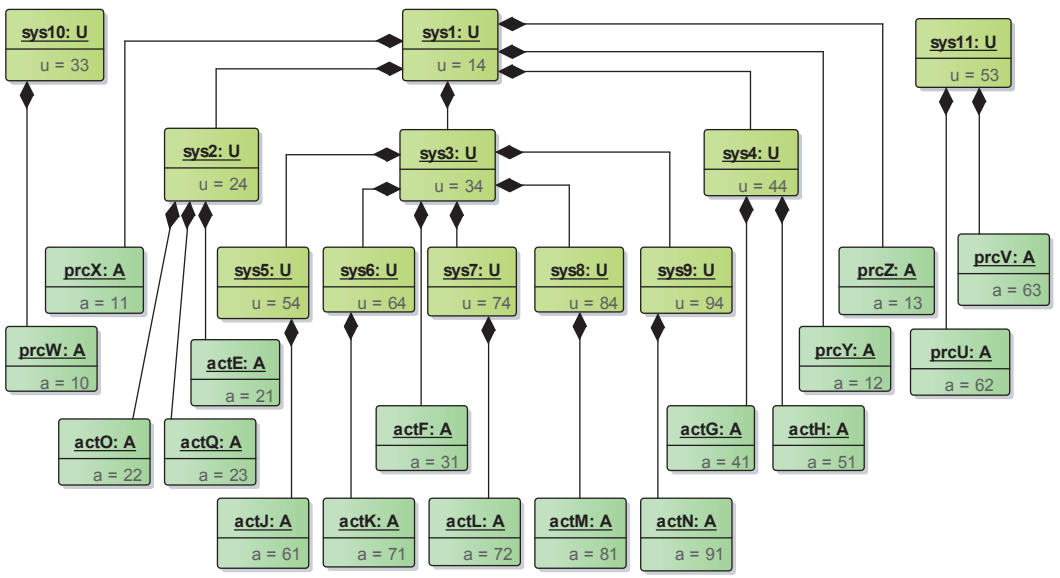

Fig. 4. Structure tree of the business units and business activities of an illustrative EntPC system

Organisational systems, if watched from the outside, are work units, $Sorg \subseteq Uw \subset U$, which are components of organisational systems of a higher level.

Among business units, we distinguish not only work units, but also operational segments and executive sectors. An operational segment, $u \subseteq Uo \subset U$, is a set of parallel work units that belong to the same organisational system and are grouped by similar products that can be mutually substituted. Work units may also be grouped if they share input resources, if their production technologies are similar and the like. Examples of operational segments include the following:

- departments of a work site (i.e., groups of its workshops) and
- work centres of a workshop (i.e., groups of its workstations).

An executive sector, $s \in Sh \subseteq Uh \subset U$, is a subset of operational segments that belong to the same organisational system, which is designed to execute managerial, preparatory or production subprocesses of work processes performed by this system. An organisational system regarded as a system that controls executive sectors is named a work system, $s \in Sw \subseteq Uw \subset U$. Controlling units of

- work systems,
- executive sectors and
- operational segments,

which belong to organisational systems of the same organisational level, form three functional layers of the executive, coordinative and allocative management in this level.

An enterprise is an independent organisational system that is involved in the production of goods or services to satisfy the requirements of consumers or other enterprises. According to the EntPC theory, every organisational system of an enterprise environment is regarded as a supplier or receiver of specific goods or services. The enterprise with its environment corresponds to the complete EntPC system. It is an integrated system that manages all business processes and controls all infrastructural processes in a given enterprise and in its business environment. Including the enterprise environment in the EntPC system causes influences from its outside processes to not be considered.

1.4. Enterprise processes

In EntPC systems, business units, $u \in U$, and business systems, $s \in S$, are identified correspondingly by the identifiers of the groups of all business activities, $a \in A$, and all business processes, $p \in Pa$, performed by them. Therefore, as collected business activities and collected business processes, they are counted among generalised business activities, $b \in B$, and generalised business processes, $p \in P$.

The business role, $g \in G$, of the business unit, $u(g) \in U$, is a group of jointly managed business activities distinguished in this unit according to the required competence and authority or required resources. The business system role, $p \in Pg \subset P$, is an analogously defined group of business processes. As a control system, the business system role controls its business processes and the roles of subordinate business units. By analogy to business units and business systems, their roles are also counted among generalised business activities and processes.

Enterprise processes are generalised business processes including business processes, $p \in Pa$, business systems, $s \in S$, their roles, $p \in Pg$, and also base processes, $p \in Pb$,

$$p \in P = Pa \cup S \cup Pg \cup Pb$$

Analogously, enterprise activities are generalised business activities,

$$b \in B = A \cup U \cup G$$

2. Control in enterprise processes

2.1. Business processes and base processes as control systems

The classical structure of a simple system of direct control (Murril, 2000) is a feedback loop consisting of a control plant, a measurement device, a controller and an actuating device. In the simplified form, measurement and actuating devices are hidden in a control plant (Bubnicki, 2005). However, the structure of a feedback control system may also be presented in another way (Fig. 5), facilitating its use for describing business process control systems. In this structure, only the actuating device is included in a control plant, whereas a measurement device is presented as a part of the controlling unit. In such systems, control encompasses the following:

- acquisition of information on a control plant and
- making decisions concerning the control plant.

Thus, the controlling unit is a composition of the information unit and the decision unit.

In a general case, controlled processes are multivariable control plants. Thus, in a self-controlling base process, which is a system of direct control with an infrastructural process as a control plant, the base information unit and the base decision unit are the corresponding collections of measurement devices and controllers. A self-controlling business process has the same structure (Fig. 5), but the internal elements of the information and decision units are different. Moreover, its control plant is a set of business activities that may be subordinate, base or business processes. Consequently, the EntPC system of an entire enterprise may be presented as a functional block diagram that includes only controlling units and infrastructural control plants (Fig. 1).

The output variables of information and decision units are referred to as information variables and decision variables, respectively. The base controlling variables affect infrastructure control plants through their actuating devices. Decision variables, in this case, are supervisory setting variables. Moreover, information variables are measured controlled variables and measured disturbances. In the case of a simple automatic control system, the base decision unit is a controller, and the base information unit is a measurement device.

The exact values of controlled variables in a base control system are not known. They differ from corresponding information variables because of measurement errors. However, everybody knows that controlled variables depend on base controlling variables and on disturbances that arise from the infrastructural environment of the control plant. Consequently, measurements of controlled variables depend on both these variables and measurement errors. The measured values of controlled variables and selected disturbances are accessible as output variables of a base information unit.

2.2. Business transitions and business events

Information units and decision units are functional units of enterprise processes, $k \in Kf$. Every functional unit is an information-decision action, $k \in Kf \subset Kid$, that is a business transition, or an information-decision process watched from the outside (Fig. 9). Business transitions, $k \in K \subset Kid$, are elementary software objects that are designed for processing information and decisions. An information-decision process, $k \in Pid \subset Kid$, is an

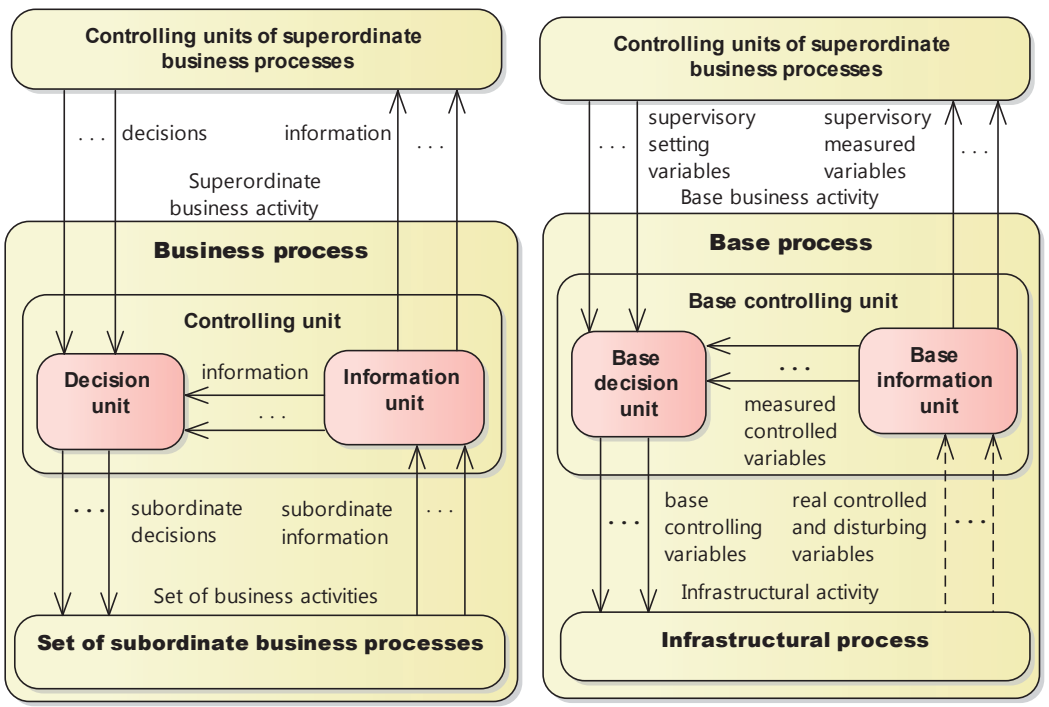

Fig. 5. Business and base processes as control systems

ordered set of business transitions, which can be executed at the same discrete-time instant. Each business transition belongs to a definite functional unit, a definite controlling unit, and consequently, a definite enterprise process and a definite enterprise activity,

$$p(k) \in P \subseteq B, for\ \ k \in K$$

Every business transition, regarded as a software object, has exactly one business operation (Fig. 9), which is an operation that processes its input variables into output variables. It has also one operation for reading input variables and one operation for recording output variables. Additionally, when an EntPC system moves to the next discrete-time instant, then business transitions shift their i-d state variables, that are their output variables. In EntPC systems, business transitions are the only software objects that perform data processing operations. All other objects of these systems, except for clocks initiating sequences of business events, have only writing and reading operations.

The i-d state variables are input and output variables of business transitions. They are passive objects of business transitions environment through which they can communicate. Guard variables and guard conditions are the other inputs and outputs of business transitions. They are binary variables used to control executions of the transitions. Guard variables, like i-d state variables, are attributes of structural objects, whereas guard conditions are attributed to the business transitions. Some business transitions, corresponding to events and gateways of the BPMN standard (Tab. 1), process only guard conditions and guard variables, but in a general case, they can perform the more complex procedures of data processing, e.g. the algorithm of digital PID controllers in direct control systems (Murril, 2000), the MRP algorithm (Orlicky, 1975) for ERP systems and the like.

Business transitions that belong to information and decision units are referred to as information transitions, $k \in Ki \subset K$, and decision transitions, $k \in Kd \subset K$, respectively. Their output variables are the same information and decision variables, which are the output variables of functional units (Fig. 6).

Business transitions are coupled with their input and output variables, which are passive objects, and do not have any direct couplings. Transitions stimulated by clock impulses at consecutive discrete-time instants investigate the states of variables in their environment in order to decide whether to begin their operations. In this sense, business transitions are autonomous software objects (Lockemann, 2006). Consequently, EntPC systems may be counted among multiagent control systems with passive interactions between agents (Monostori et al., 2015).

According to the EntPC theory, every business event, $e \in E$, is an execution of a definite business transition operation. The duration of each business operation is formally equal to 0, and all the operation is attributed to a concrete discrete-time instant. An EntPC system works properly, if the following requirements, which are axioms of the EntPC theory, are satisfied:

- first, the duration of performing a business operation is so short that the interval between the initial moment of the discrete-time period and the end moment of the operation is imperceptible relative to the length of this period;
- second, none of the business transitions can act in a given discrete-time period more than once, to enable attributing one definite value to a given i-d state variable at a given discrete-time period;
- third, in a given discrete-time instant, the business transition must act according to a definite order, to avoid casual variations of the i-d state variables.

Therefore, one part of the EntPC theory is devoted to explaining how to organise the managerial activities that replace those business transitions that do not satisfy the first of the above axioms and how to assure fulfilment of the second and third axioms (Zaborowski, 2018).

2.3. Hierarchical and transactional couplings between enterprise processes

In EntPC systems, information flows consist in recording values of variables determined by business transitions to memory places in the controlling units of individual business processes and then of reading by other business transitions. Information variables are remembered in the same controlling unit that includes recording information transitions (Fig. 6). They are read

- as controlled variables by a decision unit,
- as subordinate information variables by information units of superordinate business processes,
- and by other transitions of the same information unit. Furthermore, information transitions can generate

- disturbance information variables, as illustrated by the dashed lines in Fig. 6 that carry information on disturbances measured in a given process.

Unlike information variables, the decision variables of EntPC systems are kept not in the controlling units, from which they come but in the controlling units that include the decision transitions that read their values. To clarify, decisions are remembered where they are to be executed. Decision variables are recorded as follows:

- as superordinate decision variables by the decision units of superordinate business processes,
- as subordinate decision variables that are recorded by the decision units of business processes in the decision units of subordinate processes; they may also be recorded by the decision units of base processes in the memory places of the base controlling variables (Fig. 5),
- as order variables by the decision units of receiving processes,
- as cooperative variables by the decision units of delivery processes that transfer information on the products available for reception (analogously, transfer variables from a given process are recorded in the controlling units of receiving processes),
- as return transfer variables by the decision units of receiving processes that transfer information on received business products (in particular, on the products that have been rejected),
- as return order variables by the decision units of delivery processes that transfer information on offers and rejected orders for delivery products, and
- as external disturbance variables that carry information on disturbances measured and made available in other processes.

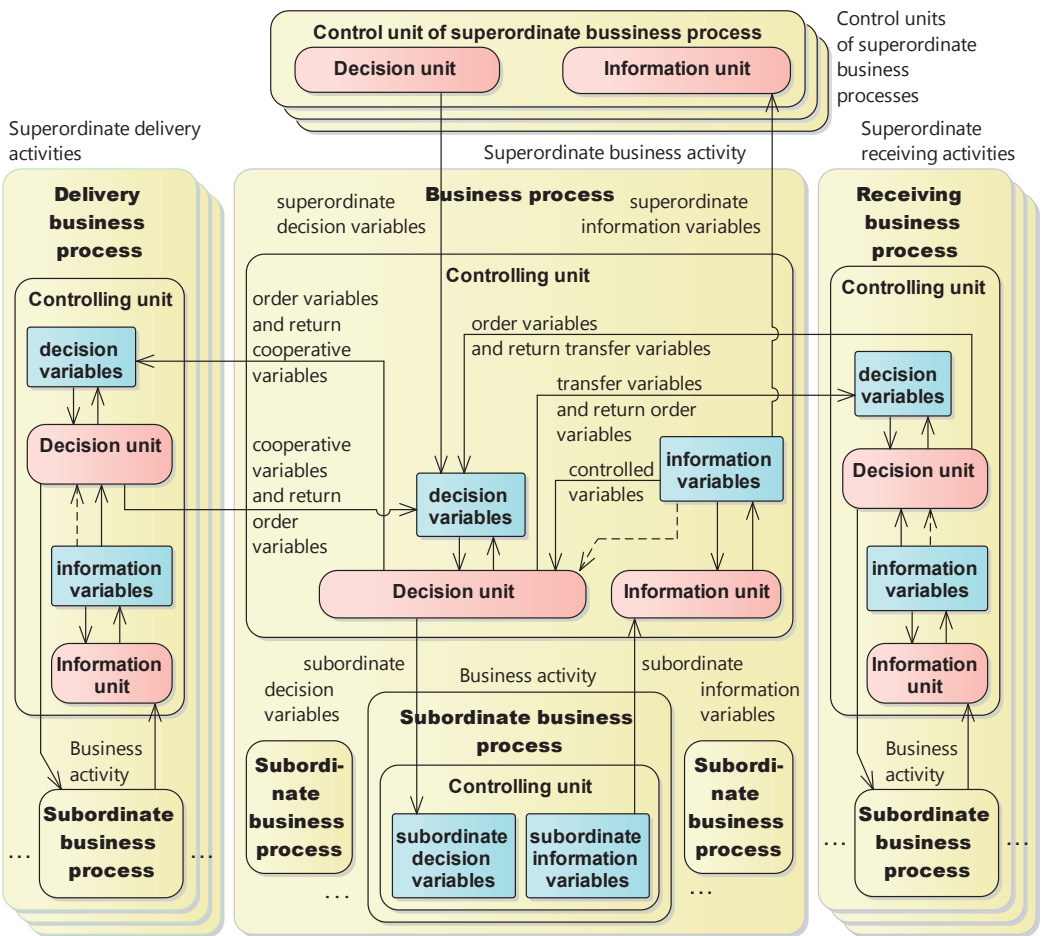

Fig. 6. Information flow between functional units of a business process

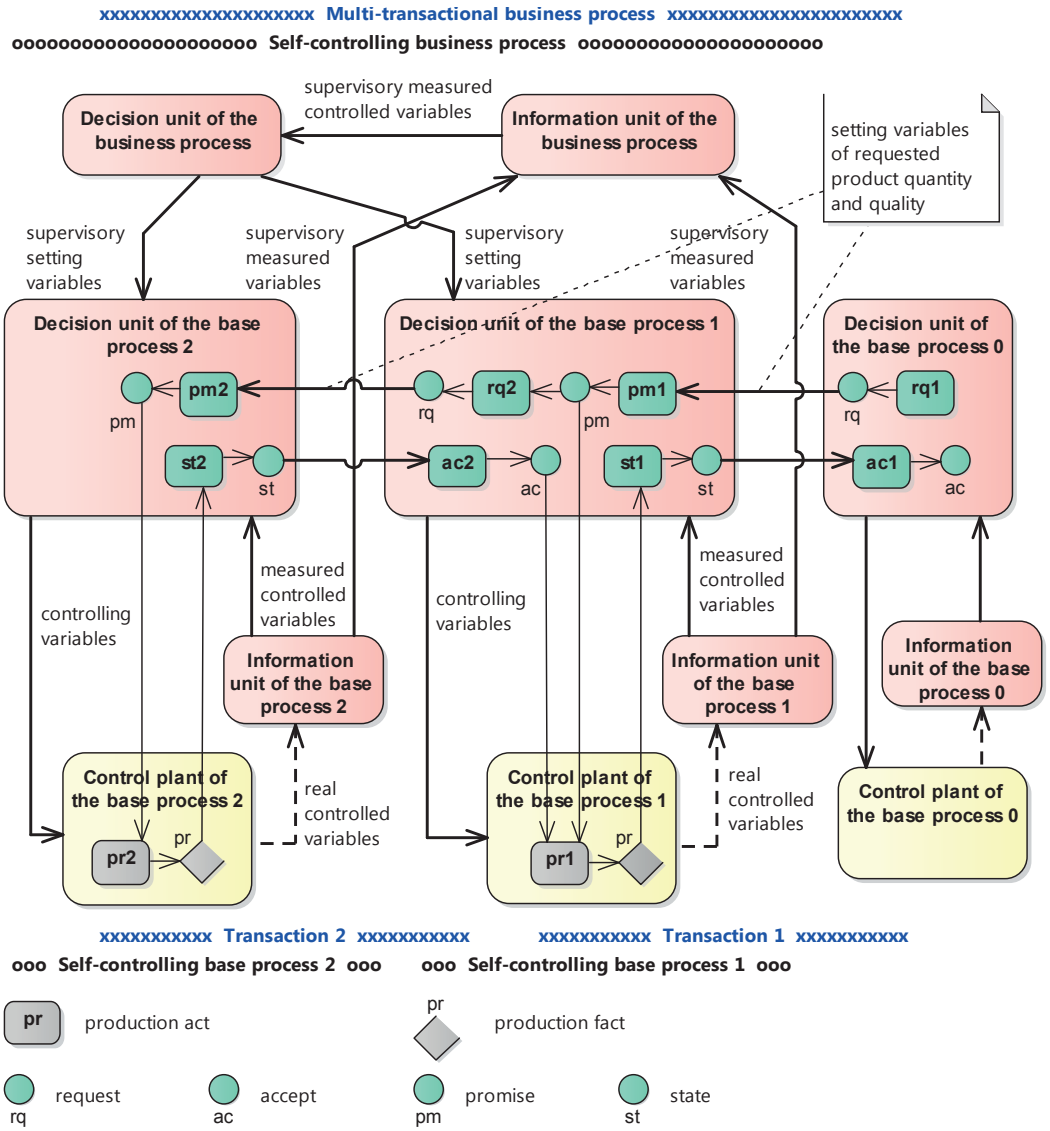

Fig. 7. Acts and facts that belong to the illustrative multi-transactional business process as elements of a corresponding self-controlling enterprise processes

In a general case, a given business process may have many superordinate processes (including business systems and their roles, regarded as enterprise processes), many subordinate activities, many receiving processes and many delivery processes. Thus, the controlling unit of a business process (Fig. 6) may have couplings with many superordinate controlling units, with many controlling units of subordinate activities and with many controlling units of delivery and receiving processes.

An extensive and thorough description of transactional couplings between actors participating in business processes is a part of the PSI theory (Dietz, 2006b). It defines a transaction as a sequence of acts that belong to two actor roles, initiator and executor (Fig. 7), and a business process as "a process that consists of an ordered collection of transaction types". In a general case, a realisation of a multi-transactional business process is "a tree structure of enclosed transactions. A transaction T2 is enclosed in transaction T1 if T2 is initiated by the executor of T1" (Dietz, 2006a).

In the PSI theory, internal structure and the functions of production acts "belong to the realm of implementation" (Dietz, 2006b). In the EntPC theory, the internal structure of processes is unknown only for the infrastructure. Therefore, in Fig. 7, transactions are collated with the base processes, although the DEMO methodology (Dietz, 2006a,b), which is based

on the PSI theory, is designed for applications at higher organisational levels.

In the transactional model of business processes (Dietz, 2006a,b) the facts that belong to the basic transaction pattern are as follow (Fig. 7):
rq – an order sent by a customer,
pm – an order realisation promised and its execution started by a producer,
st – an order realisation stated by a producer and
ac – an order product accepted by a customer.

In the i-d model of enterprise processes, the following variables correspond to these processes:
- order variables,
- subordinate decision variables,
- controlled variables carrying information on finished production orders, and
- decision variables of receiving processes, concerning withdrawing products made available by a given business process.

In the i-d model, controlled variables (information on finished orders) are not sent directly to a receiver, as in the model of a single transaction (Dietz, 2006a), but they are transformed into transfer decision variables that carry information on products available for withdrawal. This is necessary in the case of products that may be allowed for different receivers. Analogously, cooperative variables carry information on delivery products made available by suppliers.

Apart from basic patterns, there are also standard and cancellation patterns for transactions (Dietz, 2006b). The standard transaction pattern includes facts that belong to the basic pattern and the following additional facts:
dc decline – order declined by a producer,
qt quit – order repetition quit by a customer,
rj reject – product rejected by a customer, and
sp stop – delivery attempts stopped by a producer.

In the i-d model (Fig. 6), they are represented by
- return order variables,
- decision variables of a receiving process,
- return transfer variables,
- transfer variables.

There are many differences between the structures of the self-controlling and multi-transactional processes. First, the stages of self-controlling processes are enterprise activities performed by single business units, whereas in the case of multi-transactional processes each transaction is a sequence of acts that belong to two actor roles. Second, each transaction is controlled only by its initiator, whereas a self-controlling sub-process (enterprise activity) may be influenced not only by many receiving activities but also by many superordinate enterprise processes (Figs. 6 and 7). Third, in EntPC systems, acts and facts resulting from them are separated. What is more, C-acts and corresponding C-facts (e.g. decision events and records of decision i-d state variables) may belong to different actors (Fig. 6). However, despite these differences, all the facts analysed above concerning the multi-transactional model of business processes have their counterparts in the i-d model of enterprise processes.

3. Conceptual model of self-controlling enterprise processes

3.1. The EntPCL metamodel

Each EntPCL object, as an object of an EntPC system software, includes its own set of attributes, its own set of operations that are executed on the attributes and its own set of relationships with other objects. On the other hand, each EntPCL object is an element of the set of all EntPCL objects in the concrete EntPC system, $o \in O$. The EntPCL metamodel, like ArchiMate's metamodel (Iacob et al., 2012), is a set of class diagrams that impose definite relationships between EntPCL objects. A class of EntPCL objects is, like in UML, a generalisation of a set of EntPCL objects that have the same attributes and operations and the same relationships with objects of other classes (Booch, Rumbaugh, & Jacobson, 1999).

Each class of EntPCL objects corresponds to one of the concepts of the EntPC theory. The relationships between these concepts are visualised in class diagrams of the EntPCL metamodel as relationships between corresponding classes. Thus, the EntPCL metamodel may be regarded as a conceptual model (Snoeck, 2014) of EntPC systems. EntPCL, like ArchiMate (Iacob et al., 2012) and UEML (Vernadat, 2002), may be used to model enterprise reference architecture. Diagrams constructed using each of these languages for concrete enterprises present the relationships between objects of their architecture, but the metamodels that determine areas of modelled facts, are different.

The EntPCL metamodel is identical for every enterprise. However, in a specific EntPC system, its classes represent finite sets of objects, whereas the relationships between the classes represent sets of relationships between the objects that belong to the

sets. The names of sets of objects that are presented for every object in the EntPCL object diagrams are visible in the class diagrams as short names of corresponding classes. To improve readability of metamodel class diagrams, pictures of classes include also long names of the classes as well as symbols of object identification numbers. The illustrative object diagrams (Figs. 2 and 4) correspond to a fragment of the class diagram shown in Fig. 8.

Aggregation relationships between activities and processes (Fig. 2) correspond to the relation of weak aggregation between classes *B* and *P* of generalised business activities and processes. Order relationships between activities are represented by order relations between class *Bd* of generalised delivery activities and class *B*, as well as between class *B* and class *Bc* of generalised receiving activities. Composition relationships between business activities and business units, as well as between business units and business systems (Fig. 4), correspond to the relations of composition between class *A* and class *U*, as well as between class *U* and class *S*.

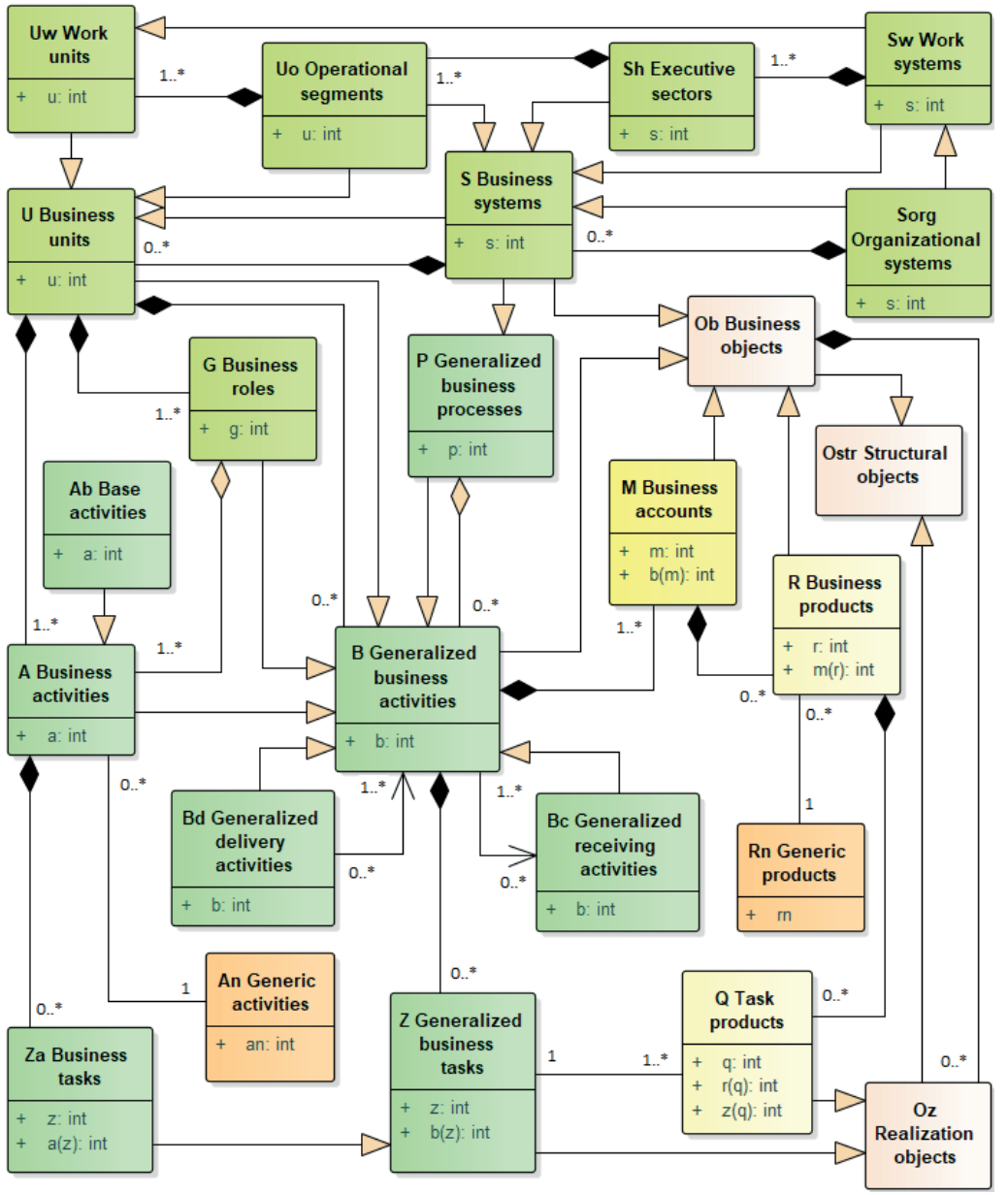

Fig. 8. Class diagram for the relationships between business and realisation objects

Delivery and receiving business activities, as well as business processes and business units, are special cases of generalised business activities, but this is not visible in the object diagrams. This is shown correspondingly in the class diagram as generalisation relations between classes *Bd, Bc, P, U* and class *B* (Fig. 8). There is also a compositional relation between classes *S* and *U*.

3.2. Structural objects

The EntPCL metamodel encompasses all structural objects of EntPC systems and all variables that are their attributes, as well as all associations that represent their relationships. Structural objects

$$Ostr = Ob \cup Oz$$

are divided into business objects

$$o \in Ob \supset B \cup M \cup R,$$

and realisation objects (Fig. 8),

$$o \in Oz \supset Z \cup Q.$$

Business activities, $a \in A$, business processes, $p \in Pa$, business tasks, $z \in Za$, business works, $w \in Wa$, and generalised business activities, $b \in B$, have been defined in the chapter 1. Generalised business tasks,

$$z \in Z = Za \cup Zu \cup Zg,$$

include not only business tasks, but also collected business tasks, $z \in Zu$, and group business tasks, $z \in Zg$, which are group executions of all business activities that belong to definite business units, $u \in U$, or to definite business roles, $g \in G$.

Business accounts, $m \in M$, that belong to a definite generalised business activity are places of information on this activity and its executions. Formally, they may be presented as components of generalised business activities, which may be divided into accounts of business activities, accounts of business units and accounts of business roles:

$$M = Ma \cup Mu \cup Mg$$

Each generalized business activity has at least three business accounts, belonging to the three corresponding subclasses:

$$m \in M \supset Min \cup Mout \cup Mb$$

Two of them group information on input and output products of a given activity. The third is a place of information related directly to the activity.

A business product, $r \in R$, is a generic product, $r^n(r) \in Rn$, that is produced or used in a definite generalised business activity and belongs to a definite account, $m(r) \in M$, of this activity, $b(m(r)) \in B$. Task products, $q \in Q$, are business products that are attributed to concrete generalised business tasks. Tasks products are components of business products, which are components of business accounts and business accounts are components of generalised business activities, which in turn are components of business units and organisational systems (Fig. 8). Thus, all structural objects belong to a structure tree (similar to the one shown in Fig. 4), whose root is the enterprise as a whole (Zaborowski, 2016b).

3.3. Functional variables and information-decision state variables

The changeable attributes of business objects and realisation objects are called respectively business variables, $i \in Ib$, and realisation variables, $i \in Iz$, (Fig. 9). Formally, they are components of business objects and realisation objects and, on the other hand, they are attributed to corresponding generic variables, $i \in In$.

Business and realisation variables are attributes of structural objects (Fig. 9). They are processed by the functional units of self-controlling enterprise processes. Therefore, they have been named functional variables,

$$i \in I = Ib \cup Iz.$$

Functional variables are divided into information variables, $i \in Ii \subset I$, and decision variables, $i \in Id \subset I$, which are, respectively, the output variables of information and decision transitions:

$$i \in I = Ii \cup Id,\ Ii \cap Id = \emptyset,$$

The set of functional variables includes the following:

- quality variables, e.g. length, diameter, colour, and temperature;
- time variables, e.g. the due date of a business task;
- existential variables, i.e. binary variables that indicate whether specific business objects exist,
- guard variables, i.e. binary functional variables that are used to control the executions of business transition operations.

In control systems, the variables attributed to a specific moment in time are often referred to as signals (Bubnicki, 2005). Therefore, the values $y_i(l,t)$ of functional variables, $i \in I$, recorded at

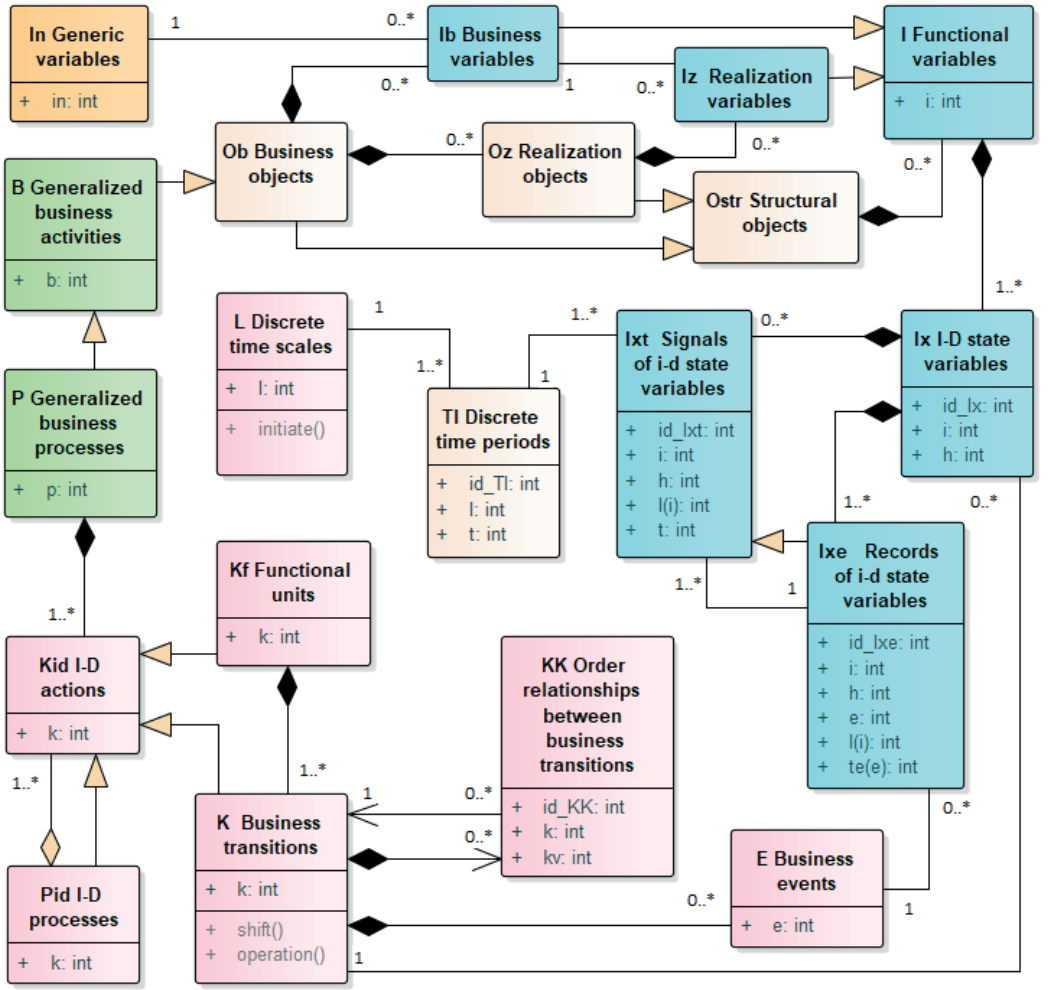

Fig. 9. Discrete time, business transitions and i-d state variables

discrete-time instants, *(l,t)* ∈ *Tl*, are values of the signals of functional variables,

$$(i, l, t) \in It \subset I \times L \times T.$$

Knowledge of the current values of functional variables is not sufficient to control enterprise processes. One should also know the values of the i-d state variables that are assigned to the instants *(l,t+h)*, shifted in time, back or forward, by a definite number h of discrete-time periods (see introduction). The value,

$$x_i(l, t, h) = x_{ih}(l, t),$$

of a signal,

$$(i, h, l, t) \in Ixt \subset I \times H \times L \times T,$$

of an i-d state variable,

$$(i, h) \in Ix \subset I \times H,$$

at a specific time instant, is equal to the value of the signal of a functional variable that is shifted in time by a definite number of discrete-time periods, $h \in H$, of the time scale, $l \in L$, applied to this functional variable,

$$x_{ih}(l, t) = y_i(l, t + h), \quad (4)$$
$$for\ h_i^- \le h \le h_i^+,\ i \in I,\ (l, t) \in Tl.$$

Conversely, the value of a functional variable signal is equal to the value of the signal of the i-d state variable with a zero-time shift:

$$y_i(l, t) = x_{ih}(l, t) \mid h = 0 \wedge (i, h) \in Ix, \quad (5)$$
$$for\ t_l^- \le t \le t_l^+,\ l \in L,\ i \in I.$$

Formally, an i-d state variable is a component of a functional variable (Fig. 9) and, indirectly, a component of a specific business object, a specific business activity and a specific business unit. One functional variable may correspond to many i-d state variables. I-d state variables, like functional variables,

are divided into information state variables, $(i,h) \in Ixi \subset Ix$, and decision state variables, $(i,h)\ Ixd \subset Ix$.

Moving to a new discrete-time instant does not change the values of i-d state variables but does change their identifiers. Therefore, immediately after creation (by a clock), the initial instant of a current discrete-time period, $(l,t) \in Tl$, for a given time scale, $l \in L$,

$$(l,t) \coloneqq (l,t+1), \tag{6}$$

and prior to making current information on the i-d state, one should decrease the values of the time shifts of the i-d state variables by 1 relative to the current time instant (Zaborowski, 2018).

Business events that are regarded as executions of business transitions may insert the records of i-d state variables,

$$(i,h,e) \in Ixe \subset Ix \times E,$$

into the system memory. Each record (i,h,e) of an i-d state variable (i,h) is also an effect of one definite event, $e \in E$, and is a formal component of this variable. Each record of an i-d state variable corresponds to the i-d state variable signal at the instant the record is created and, perhaps, to the signals at certain future time instants.

Access of business transitions to their input i-d state variables and general description of procedures for processing i-d state variables are discussed in (Zaborowski, 2018).

Conclusions

Self-controlling enterprise processes have been defined in this study as a new category of business processes. It encompasses not only production, preparatory and managerial business processes, but also business systems and their roles. Events, gateways, conditions and other elements that are used for managing the sequence of task executions have been grouped in one controlling unit of a given process. Additionally, all business transitions, which control the quantity and quality of products that are processed in a production-oriented business process, are also included in its controlling unit. It has been demonstrated that integrated management and direct control systems may be built as integrated enterprise process control systems (EntPC systems), which are networks composed of infrastructural control plants and of controlling units of multistage, multilevel self-controlling enterprise processes.

To model the structures of concrete business processes and the details of the structures of process management systems, one can use EntPCL diagrams, which are UML object diagrams that fulfil the structural constraints imposed by the class diagrams of the EntPCL metamodel. The EntPCL metamodel is a conceptual model of EntPC systems. It is the base of the Enterprise Process Control Framework (EntPCF), which is a description of the structure and behaviour of EntPC systems, and it underlies the Enterprise Process Control (EntPC) theory. The most important of many EntPCL class diagrams have been presented in this study. They describe relationships between subclasses of structural objects and between structural objects and information-decision state variables of EntPC systems.

Obviously, the EntPCF may be used as a framework for comparing different management methods and algorithms, e.g. IT tools for Business Intelligence development (Olszak & Żurada, 2015). In addition, the i-d state variables of the controlling system, together with the state variables of infrastructural processes, are state variables for any entire EntPC system. Therefore, the EntPC theory may facilitate transferring the results of the classical control theory to the systems of enterprise management, e.g., to analyse enterprise stability and controllability. It is especially useful for the industry 4.0 enterprises (Kagermann et al., 2013), because their management systems should react in real time to the enterprise state changes (Youssef et al., 2017) and, on the other hand, real-time control systems are the subject of the control theory.

The i-d model of enterprise processes differs essentially from the currently dominant standards for modelling business processes. Moreover, a significant number of new concepts and new interpretations of concepts that belong to three different domains — cybernetics, informatics and management science — may discourage the interest in the EntPCF. Therefore, in addition to the cognitive values discussed previously, one should show the practical benefits that could result from its application. It is also important to present examples of modules of ERP, MES, SCADA and PLC systems that may be implemented as corresponding modules of EntPC systems. A method of embedding such modules in the EntPCF structure has been presented (Zaborowski, 2016a) by the example of the well-known MRP algorithm (Orlicky, 1975).

In practice, it is important that class diagrams of the EntPCL metamodel are similar to class diagrams of the UML, which is designed for modelling software of IT systems. Therefore, it may be the starting point for creating the software framework for enterprise process control (SFEntPC), which will be used for designing executable models and generating software for concrete EntPC systems. The tree structure of composition relationships between organisational systems, enterprise processes, business transitions, structural objects and i-d state variable (Figs. 8, 9) should facilitate implementation of the SFEntPC as an extension to the Eclipse Modeling Framework (EMF) (Steinberg et al., 2008).

The controlling units of enterprise processes (Fig. 1) will be replaceable building blocks in the software generated in the SFEntPC environment. Thus, re-engineering of a given self-controlling enterprise process, perceived as a branch in an enterprise structure tree, relies on removing from it the controlling units and infrastructural processes that belong only to the sub-processes selected for elimination and embedding in it the complete controlling units and infrastructural processes of new sub-processes. The enterprise itself is a self-controlling enterprise process as well. So, this type of re-engineering of enterprise processes is also re-engineering of the enterprise software. Such an operation may be performed by business analysts, without the participation of IT engineers. This will obliterate the "business-IT divide", which refers to the necessity of difficult and prolonged arrangements between business analysts, who understand the actual goals of process re-engineering, and IT engineers, who are authorised to make changes to the structure of management systems software (Smith & Fingar, 2003).

Acknowledgements

This work was supported by the WSB University.

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Appendix

Symbol	Description
A	business activities
Ab	base business activities
An	generic activities
B	generalised business activities, enterprise activities
Bc	generalised receiving activities
Bd	generalised delivery activities
E	business events
G	business roles
I	functional variables
Ib	business variables
Id	decision variables
Ii	information variables
In	generic variables
It	signals of functional variables
Ix	i-d state variables
Ixd	decision state variables
Ixe	records of i-d state variables
Ixi	information state variables
Ixt	signals of i-d state variables
Iz	realisation variables
K	business transitions
Kd	decision transitions
Kf	functional units
Ki	information transitions
Kid	information-decision actions
L	discrete-time scales and their clocks
M	business accounts
Ma	accounts of business activities
Mb	accounts directly related to activities
Mg	accounts of business roles
Min	input business accounts
$Mout$	output business accounts
Mu	accounts of business units
$Ostr$	structural objects
Ob	business objects
Oz	realisation objects
P	generalised business processes, enterprise processes

Pa	business processes
Pb	base processes
Pg	business system roles, group processes
Pid	information-decision processes
Q	task products
R	business products
Rin	input products
Rn	generic products
$Rout$	output products
S	business systems
Sh	executive sectors
$Sorg$	organisational systems
Sw	work systems
Tl	discrete-time periods
U	business units
Uh	executive units

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ISMSME International Society for Manufacturing, Service and Management Engineering

received: 5 September 2018
accepted: 15 December 2018

pages: 55-64

Pilot Study on the Application of Employee Scheduling for the Problem of Safety Instrumented System Design and Maintenance Planning for Remotely Located Oil and Gas Facilities

Yury Redutskiy

ABSTRACT

The technology of production, transportation, and processing of oil and gas involves various hazardous processes. To mitigate the risk that these processes pose, the technological solutions work closely with the automated control and safety systems. The design and organisation of maintenance for the automated safety instrumented systems (SIS) have a significant bearing on the overall safety of operations in this industry. Over the past few decades, many hydrocarbon resources have been discovered in unconventional environments, such as remote, offshore, and arctic locations. Transportation of engineering personnel to these remote locations and back, and thereby, the organisation of the shift work poses additional challenges for the petroleum sector. Under such circumstances, the workforce-related costs play a considerable role in the overall cost of the technological solution and thereby the decisions regarding the workforce organisation should be addressed in the framework of evaluating and choosing the appropriate safety measures. That is why the research presented in this paper aims to address the lifecycle of the technological solution integrating the problems of SIS design, maintenance planning, and employee scheduling into a single decision-making framework to optimise the set of technical and organisational safety measures inherent in the SIS. The performance and maintenance of the SIS are described with a Markov model of device failures, repairs and technological incidents occurrence. The employee scheduling part of the mathematical model utilises the set-covering formulation of maintenance crews taking particular trips. A black-box optimisation algorithm is used to find reasonable solutions to the integrated problem of engineering design and workforce planning. The decisions include the choices of the components and structures for the safety system, the facility overhaul frequencies, the maintenance personnel size, as well as the schedules of trips and shifts for the crews.

KEY WORDS

black-box optimisation, employee scheduling, maintenance planning, Markov Analysis, oil and gas industry, remote and arctic locations, risk management, safety instrumented system

DOI: 10.2478/emj-2018-0022

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Introduction

Over the past few decades, the oil and gas industry has seen a shift to exploration, development, and production of the hydrocarbon reserves in nonconventional environments such as deep sea and Arctic locations due to many large deposits having been discovered in these locations (Bourmistrov et al., 2015). The harsh environmental conditions at such locations as well as their poor accessibility by means of transportation pose significant challenges to the industry whose processes are inherently hazardous due to the handling of toxic, flammable and explosive

substances. When incidents occur on such hazardous facilities, they may result in significant economic losses, harm to the personnel and technological assets, substantial damage to the environment, and negative socio-political consequences. Proper design of the processes and the industrial instrumentation has a crucial bearing on the safety of operations in the oil and gas sector. To ensure the safe and proper performance of the hazardous technology, Safety Instrumented Systems (SIS) are put in place as an essential part of the process automation system. Safety measures inherent in SISs are defined and regulated by the international standard IEC 61508 (1997) and IEC 61511 (2003), as well as the national regulations of the petroleum producing countries, such as (STC Industrial safety, 2014) and (Norwegian Oil and Gas, 2001). The standards define safety instrumented systems through the structure of an automated system's control loop (Fig. 1), which includes process value transmitters (i.e., sensors), logic solvers (programmable logic controllers), and final control elements (actuators, e.g. valves, pump drives, switches, etc.). At any hazardous facility, several SISs are usually put in place. They act as a series of barriers protecting the personnel, technological assets, environment, etc. Some of these SISs aim to prevent the hazardous event from taking place, while others aim to mitigate the consequences in case such an event occurs. Among the safety systems at the oil and gas facilities aimed at preventing the incidents, Emergency Shutdown (ESD) systems are considered to ensure the most substantial risk reduction (CCPS, 2010). The ESD systems monitor the course of the processes and shut down the technology when they detect situations that may quickly escalate to hazards with dire consequences. Therefore, careful consideration of the measures related to the design and maintenance of the ESD systems are crucial for the smooth and safe operations.

Maintenance of the technological solution and the automated SISs is an issue of particular importance. The safety systems' instrumentation is put in place to mitigate the risks. However, SISs themselves contribute to the uncertainty of operations. The devices may either fail to perform their function or trigger a process shutdown without any actual critical situation. To ensure the proper work of the safety barriers, first of all, the instrumentation's self-diagnostic capability is used, and second, periodic proof tests are performed. Therefore, maintenance at oil and gas facilities is conducted in two forms: continuous and periodic. The former implies repairing or replacing the devices as soon as problems become revealed by their self-diagnostics. The latter comprises the full-scale checking and repairing of the instrumentation and the technological units, which has to be performed with a particular frequency.

A certain number of engineers should be continuously available at the facility to monitor the operations and, when necessary, conduct the maintenance. As stated earlier, many production sites are nowadays located in unpopulated areas far from large cities and industrial centres. Engineering personnel in the petroleum sector has to engage in shift-type of work: workers travel to the remotely-located facility and stay there for a certain period. During these periods, the daily work is organised using a specific (i.e., work–rest) schedule. The specifics of continuous and periodic maintenance require that at any point in time, a certain number of servicepersons should be available to perform maintenance.

The purpose of this research is to address the problems of the SIS design, maintenance planning, and employee scheduling to optimise the set of technical and organisational safety measures in a single decision-making framework to explore the reliability and economic trade-offs and at the same time ensure

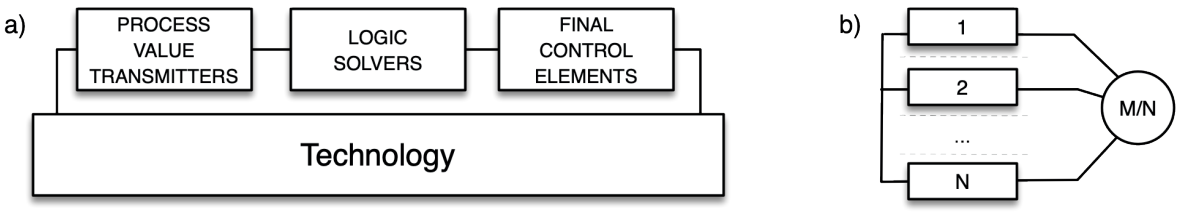

Fig. 1. Structure of a safety instrumented system: a) control loop; b) M-out-of-N redundancy architecture
Source: based on IEC 61508 (1997) and IEC 61511 (2003).

proper maintenance that the SIS requires for smooth and safe operations.

1. Overview of the research area

The problem of safety instrumented system design has been addressed by various researchers over the past four decades. An extensive overview of modelling approaches relevant to the design and operations of industrial safety systems may be found in the book (Kuo & Zuo, 2003). The two international standards, namely IEC 61508 (1997) and IEC 61511 (2003), provide an insight into safety and reliability quantification. The standards primarily suggest applying such approaches as Reliability Block Diagrams and Fault Tree Analysis as two straightforward and visual methods. Some researchers, e.g., Bukowski (2006), Jin et al. (2011), and Redutskiy (2017) suggest applying Markov Analysis as a flexible modelling tool allowing to incorporate various nuances of device failures and repairs as well as technological incidents and restorations.

In addition to the issues of reliability of the engineering solution, this paper highlights an aspect of workforce planning and employee scheduling as they are relevant to maintenance work conducted at remotely-located hazardous facilities. As stated in (van den Bergh et al., 2013), the early models were based on a set-covering formulation proposed by Dantzig (1954). In the paper (Castillo-Salazar et al., 2016), the authors provide an overview of various applications of employee scheduling models and issues relevant to the various problem settings. Among the kinds of personnel scheduling problems named by these researchers, one class of problems (referred to as "workforce scheduling and routing problems") is perhaps most relevant to this study. This category of scheduling problems relates to certain requirements for servicepersons to arrive at a given location and perform the necessary activity. Real-life applications of such problems include nurse visitations of patients at their homes, technicians performing repairs at the clients' location, security personnel patrolling the premises, etc. A distinctive characteristic of this class of workforce problems is that the demand for personnel is deterministic and it has to be satisfied exactly, unlike many other problem settings such as call centres or retail stores where the demand is stochastic. This aspect is especially relevant to oil and gas facilities given the hazardous nature of the processes operated by this industry.

The research (Helber & Henken, 2010) highlights an important issue related to the broad pool of employee scheduling models. Decisions directly influencing the staffing size requirements and decisions on scheduling the shifts should be made simultaneously in one modelling framework. It would help to explore a trade-off between the quality of the process performance and the workforce-related costs.

An interested reader may refer to the paper (van den Bergh et al., 2013) as a very comprehensive overview of the personnel scheduling issues, models and solution approaches. The authors review a variety of problem settings, details regarding shift organisation, workers' qualifications, and many other aspects.

In this paper, the problem of SIS design, maintenance planning and employee scheduling is addressed with the idea of exploring a trade-off between the investments into the SIS's complexity, expected losses (due to the process downtime and the costs associated with the residual risk), as well as the costs associated with workforce organisation measures. The lifecycle cost is evaluated, and personnel requirements are estimated based on SIS design and maintenance-related decisions and the system's performance evaluated by means of Markov Analysis, while the employee scheduling is modelled as a set-covering problem considering the location of the engineering company, the duration of the trips, and the working hours. The genetic algorithm is applied to solve the problem for several experiment settings.

2. Problem formulation

This paper follows the research (Redutskiy, 2017) on the safety system design and maintenance, and elaborates on it with consideration of maintenance organisation decisions through employee scheduling, which is a relevant issue for modern-day oil and gas industry, while production operations move to non-conventional environments and locations. The aspect of workforce organisation becomes quite important since the personnel transportation costs from the industrial centres to these remote production sites and back starts playing a significant role in the overall costs of designed industrial solutions. Also, the data for the computational example presented in the next section, such as device options, their reliability char-

acteristics, and costs, architecture alternatives, etc., are adopted from the mentioned research.

Further, in this section, a generalised mathematical model formulation for the aggregated decision-making on the safety system design, maintenance planning, and workforce organisation is presented.

The investment decisions comprise the automated system's components and architecture, and also, an aspect of recruitment of the workforces necessary to ensure the maintenance of the technological solutions throughout its operations. To provide this service, the company may send employees from the main offices (or headquarters), which are in many cases located in large industrial centres. The production sites, on the other hand, are located in remote areas. Sending the engineering personnel from large cities to these remote areas usually includes a combination of various means of transportation, such as airplane flight to some smaller place located closer to the production site, and afterwards, a helicopter flight to the actual production site such as an offshore platform or an Arctic location poorly attainable by transportation. Such trips usually turn out to be rather long and costly. For such situations, it has become a common practice to open a subsidiary company in a city or a town located not too far from the facility location and hire local engineers. Initial investments associated with establishing a local subsidiary are mostly related to training the newly hired personnel to operate the facilities and processes specific to the oil and gas sector. In this research, the optimisation model accounts for both options: sending the maintenance personnel from the head offices as well as opening local offices.

The operational costs include such aspects as electricity consumption, replenishment of maintenance tools and spare parts, production losses due to facility downtime, and also, workforce-related costs, such as travel costs, subsistence costs, and wages. The safety system's life is usually ten years or more. However, to account for maintenance requirements, one-year timespan is split into a set of 52 weeks to estimate the annual costs of operations.

The employee-scheduling part of the model is based on the set-covering formulation proposed by Dantzig (1954). The requirement for maintenance personnel has to be satisfied exactly given the hazardous nature of the processes in the oil and gas industry. Therefore, the "hard" demand constraint is used in the model. The workforce scheduling formulation is extended to account for the possibility of workers travelling from different locations (headquarters and subsidiary), as well as the organisation of daily work–rest schedule. The daily schedule alternatives are 8-hour daily work shifts and 12-hours shifts. Pay rates are adjusted for various trip duration options and daily work schedules to reward the employees for the longer working periods.

The maintenance personnel requirements are modelled for the two kinds of maintenance: continuous and periodic. The former implies dealing with device failures during facility operations. For this phase, the number of workers needed at the facility is calculated based on the warranty rules stating that all the failures should be fixed within a specified amount of time. Personnel requirements for the proof tests are declared with consideration of each system's architecture and the amount of time needed to test and repair each device.

The system's reliability is quantified through the average probability of failure on demand (PFDavg) indicator specified in the standards IEC 61508 and IEC 61511. This indicator has a significant bearing on risk cost, which is associated with the likelihood of hazardous events at the facilities and with risk reduction ensured by the safety system.

To conclude, the problem addressed in this research covers decisions on the following set of safety measures:

- device models for subsystems of process value transmitters, logic solvers, and final control elements;
- MooN redundancy architectures for each subsystem (Fig. 1b);
- additional electrical separation within subsystems;
- test interval (TI), i.e., a period between two consecutive proof tests;
- establishment of a local subsidiary and hiring local engineers;
- number of maintenance workers required to be available at the facility at any point in time to conduct continuous maintenance and periodic proof tests;
- number of crews taking particular trips and working under a particular schedule;
- the daily schedule for a particular trip.

2.1. Reliability quantification

Reliability assessment is conducted in two steps. First, a birth-death Markov model is used to evaluate the device failures in each particular subsystem given the instrumentation choice and the choice of the

subsystem's architecture. The modelling results allow obtaining the reliability characteristics (i.e., dangerous and safe failure rates) for each subsystem of the SIS. The second step utilises these reliability characteristics of the subsystems as well as the likelihood of technological incidents within a lifecycle model for the given SIS configuration and technology. This lifecycle evaluation is also conducted with the Markov Analysis. The outcome of this modelling approach includes the values of average probability of failure on demand (PFDavg) for the given technological solution, expected facility downtime, and yearly failure rates for the dangerous and safe failures of the entire SIS.

An interested reader is encouraged to refer to (Redutskiy, 2017) for the details of the mathematical modelling approach used for the lifecycle evaluation of the SIS performance. In this paper, the long descriptions of these models are not provided, because the focus of this research is on employee scheduling aspect.

2.2. Lifecycle modelling. Generalised mathematical model formulation

The text below presents the generalised mathematical model for the design of a safety instrumented system, and planning and organisation of its maintenance through employee scheduling . The notations are explained in Tab. 1.

The objective function (1) is a decision-making criterion for lifecycle cost minimisation. Some arguments in the expression (1) are given in the form of arrays. They are explained in (2).

The developed solution has to maintain a given safety integrity level (SIL), specified in IEC 61508 and IEC 61511. This requirement is expressed in constraint (3). Logical constraints (4) and (5) restrict the selection of the device model and redundancy architecture for each subsystem to only one alternative. The following constraints (6) – (13) are related to employee scheduling. The model decides whether to send the maintenance personnel from head offices of the engineering company or to open a local subsidiary somewhere closer to the remote facility, hire local engineers and use this local workforce for the purpose of SIS maintenance. Since there are two potential sources of the maintenance workforce in this model, it has to be specified that the headquarters of the engineering company already exist (6), whereas the local workforce may only be used if the local offices are opened (7). Constraint (8) is the extension of the Dantzig's set-covering constraint, specifying that the number of crews travelling to the remote facility should meet the demand for the personnel. Constraint (9) imposes an additional requirement for the personnel travelling from the headquarters, in the case certain special skills are needed in some periods (e.g., supervision of proof testing). Constraint (10) declares that only one alternative of the daily work–rest schedule may be chosen for any particular trip. Constraints (11) and (12) specify the required number of workers for the normal course of operations and the weeks when proof testing takes place. Constraint (13) specifies the maximum time an employee may spend on trips to the remote facility.

The economic criterion (1) used in this model is described in detail in (Redutskiy, 2017). The three main components of the lifecycle cost are procurement cost (project start-up costs, cost of the devices and additional measures), cost of operations (electricity consumption, test costs, production losses, workforce-related costs), and risk costs (expected losses associated with residual risk). The cost structure for this research has been expanded by including the relevant aspects of employee scheduling into the capital expenditures (i.e., establishing a local engineering subsidiary, its staffing size, and training the newly hired employees), as well as operational expenditures (i.e., travel costs from headquarters and local offices, pay rates, and trip durations for maintaining the remote facility.

$$\min C_{lifecycle}(X^{dev}, X^{arch}, X^{sep}, Y^{trip}, TI) \tag{1}$$

$$X^{dev} = \{x_{d,q}^{dev}\},\ X^{arch} = \{x_{r,q}^{arch}\},\ X^{sep} = \{x_{q}^{sep}\},\ Y^{trip} = \{y_{t,l}^{trip}, x_{t,s}^{DS}\} \tag{2}$$

$$SIL^{REQ}(X^{dev}, X^{arch}, X^{sep}, TI) = SIL^{*} \tag{3}$$

$$\sum_{d \in S_q^{dev}} x_{d,q}^{dev} = 1,\ \forall q \tag{4}$$

$$\sum_{r \in S_q^{arch}} x_{r,q}^{arch} = 1,\ \forall q \tag{5}$$

Tab. 1. Notations for the SIS design, maintenance planning, and employee scheduling optimisation problem

Notation	Description
	Indices and Sets
w	index of weeks in the technological solution's lifecycle
q	index for subsystems of the SIS: q = 1: sensors; q = 2: logic solvers; q = 3: final control elements
d	index for device models
r	index for redundancy architecture options
t	index for trips
s	index for daily schedule options
l	index for locations, from which the maintenance personnel is travelling to the remotely located facility: either headquarters or a locally established subsidiary company $l \in \{HQ, LS\}$
S_q^{dev}	set of device alternatives for subsystem q
S_q^{arch}	set of redundancy architecture alternatives for subsystem q
S^{trip}	set of trips (given all possible trip start times and durations)
S^{DS}	set of alternative daily work schedules (work–rest schedule during each day)
	Parameters
$N_{r,q}$	the total number of devices in subsystem q given the redundancy option r
$M_{r,q}$	number of devices in subsystem q given the redundancy option r required to be operating
$T_{d,q}^{repair}$	repair time of chosen device model d in in subsystem q
$T^{UBrepair}$	the upper bound on the repair time for the entire SIS (for continuous maintenance)
$\sigma_{w,t}$	a binary parameter indicating whether week w is covered by the trip option p or not.
$y_w^{req.fromHQ}$	number of workers from the headquarters of the engineering company (special requirement for employees) who need to be present at the facility during week w
S_s^{crew}	crew size associated with any particular daily work schedule alternative s
T_l^{UBtrip}	upper bound on the time workers from location l spend annually in trips to the remote facility
	Functions
$C_{lifecycle}$	lifecycle cost of the solution, [currency units (CU)]
SIL^{REQ}	risk reduction requirement for achieving a certain safety integrity level defined in [7] and [8]
	Decision Variables
$x_{d,q}^{dev}$	binary variable: equals 1, if device model l is chosen for subsystem q; 0, otherwise
$x_{r,q}^{arch}$	binary variable: equals 1, if redundancy option r is chosen for subsystem q; 0, otherwise
x_q^{sep}	binary variable: equals 1, if additional electrical/physical separation is introduced for subsystem q; 0, otherwise
x_l^{est}	binary variable: equals 1, if a company is established at location l; 0, otherwise
$y_{t,l}^{trip}$	integer variable: number of service crews taking trip t to travel to the facility from location l to ensure maintenance (for each t^{th} trip, the duration of the trip and the starting time is specified)
$x_{t,s}^{DS}$	binary variable for daily schedules: equals 1, if crews taking trip t are to work under daily schedule s
y_w^{req}	integer variable: number of workers whose presence is required at the facility during week w
TI	integer variable: time between two consecutive proof tests, [weeks]

$$y_{t,LC}^{trip} \leq B \cdot x_{LC}^{est}, \quad t \in S^{trip} \tag{7}$$

$$\sum_{l\in\{HQ,LS\}} \sum_{t\in S^{trip}} \sigma_{w,t} \cdot y_{t,l}^{trip} \geq y_w^{req}, \quad \forall w \tag{8}$$

$$\sum_{t\in S^{trip}} \sigma_{w,t} \cdot y_{t,HQ}^{trip} \geq y_w^{req.fromHQ}, \quad \forall w \tag{9}$$

$$\sum_{s\in S^{DS}} x_{t,s}^{DS} = 1, \quad \forall t \tag{10}$$

$$y_w^{required} \geq \sum_q \sum_{r\in S_q^{arch}} x_{r,q}^{arch} \cdot \sum_{d\in S_q^{dev}} \left(N_{r,q} - M_{r,q}\right) \cdot \frac{T_{d,q}^{repair}}{T^{UBrepair}}, \quad w = \{1..52\} \tag{11}$$

$$y_w^{req} \geq \sum_q \sum_{r\in S_q^{arch}} N_{q,r} \cdot x_{r,q}^{arch}, \quad w = \{TI; 2\cdot TI; 3\cdot TI; \ldots; 52\} \tag{12}$$

$$\sum_w \sum_{t\in S^{trip}} \sum_{s\in S^{DS}} S_s^{crew} \cdot x_{t,s}^{DS} \cdot \sigma_{w,t} \cdot y_{t,l}^{trip} \leq T_l^{UBtrip}, \quad \forall l \tag{13}$$

4. Computational experiment

The model of the SIS design, maintenance planning, and employee scheduling demonstrated in the previous section of this paper, cannot be used in the general form for solutions that require the use of classical algorithms applied for integer programming problems. This model utilises the solution to ordinary differential equations (Markov Analysis for reliability quantification) whose dimension depends on the decision variables, and also, the safety integrity level requirement constraint represented in a table form (refer to IEC 61508 and IEC 61511), part of which needs to consider conditional statements. The programming environment of Mathworks Matlab has been used to develop a script function for this model. The developed script includes (Fig. 2):

- two Markov models for reliability assessment of the SIS design, included in the objective function (1) and the SIL requirement constraint (3), as well as logical constraints (4) and (5);
- staffing size evaluation represented in constraints (11) and (12) of the generalised model;
- employee scheduling model minimising the workforce-related costs, which are a part of the objective function (1), whereas the constraints are represented by set-covering formulation (8) and (9), logical expression (10) for the daily work schedule choice, additional logical expressions (6) and (7) related to the establishment of local offices, as well as limitation of the time the personnel has to spend in trips (13);
- the overall lifecycle cost evaluation represented by the objective (1).

A black-box optimisation algorithm, namely a genetic algorithm run by ga solver in Matlab's optimisation toolbox, has been used to solve the problem.

The case data for the experiments, as well as the instrumentation alternatives, have been used from the example provided in the paper (Redutskiy, 2017). The additional data regarding the shift work is provided in Tab. 2. Each employee either works for 8 hours a day (thereby, a crew must consist of three workers to cover all 24 hours in a day) or 12 hours a day (a crew must include two engineers). Each crew can come to the remotely located facility for a duration of one, two, four or six weeks. Each trip may start at any given week of the year (from week 1 to week 52). The company has a system of bonuses in place aimed to reward the employees taking long trips (hence the pay rate cost modifiers). All the costs that are further given and calculated are provided in the artificial currency units (CU), same as in the paper, where the data for the SIS design problem is adopted.

The algorithm for the problem was run three times for three different approaches to periodic testing frequency choice:

- test interval (TI) within the range between 4 and 52 weeks;
- test interval (TI) within the range between 26 and 52 weeks;
- test interval (TI) fixed at the value of 52 weeks.

The results of the algorithm are summarised in Tab. 3. From these results, one may observe that workforce-related expenditures (establishing a local

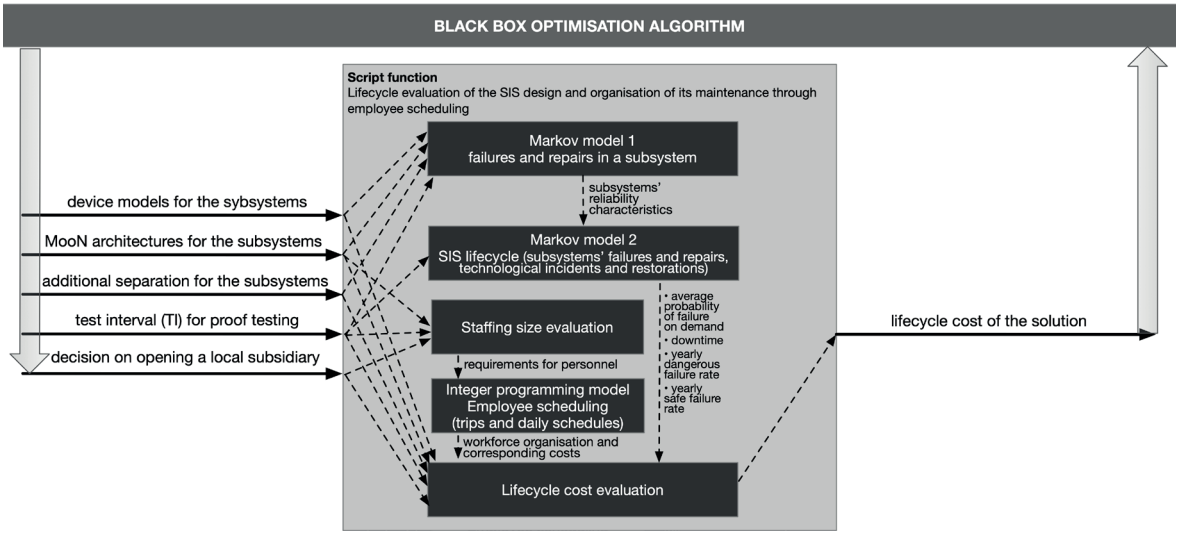

Fig. 2. Summary of the optimisation approach

Tab. 2. Alternatives for trips and daily work schedules

Daily work schedule alternatives			
#	Description	# of workers in a crew	Pay rate, CU/day
1	8 hours of work, 16 hours of rest	3	125
2	12 hours of work, 12 hours of rest	2	250
Trip alternatives			
#	Description	Pay rate modifier	
1	1-week trip	1.00	
2	2-week trip	1.25	
3	4-week trip	1.50	
4	6-week trip	2.00	

Tab. 3. Optimisation results for the three experiment settings

Results	Experiment 1	Experiment 2	Experiment 3
	TI choice within range		
	between 4 and 52 weeks	between 26 and 52 weeks	fixed at 52 weeks
Costs, mln CU:			
Lifecycle cost	9.05	10.62	11.59
Procurement cost	1.08	1.12	1.16
Cost of operations	7.76	7.96	8.57
including workforce-related costs	5.18	4.75	4.40
Risk costs	0.21	1.54	1.86
Opening a local subsidiary	yes	yes	yes
Reliability inductors:			
Average probability of failure on demand	6.175·10-5	5.531·10-4	7.017·10-4
Expected facility downtime yearly, h	374	605	837
Choice of TI, [weeks]	12	28	52

subsidiary, hiring and training engineers, transportation of personnel to the facility location and back, wages, etc.) constitute more than 50% of the operational costs of the SIS. Therefore, it appears reasonable that the employee scheduling decisions are made based on the concern of the travel costs. In every experiment, the algorithm suggests opening a local subsidiary and organising the majority of trips from these local offices. "One-shot" arrangement of establishing a local company and training a number of engineers proves to provide considerable savings on travelling to the remote facility in comparison to organising the maintenance entirely from the engineering company headquarters. For all the three experiment settings, the algorithm has determined that no more than 20 maintenance engineers need to be hired for the local subsidiary.

Based on the reliability quantification (the Markov models), the algorithm has determined that four servicepersons are required to be available at the facility at any time to maintain the safety system, whereas during the periodic proof tests, the requirement is 20 workers.

When it comes to the details of employee scheduling, the preferable decision from the alternatives (Tab. 2) is chosen as follows. For the normal course of operations, four crews are used with the four-week shifts with 8-hour daily work schedule (therefore, three people in a crew). For the weeks when the proof tests are conducted, the algorithm suggests one-week shifts with an additional 16 crews of two workers each working on a 12-hour daily schedule.

The workforce-related cost is the highest for Experiment 1 and the lowest for Experiment 3. It may be explained by the decreasing frequency of proof tests in the experiments which leads to fewer expenses for the additional crews travelling to the remote facility for these periodic overhauls.

Another significant component of the operational expenditures is production losses due to the

facility downtime. One may observe from Tab. 3 that in the case the proof testing of the SIS is conducted rarely, the expected downtime is quite long. It is attributed to the relatively big chances of the safety system's self-diagnosed dangerous failures and its spurious tripping. On the other hand, the more often the proof testing takes place, the less these two failure mechanisms influence the performance of the SIS, and, thereby, the shorter is the expected downtime and the lower the corresponding production losses.

In addition, according to Tab. 3, the procurement costs for the SIS grow with the choice of a larger TI, which may be explained by the need for more elaborate architectures of the SIS, and, therefore, more significant capital investments into the safety measures.

From these modelling results, one may conclude that the best test interval alternative is three months. Despite the significant role of the workforce-related expenditures, the rapid growth of expected production losses due to downtime has a great bearing on operational costs, and by extension, on the total lifecycle cost of the solution. The demonstrated results indeed reflect the real-life situation: the companies operating the facilities are concerned not only with the investments and hiring decision, but the overall cost evaluation for the solution's lifecycle, with the continuity of operations (little downtime), and also, such things as the preventing the incidents and avoiding the hazardous consequences of the incidents. In this case, the best solution is the most reliable one, i.e., demonstrating the lowest value of the average probability of failure on demand.

These results also prompt companies concerned with uninterrupted operations to pay attention to all possible causes of the facilities' downtime. In some cases, decision-makers' focus on the facility downtime may solely concern the proof testing frequency. Following such an approach, the managers want to restrict the frequency of testing to no more than once every six months or once a year (our Experiments 2 and 3). The modelling results suggest that it is reasonable to consider all possible causes for the downtime: proof tests, self-diagnosed failures, and spurious tripping, to figure out the best solution.

Conclusions

This research has combined the problems of design of a safety system with planning the workforce to maintain this system. It contributes to the areas of engineering design and employee scheduling. Addressing these issues with the consideration of conducting the maintenance at remotely located facilities and organising the work in shifts, brings up the importance of workforce-related decisions in the lifecycle of the technological solution in the petroleum sector as it faces the new challenges of the non-conventional environments where the resources are nowadays developed. Connecting the employee scheduling decisions with the SIS design and maintenance decisions allows exploring the reliability and economic trade-offs while aiming to ensure the safety of operations at hazardous industrial facilities by properly organising its maintenance.

Employee scheduling as part of this research has been based on the required staffing level suggested by an SIS design decision-making framework with Markov models incorporated in it. In real-life projects of the petroleum sector, the maintenance decisions may be more complex. One of the directions to improve this model is to incorporate various maintenance policies, such as sequential, parallel, staggered, partial and mixed testing policies. These considerations would directly influence the personnel requirements as well as the overall system's performance in terms of reliability.

Finally, this research has been limited to the issues related to the workforce providing the maintenance to the emergency shutdown system alone. As mentioned earlier, in practice, there are several process control systems and automated safety systems deployed for any hazardous industrial facility. All these systems are maintained by the engineering personnel with similar skills. Therefore, it makes sense to approach the problem of a facility personnel planning and scheduling from a broader perspective of the entire process automation solution deployed on a given facility.

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sciendo

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 30 June 2018
accepted: 25 November 2018

pages: 65-75

Definition and classification criteria of logistics services for elderly

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ABSTRACT
An ageing population is a natural and inevitable phenomenon that constitutes an opportunity for the development of the logistics services industry. This is related to the fact that a new demographic profile of the world is determined by a growing number of customers — seniors – with special needs that generate the demand for services such as carriage and home delivery of food and medicines. Therefore, considering the growing demand for logistics services intended for older adults, there is a justified need to develop theoretical knowledge in this area. The paper aims to define a logistics service dedicated to an elderly person as the ultimate recipient as well as to identify the classification criteria of such services. The first part of the article is based on a literature review and presents definitions of a service and a logistics service according to various researchers. It also identifies different classifications of logistics services. These theoretical aspects provided a basis for authors to propose the notion of a logistics service and a catalogue of criteria for systemising logistics services dedicated to older adults. Logistics services for the elderly may be grouped according to classification criteria applicable to what is widely understood as logistics services in source literature. The classification criteria are the type of service, the immateriality of service, the frequency of contacting the customer, the type of purchaser market, the degree of service customisation, the type of a relationship between the service enterprise and the customer, and the place of service provision. Nonetheless, due to the customer-oriented approach in logistics, the authors proposed the classification criteria of these services with regard to age, financial situation, needs, health, expectations, hobby, skills and problems of older adults. Such an approach to classification is determined by considerable inherent diversification of the discussed group of customers as well as a specialised catalogue of logistics services. The classification of logistics services may contribute to the improved design of such services.

KEY WORDS
logistics service, elderly, definition, classification, ageing population

DOI: 10.2478/emj-2018-0023

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Introduction

In the period of the last 25 years, a systematic growth in the percentage of older adults has been observed. The research conducted by the Department of Economic and Social Affairs of the United Nations indicated that the ageing process of societies is also noticeable on the global scale. It is forecasted that globally, the number of people over 60 years of age will grow from 841 million in 2013 to 2 021 million in 2050, and to 2 985 million in 2100. Hence, in 2100, this group will constitute 355% of seniors living in 2013 (World Population Prospects, 2013). In Poland,

the percentage of older adults is growing as well. According to the Central Statistical Office of Poland, the country had 6 520 247 people aged 65 years and over in 2017. It is forecasted that in 2050, this number will almost double and reach 11 097 488. While analysing the demographic structure in Poland in terms of age, it can be observed that in 2017, older adults constituted 17% of the entire population, and in 2050 — as the Central Statistical Office of Poland reports — this percentage will reach 32.7% (https://bdl.stat.gov.pl) This disturbing demographic trend is primarily caused by the lengthened average life expectancy and a decline in the number of births.

The ageing society thus constitutes a challenge to be faced by many developed countries across the world. This issue entails both economic and sociopolitical consequences. On the one hand, the process of society's ageing is perceived as a negative phenomenon that determines many threats (Szukalski, 2012, pp. 6-7). The growth in the population of older adults means growing budget expenses for retirement and disability allowances, medical care and care services. Besides, ageing labour resources mean a decrease in employee productivity. On the other hand, it offers an enormous opportunity for economic growth and development (Golinowska, 2011; New waves of growth. Unlocking opportunity in the multi-polar world, 2011), which is increasingly recognised. The challenge posed by the greying world has been observed by the Commission and the Council of the European Union. The current policy aimed at older adults prioritises organisations that engage in initiatives for the support of older adults. As stressed by the European Commission, Europe's ageing process may constitute a chance for improving the competitiveness of the European economy by means of, e.g. creating new markets of goods and services adjusted to the needs of older customers (European Commission, 2006).

The world's new demographic profile has also been noticed by the business sector that is beginning to perceive older inhabitants as a new group of customers. The population of older adults is becoming a megatrend in logistics (Tinnilä, 2012), which can fundamentally change the functioning of logistics companies, their mode of operation, and competition. It is a significant direction, tendency or power that emerges globally or locally and is capable of operation in the future and that exerts a significant impact on almost every aspect of the functioning of societies and logistics itself (Bujak, 2016, p. 1257). A logistics service provider DHL has also noted the issue of an ageing society as a growth opportunity for logistics enterprises, highlighting a significant role of the grey power logistics (the logistics for older adults) in the functioning of the logistics industry. DHL claims that the growing percentage of the elderly will result in a need for new logistics services (Logistics trend radar, DHL, 2016, p. 16). Therefore, enterprises that provide logistics services should systematically study trends that are likely to shape the sector in the future (Nazarko et al., 2015a) and adjust or design logistics services that correspond to needs of ageing customers. However, firstly it is important to recognise the needs and expectations of customers who constitute an internally diverse group. Furthermore, an ageing population poses a challenge not only for the business and infrastructural environment (Nazarko et al. 2015b) but also science. The implementation of innovative logistics solutions gives rise to the need to develop the related theoretical aspects.

This article undertakes to devise a definition of a logistics service for an older adult as the ultimate recipient and indicate the classification criteria of such services. The first part of the article is based on a literature review and presents definitions of a service and a logistics service according to various researchers. Also, it identifies different classifications of logistics services. These theoretical aspects provided a basis for the authors to offer the notion of a logistics service and a catalogue of criteria for systemising logistics services dedicated to seniors. Logistics services for the elderly can be classified according to various criteria existing in the literature. Nonetheless, considering the recently noticeable stress on customer orientation in logistics, the authors propose a different approach to the classification of such services.

1. Definition and classification of logistics services - a literature review

The source literature provides a number of various definitions of a service. One of the first definitions was devised in 1960 by the American Marketing Association, which defined services as activities, benefits, or satisfactions which are offered for sale, or provided in connection with the sale of goods (de Vries et al., 2012, p. 2). However, this definition limits the scope of services since it suggests that services are

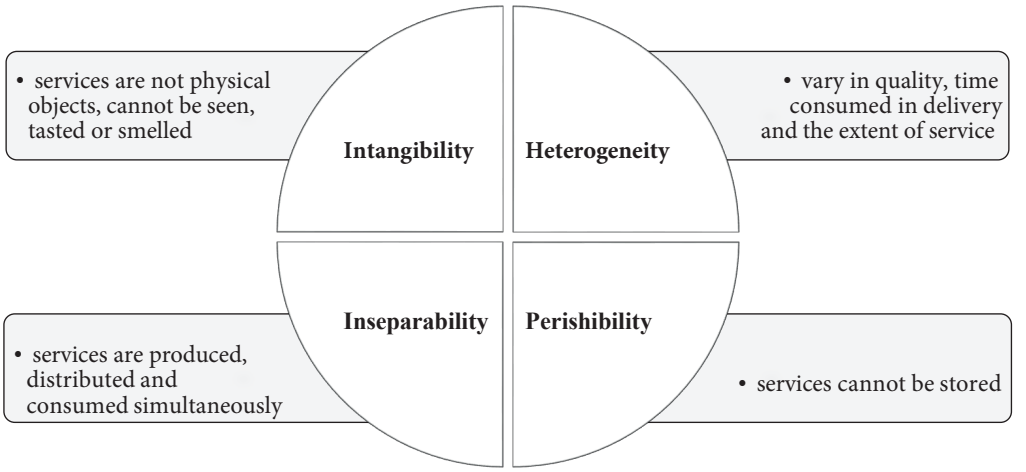

Fig. 1. Service characteristics

Source: based on (Bhattacharjee, 2012, p. 4).

offered solely together with products sold. In 1963, Regan presented another concept of a service, defining it as "represent[ing] either intangibles yielding satisfactions directly (insurance), tangibles yielding satisfactions directly (transportation, housing), or intangibles yielding satisfactions jointly when purchased either with commodities or other services (credit, delivery)" (Regan, 1963, p. 57). In this manner, the author treated services as immaterial values that can be sold in the same way as products. His definition may be complemented with Judd's statement, adding that a service is all that is neither solid nor liquid (Judd, 1964, p. 58). Moreover, Gummesson suggested that "services are something that can be bought and sold but which you cannot drop on your foot" (Gummesson, 1987, p. 19). According to another definition, "services are intangible activities that perish relatively quickly and which, during interactive consumption, satisfy direct needs rather than the desire for material possession" (de Vries et al., 2012, p. 13). A frequently cited definition of a logistics service was offered by Kotler, who interpreted a service as "any act or performance that one party can offer to another that is essentially intangible and does not result in ownership of anything. Its production may or may not be tied to a physical product" (Kotler, 1997, p. 467).

A common element of the above definitions is attributing a service with immaterial character. Services can be exchanged even though they are not tangible (Bhattacharjee, 2012, p. 2). Moreover, services are activities that should bring customer satisfaction. They are assigned with certain basic characteristics such as intangibility, heterogeneity, inseparability and perishability (Grönroos, 1998, p. 322; McDonald & Payne, 2006, p. 17; Parry et al., 2011, p. 20; Bhattacharjee, 2012, p. 4) (Fig. 1).

Services are not physical objects; hence, customers cannot see, touch or smell them (intangibility). They are experiences rather than things. Services are characterised by heterogeneity since they vary from one another according to the context, nature, requirements of each customer, different quality standards associated with different costs, as well as with regard to regions or cultural background. Still, the inseparability of services means that services are produced, distributed and consumed simultaneously. Services are perishable because there is no possibility to keep them in stock.

Among many services provided to individual and institutional customers, a logistics service has gained significance in recent years. Source literature provides many definitions of logistics service; however, no universal explanation of this notion exists. The definition and the scope of logistics services have undergone changes together with the development of the logistics services industry. Until the late eighties, a traditional transport sector functioned divided into transport as well as forwarding and mail branches. In the nineties, logistics service operators began to create the so-called logistics service packages involving storage services, stock management and additional services, e.g. packaging or labelling. The end of the nineties saw the development of, a concept of managing and optimising supply chains and supply networks based on close-knit cooperation of logistics operators with manufacturing and trading enterprises. Logistics services of that time began to assume a form of

Tab. 1. Logistics service definitions

Author, Year	Definition
Gołembska, 1999	A logistics service is transportation and storage of logistics products organised by a company together with full formal and legal handling, including customs. A logistics service is a response to customer demand and expectation associated with the provision of a proper product in due time, at an agreeable price, while preserving an adequate quality level of this service
Tseng et al., 2005	Logistics services support the movement of materials and products from inputs through production to consumers, as well as associated waste disposal and reverse flows. They include activities undertaken in-house by the users of the services (e.g. storage or inventory control at a manufacturer's plant) and the operations of external service providers. Logistics services comprise physical activities (e.g. transport, storage) as well as non-physical activities (e.g. supply chain design, selection of contractors, freightage negotiations)
Gołembska, 2007	A logistics service is a logistics product constituting a set of wishes and expectations of a customer; a logistics service is provided by means of logistics management, which is a process of service planning and performance that considers an analysis of needs, possibilities and means of providing such a service in the entire supply chain from the manufacturer to the consumer
Kopeć, 2007	A logistics service means organising transportation and storage of logistics products by a company together with full formal and legal handling, including customs
Rydzkowski, 2011	A logistics service means performing activities involving the execution of one or many logistics functions towards the ordering party by the service provider, based on contractual provisions. The components of a logistics service are transport, forwarding and logistics as well as additional services
Srivastav & Chandra, 2013	Logistics services can be described as services involved in the processes related to planning, implementation and controlling of the flow of materials/goods, services, information, and funds between the point of origin and the point of destination to meet customer requirements in an efficient and effective manner
Jeszka, 2013	Logistics services entail gainfully provided services of forwarding, transport, storage as well as related services and those supporting the process of the commodity flow between various foci of the supply chain
Rosa et al., 2017	A logistics service means an activity aimed at satisfying logistics the needs of business entities and people

Source: elaborated by the author on the basis of the literature.

customised logistics services and their development was growingly determined, e.g. through the use of integrated ICT systems (Jeszka, 2013, p. 56; Ciesielski, 2005, p. 10).

The notion of a logistics service is very broad; thus, it is differently defined in source literature. Tab. 1 presents selected definitions.

An analysis of the above-presented definitions for a service and a logistics service can lead to the identification of common features that can be ascribed to a logistics service. These are:

- a logistics service is an activity, operation or process;
- logistics services aim to satisfy the needs of customers;
- logistics services involve transport, forwarding, storage and other services supporting the process of the flow of commodities/persons, information and financial means among the foci of supply chains;
- logistics services may have a physical (e.g. transport and storage) or non-physical character (e.g. designing a supply chain and transport planning);
- logistics services are provided for gainful purposes by specialist companies;
- a logistics service should be provided to the customer in accordance with the principle of 7R's proposed by Shapiro and Heskett in 1985, namely, right product, right quantity, right condition, right place, right time, right customer, and right price (Coyle et al., 2007, p. 52).

There is no official logistics service classification. Logistics does not have its own General Agreement on Trade in Services (GATS) classification in the World Trade Organization (WTO) Services Sectoral Classification List: MTN.GNS/W/120. Logistics services are classified there only as Transport Services (MTN.GNS/W/120 11). Still, many researchers attempted to classify logistics services, applying various classification criteria. For instance, Gołembska proposes the following classification criteria of services: the type of service, the degree of service immateriality, the frequency of customer contact, the motive for service purchase, conditions for service provision, the type of service purchaser (Gołembska, 2010, pp. 258-259). Services can also be classified according to the type of satisfied needs (manufacturing, consumption and collective consumption services), the type of

Tab. 2. Logistics service classification

Author, Year	Classification
Ciesielski, 2006	basic services associated with movement and storage: carriage, storage, packaging, package return services, waste management, supply consolidation and conditioning, JIT system execution, procurement, distribution; additional services: executing customer orders, stocktaking, commodity inspection, labelling, post-sales service, publicity, research on demand and forecasting; financial services: insurance, transaction financing, payment, commission sales, financial record-keeping; information services: providing information on supply and sales markets as well as the course of logistics processes in a manner that suits the needs of the company's strategic and operational management
Vasiliauskas & Barysienė, 2008	physical services: basic (storage, good reception, picking and packing, re-packing and labelling, return of goods, delivery from storage), intermediate (consolidation, deconsolidation, preparation for freezing, thawing, sawing, prepare for delivery and pack, set building, sequencing, product, resorting and labelling, cross-docking) and advanced (assembly of components, operate vendor, management inventories in stores, or stock-keeping facilities, recycling with waste, handling and reconditioning, unpacking and quality control); administrative services: basic (tendering and contracting other LSP, tendering and contracting carriers, insurance services stocktaking), intermediate (payment services, order administration and customer service, claims handling, export clearance and import, clearance, forwarding services, financial services, provide one-stop logistics service purchase) and advanced (forecasting and inventory management, administration of minimum and protective inventories, purchase and call-offs, delivery planning and management and follow up, exception management, design of individual logistics set-ups, implementation of logistics set-ups, operation of customer logistics set-up, responsible for the customer logistics operations)
Kisperska-Moroń & Krzyżaniak, 2009	a carriage service — a basic service that is limited merely to the execution of the carriage process; a forwarding service — organisation of the carriage process in the following stages: operations preceding the carriage process, inspection of the carriage process, and operations performed upon its completion; a logistics service which may involve: transport, storage management, stocks handling, packaging, customer and order servicing
Rydzkowski, 2011	logistics operations: transport, stocks management, packaging, cross-docking; logistics processes: forwarding, JIT supplies, distribution; TSL-specific services: courier services, transhipment (terminal) services, transport packaging trade, intermodal transport; extended services: supplies with subassembly, distribution with product finishing; services oriented at the level of services: Vendor Managed Inventory (VMI)/Custom Managed Inventory, continuous complementation, comprehensive logistics services
Jeszka, 2013	forwarding services; transport services; storage and terminal services; additional services
Gleissner & Femerling, 2013	order processing; warehousing, incl. transhipment; transport services incl. transhipment
Rosa et al., 2017	physical operations associated with transport and storage (e.g. carriage, goods distribution, return policy, conditioning, operating the Just-in-time system, packaging, special-purpose carriages, waste management); servicing operations (e.g. order preparation, logistics counselling, stocktaking, quality inspection, customer contact, remedy activities, sales promotion); informative operations (e.g. stocks management, data processing, statistics)

Source: elaborated by the author on the basis of the literature.

purchaser market (services for individual and institutional purchasers), the degree of service customisation (standardised or adjusted to the demands of individual purchasers), the nature of service demand (services with high or low demand dynamics), type of relations between a service provider and a customer (services provided in direct or indirect contact with the customer), physical site of service provision (services rendered on the premises of the service provider, at the customer's seat, remotely or on a neutral ground), purpose of the service provider/nature of remuneration (services provided for commercial and non-commercial purposes) (Czubała et al., 2012, pp. 21-28). Logistics services can also be grouped with regard to two categories: resource-driven logistics services — physical services whose execution requires technical equipment; and skill-based services — services that entail planning, organisation, supervision etc. (Rosa et al., 2017, p. 16). Bhattacharjee distinguishes three groups of services depending on the type of a recipient/customer: services for individual consumers, business to business end users and industrial end users. Furthermore, services can also be classified as high contact services that involve a higher degree of contact from the customers and low contact services (Bhattacharjee, 2012, p. 18).

With regard to the diversity of service classification criteria that exhibit the heterogeneity of services, source literature may provide various classifications of logistics services.

Based on the compilation presented in Tab. 2, there is no single universal set of logistics services in the literature. Moreover, these classifications demonstrate the diversity of services. This is primarily connected with the development of the logistics services market where the level and scope of the offered logistics services is changeable. The authors of the classification of logistics services undoubtedly identify and distinguish three major groups of logistics services: transport, forwarding, and storage services. Other logistics services that improve the functioning of supply chains constitute a group of services termed auxiliary or additional.

2. Logistics services for elderly

With regard to the demographic perspective which entails a growing share of the elderly in the total population as well as increasing life expectancy, some economic sectors are expected to grow. Bran et al. identified the main beneficiaries of the current demographic situation which include (Bran et al., 2016, p. 132):

- the health sector (especially medical devices, pharmaceuticals and eHealth);
- the construction sector, especially focusing on smart homes which support independent living;
- personal and autonomous transport services (actions, programmes and services designed to facilitate the access of older adults and people with disabilities to public transport services);
- personal banking and e-banking services;
- the tourism sector.

All these economic and social activities can be supported by logistics. In the era of ageing societies, enterprises operating in the logistics industry face an enormous challenge with regard to the newly emerging group of customers. At present, the logistics services market is occupied by companies categorised by Płaczek as carriers, forwarding and transport enterprises; 3PL logistics operators, national mail operators and courier companies; logistics, storage and distribution centres; 4PL logistics integrators, logistics electronic platforms, 5PL virtual logistics operators, and electronic application providers (Płaczek, 2012, p. 166). These businesses have different profiles of activity, diversified with regard to the used logistics infrastructure and providing a range of various logistics services. According to the authors of this article, any of these enterprises will be able to provide services to older adults. Required services will be delivered directly to this group of customers as well as indirectly, by means of logistics support provided to institutions that render services or offer products dedicated to older adults.

In order to develop and gain competitiveness, businesses that operate on the market of logistics services should design strategies for integrating logistics operations with medical and preventive care provision. A growing percentage of the elderly will stimulate growth in the demand for medical and care services (Ejdys & Gedvilaite, 2017), the delivery of which is often made possible with the support of logistics. The authors claim that the development of new distribution channels for medicines and food will be required in towns and remote rural areas. Such added last-mile solutions as meals-on-wheels or home delivery of medicines and food will become more popular. Medicinal or food products are frequently sensitive to temperature or humidity variations. Hence, cold-chain networks will stand a good chance of development.

A growing number of older adults constitutes a challenge to packaging manufacturers who should account for the physical and health aspects of this particular group of customers. Product packaging mainly dedicated to older adults should be light and easy to use. Product descriptions, the manner of their use or prices should be printed using large enough font for those with impaired vision to read

A new demographic tendency will also give rise to the development of various forms of logistics support dedicated to entities operating in the field of service provision for older adults, namely, hospitals (Kauf, 2014), social care facilities, blood donation centres, pharmacies, associations and foundations. As entities operating in the business area, these institutions may become beneficiaries of the same logistics services that were already classified in Tab. 2. Moreover, these entities may use tools or management concepts known in business logistics. The concept of logistics management was defined by Sołtysik as "a process of complex planning, organisation and controlling of logistics operations [processes and logistics activities] executed to ensure the effective and efficient flow of materials, semi-products and finished goods in organisations, logistics chains or supply chains" (Sołtysik, 2003, p. 58.). It may help these organisations find answers to a number of important questions, e.g. how many services should be provided and how to shape relations between customers and service providers (Detyna & Twaróg, 2013, p. 41). Moreover, according to the glossary of the Council of Supply Chain Management Professionals, logistics management activities typically include inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of third-party logistics services providers (CSCMP, 2013, p. 117).

Logistics support is also required in the activity of manufacturers offering products and services dedicated to the elderly, e.g. in generotechnology. Generotechnology is a technology domain that refers to technology tools and services that assist older adults to offer a more independent, healthy, comfortable, safe, and socially engaged life (Mostaghel & Oghaz, 2017, p. 1970). To improve the quality of life of seniors, producers design innovative products and solutions, including, among other things, robots (Ejdys & Halicka, 2018), telecare (van den Berg et al., 2012; Mitseva et al., 2012) or smart homes (Majumder et al., 2017; Frisardi & Imbimbo, 2011). Their launch requires the commitment of many entities, also including logistics service providers.

Due to the growing need of the elderly for logistics services, there is a consequent need for the development of theoretical aspects associated with this issue. To the best of the author's knowledge, source literature offers no definition of a logistics service dedicated to older adults. It also lacks a classification set of such services. Therefore, the article aims to fill this gap. The authors, at this stage of their research — prior to the empirical study to be conducted among the population of the elderly and logistics services providers — are not able to classify logistics services for older adults. They merely identify possible criteria, according to which these classifications could be made.

Considering definitions of a service and a logistics service as well as a set of identified crucial components of the notion of a logistics service presented in the first part of the article, the authors attempted to devise a definition of a logistics service dedicated to an older person.

A logistics service for an older person is an activity or a set of activities connected with performing transport, forwarding, storage and other additional services that support the functioning of specific entities within a supply chain, aimed at satisfying the needs of an older person in accordance with the principle of 7Rs. It should be emphasised that a logistics service can be provided to the senior directly (e.g. home delivery of medicines) or indirectly, via such entities as hospitals, social care facilities, blood donation centres, pharmacies, associations and foundations providing assistance to the elderly (e.g. storing medicines).

Fig. 2 illustrates the proposed notion. Logistics services were classified into two groups: (1) services provided directly to an older adult and (2) services rendered indirectly, via entities offering support to the elderly. The figure also presents examples of logistics services.

Logistics services for older adults can be classified according to various criteria. According to the authors, it is justified to group them with regard to the following criteria proposed by Gołembska (Gołembska, 2010, p. 258-259) as well as Czubała et at. (Czubała et al., 2012, pp. 21-28):

- the type of service (e.g. transport to the health facility, home delivery of medicines);
- the degree of service immateriality (e.g. transport of a patient to the hospital, planning the delivery of cleaning agents to the social care facility);

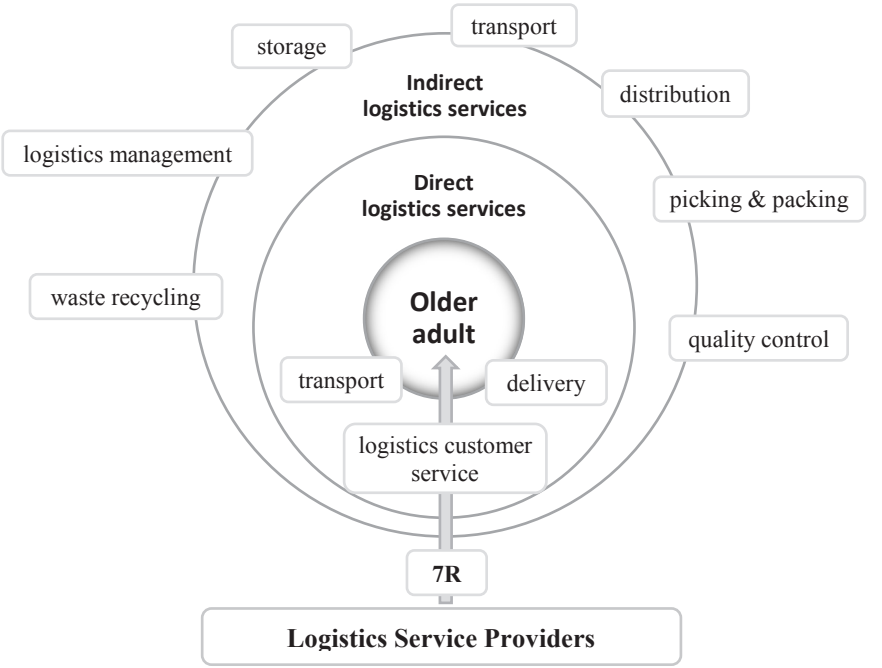

Fig. 2. Definition of logistics services for older adults

- the frequency of customer contact (e.g. daily home delivery of meals, transporting a senior for tourist purposes);
- the type of purchaser market (services for individual purchasers, e.g. seniors; institutional customers, e.g. hospitals, social care homes, manufacturers of products dedicated to older adults);
- the degree of service customisation (standardised, e.g. home delivery of medicines; adjusted to the requests of individual purchasers, e.g. transporting a wheelchair-bound, older person to the sanatorium);
- the type of relationship between the service provider and the customer (services rendered in direct contact with the recipient, e.g. home delivery of medicines; indirect contact with the recipient, e.g. logistics management in hospitals);
- the physical site of service provision (services provided on the premises of a logistics company, e.g. storage of medicines; at the customer's seat, e.g. home delivery of medicines; remotely, e.g. online shopping);
- the purpose of the service provider/nature of payment (commercial services, e.g. transportation of a customer; non-commercial services, e.g. free transport of organs for transplantation).

- Logistics services for seniors may also be grouped with regard to two categories proposed by Rosa (Rosa et al., 2017, p. 16):
- resource-driven logistics services (e.g. transportation of patients, storage of medicines);
- skill-based services (e.g. planning, organisation and supervision of transport of the elderly).

Considering the recently noticeable stress on customer orientation in logistics, the authors (Detyna & Twaróg, 2013, p. 43) proposed different classification criteria. From the perspective of the development of logistics services, logistics services for older adults should be grouped according to age, financial situation, needs, place of residence, health, expectations, hobby, skills and problems (Fig. 3).

The criteria proposed above stem from key factors of customer orientation in logistics, namely, marketing perspective, market segmentation, quality of service and logistics strategies subject to the interests of customers (Harrison & van Hoek, 2010, pp. 67-68; Michalczuk & Widelska, 2011). At present, older population — customers/recipients of logistics services — is an internally diversified market group. Elderlies have various needs that frequently result from their age, health and material condition as well as interests, likings and aspirations. Moreover, they are characterised by a different level of knowledge on the multichannel environment or skill to apply information and communication technologies (ICT).

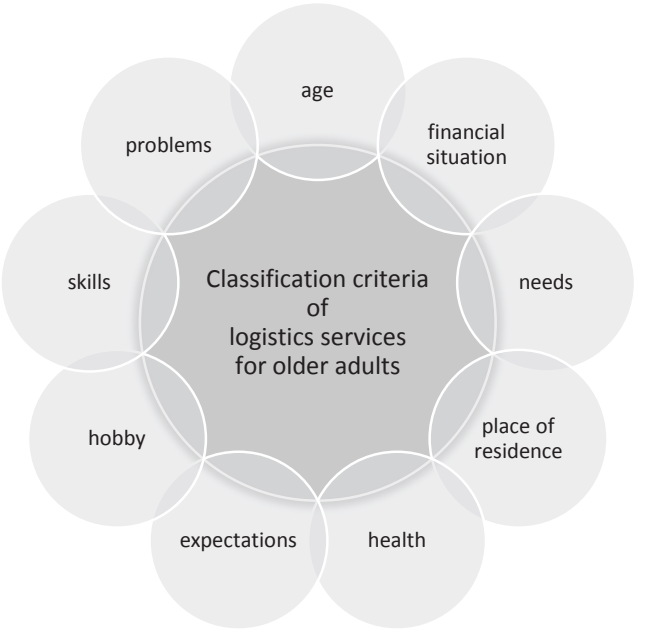

Fig. 3. Classification criteria of logistics services for older adults

Thus, strategic decisions concerning logistics services offered by logistics service providers should be based on firstly identified problems and needs as well as features of older adults. Recognising their expectations, habits, interests, age or material differentiation will allow to conduct a typology of this group of customers and subsequently adjust or design new, desired logistics services.

Conclusions

Nowadays, in most developed countries, the service sector has gained importance and services have captured markets on the global scale (State of the Services Economy Report, 2017; Kozłowska, 2017). The logistics services market grew in line with the development of information and computer technologies as well as globalisation of the electronic trade. The authors claim that this industry constitutes a continuously open space for innovative solutions, including services dedicated to older adults. In the era of ageing societies, enterprises operating in the logistics sector face many challenges. It is highly likely that this trend shall give rise to new business models and strategies for logistics management. One of the challenges is undoubtedly designing and offering logistics services that satisfy the needs and expectations of an internally diversified group of customers, i.e. older adults. Their development also requires strong theoretical foundations that can be brought by science and related empirical research. This article is the first step to fill the theoretical gap in the literature with regard to the definition and classification criteria of logistics services for older adults.

The authors of this article are conscious of the fact that the proposed classification criteria of logistics services are general and should be narrowed down. With this regard, it is planned to conduct empirical research which will lead to creating a catalogue of needs, expectations and problems of the elderly. It will allow to expand the classification criteria of logistics services and identify examples of such services for specific groups of customers. Moreover, the classification criteria can be combined, hence their various sets should be devised and analysed. The development of classification criteria of services and service categorisation may improve the process of market segmentation and facilitate the creation of profiles of the described group of customers. The knowledge of market segments may be subsequently used in the development of a logistics strategy of customer care, modes of communication with customers as well as means of reaching them. Depending on various features of customers or their expectations, the classification of logistics services classification may foster the design of personalised logistics

solutions. In applying the classification criteria, enterprises will be able to adjust their offer to specific market segments. Offer differentiation, dedicated products and services are aimed at establishing purchaser loyalty and increasing the level of their satisfaction. Moreover, the elaboration of the logistic services classification based on the results of the research on the needs and expectations of older people may contribute to the prioritisation of logistics services dedicated to older adults, as well as indicate future directions of the development of such services.

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Volume 10 • Issue 4 • 2018

sciendo

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 5 July 2018
accepted: 30 November 2018

pages: 76-84

Strategic development of cargo transit services: a case study analysis

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ABSTRACT

Purpose. Recently, foreign economic activity in Ukraine has gradually shifted towards the European Union (EU). The EU's special interest in the potential of Ukraine's transit transport lies in the geographical position of the country, which is located on the main routes of international freight traffic. The article aims to study the status and development opportunities in the field of transit freight transport of the Ukrainian railway joint-stock company (JSC Ukrzaliznytsya) within the framework of European integration. Methodology. The article presents the analysis of the activity of the JSC Ukrzaliznytsya in the field of transit freight transport for the period of 2005-2017 and outlines the strategic prospects for its development as a significant transit route considering the conditions of European integration. The methodology included theoretical and practical research using statistical methods; methods of comparative analysis; ABC analysis method; and taxonomic method.

Results. The JSC Ukrzaliznytsya was analysed to determine the status of its activity in the field of transit freight transportation for 2005-2017. A structural-dynamic analysis was made to estimate cargo volumes transported by railway enterprises and related revenues. 18 types of cargo were identified using the ABC analysis method based on two indicators, namely, "volumes of transportation" and "revenues from cargo transit". Also, taxonomic indicators of the level of system development were considered and revenues from cargo transit for the analysed period were estimated. Finally, recommendations were proposed regarding the development of a joint-stock company as a strategic cargo transporter under the conditions of European integration with Ukraine. Practical implications (if applicable). The results of the conducted research and performed calculations confirmed the need to refocus the management activity of the JSC Ukrzaliznytsya in the field of cargo transit towards strategically important cargoes, which have the largest share in the structure of financial results. This will enable the company to achieve its leading role as a strategic transit carrier of the European Union in the near future.

KEY WORDS

strategic development, transit transportation, railways, transit, management, income, European integration

DOI: 10.2478/emj-2018-0024

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Introduction

Rail transport is one of the key strategic areas for the cooperation between the EU and Ukraine. The joint action plan of the EU and Ukraine should implement the concept of a national strategy for the sustainable development of the transport system to improve all the transport modes in accordance with the White Paper on Transport of the EU. The plan also obligates the EU and Ukraine to work in partnership implementing transport and railways measures and reforms. Recently, foreign economic activity in Ukraine has gradually shifted towards the European

Union. However, Ukraine's economy is strongly dependent on metals, heavy industry and agriculture, and uses almost ten times more transport traffic relative to the gross domestic product than the EU countries. The volume of transit traffic is heavily dependent on bulk cargo by rail and sea. The level of development of the domestic transport infrastructure is much lower than the standards of the European Union and does not meet the existing security conditions. But Ukraine's significant advantage is its strategic and geographic location, which is on the main routes of international freight traffic. Four of the ten pan-European corridors that the EU has committed to support pass through the territory of Ukraine. All this leads to a great interest of the EU in the Ukrainian transit and transport potential. Given these facts, the article aims to study the status and development opportunities in the field of transit freight transport of the Ukrainian railway joint-stock company (JSC Ukrzaliznytsya) within the framework of European integration.

The paper is structured as follows. Firstly, the article describes the phenomenon of the efficient use of the Ukrainian transit potential. The emphasis was placed on different perspectives suggested by researchers of this topic. Secondly, research methods are presented followed by results and their detailed analysis. Finally, conclusions and limitations of the study are presented.

1. Literature review

The problem of the efficient use of the Ukrainian transit potential has been addressed in many research publications authored by domestic and foreign scientists. Various aspects of this issue have been investigated. For example, Minina (2010), Lyfar (2011) and Kovalska (2014) devoted their research to regional peculiarities of transit capacity building. In turn, Tkachenko (2008), Marov (2014) reflected on the existing strategies for the development of the Ukrainian transit potential. In the context of the economic safety of transport, the development of the transit potential was explored by Bludova (2006), Novykova (2003), Platonov (2015), Britchenko & Cherniavska (2017), Moravcikova et al. (2017). The development basics of the Ukrainian transit potential with the use of cargo shipping were considered by Shyptsov (2008) and Lypynska (2012). Bludova (2006) and Chorny (2015) analysed the question of the development and implementation of a flexible tariff policy for freight transportation in international communications. The estimation of the Ukrainian transit potential in relation to the world economy was made by Kliestik et al. (2018a), Petrenko (2017) and Minich (2017), whilst Stroiko and Bondar (2017) conducted a comprehensive study of the state of the Ukrainian transport infrastructure and substantiated the possibility of integrating the Ukrainian economy into the European and global economic systems through the efficient use of the transit potential. The latter issue was also analysed by Androniceanu (2017). Karpenko et al. (2018) presented integral performance indicators that can be used to determine the impact on the overall operation efficiency of transport and logistics clusters as one of the conditions for the use of transit potential. Sroka (2015) concentrated on studies of the logistics network and produced a detailed analysis of their formation and functioning. Other researchers, such as Sobczak et al. (2018), proved that transport networks were the most important elements of the modern economy, and Sinkevičius et al. (2016) drew the attention to the necessity of integrating the railway transport into an intermodal or multimodal transport chain. Studies by Oláh et al. (2018a, 2018b, 2018c) will help to provide more transparency to the market segment of international logistics centres and will give a posi¬tive impulse to further successful development of sustainable macro-logistics concepts in Europe. With the help of taxonomic and econometric analysis methods, the research by Czech and Lewczuk (2016) proved the significant influence of transport on the level of economic development of a country. These findings were confirmed by Ciobanu & Androniceanu (2018) as well as Sebestova (2018). Yildiz (2017) identified the relationship between logistics efficiency indicators and global competitiveness levels, and Zhuravskaya et al. (2016) developed recommendations for the improvement of the management principles for rail transport enterprises. The available literature shows that the problem is complex and multidimensional as well as analysed from different perspectives and points of view.

2. Research methods

In order to achieve the set goal and solve certain tasks, the following methods were used in the article: 1) statistical methods and methods of comparative analysis — for the study and evaluation of the state of

the JSC Ukrzaliznytsya in the field of cargo transit for 13 years from 2005 to 2017; and for structural–dynamic analysis of cargoes transit volumes transported by railways as well as income from the cargo transit for the same period; 2) the ABC analysis method for grouping 18 types of cargo based on two indicators, namely, "volume of transportation" and "revenues from cargo transit" for 2005-2017.

The taxonomic analysis (Plyuta, 1980) was used to determine the development level of the revenue system used by the JSC Ukrzaliznytsya for earnings from cargo transit. Using this method to calculate the taxonomic development ratios, multidimensional statistics were used, and the revenues from cargo transit were analysed. The taxonomic index was calculated by constructing a matrix of observations, standardising the matrix elements, developing a matrix of standardised values, constructing the vector, i.e. the standard, defining the distance between the matrix elements and the vector, and calculating the taxonomy coefficient (Kliestik et al., 2018b). The use of the matrix of standardised values for the construction of the taxonomic indicators allowed avoiding the cost meters. Values of the taxonomic index range from 0 to 1, and indicate the development level of the system.

The scientific, theoretical and methodological basis of the research consisted of research efforts and publications, conference proceedings in the field of cargo transit transported by rail, and issues related to the European integration policy applicable to the JSC Ukrzaliznytsya in the field of transit transportation. The following information was used for the study: statistics of the Ministry of Infrastructure of Ukraine, the State Statistics Service of Ukraine (official website of the State Statistics Service, 2018), statistical reporting and initial documentation of the JSC Ukrzaliznytsya (official website of the Ukrainian Railways, 2018); Internet resources, etc. Economic calculations were made using modern methods and computer technologies for the processing of statistical materials.

3. Research results

One of the important aspects in the policy of the European integration of Ukraine is the integration of the transport networks. The effective and economic operation of the Ukrainian transport system plays a strategic role in the development of the national socioeconomic system. The development of international rail freight transport in general and cargo transit in particular, plays an important role in ensuring foreign economic relations of Ukraine. Consequently, the status of the JSC Ukrzaliznytsya is that of an important player in the market of international cargo transit, ensuring the growth in the profitable part of the railway operation. The company's role as a strategic transit carrier is ensured by the favourable geographic location of the country and the availability of international railway transport corridors. In general, the Ukrainian railway network in its length is the fourth in Europe and the thirteenth in the world (official website of the JSC Ukrzaliznytsya, 2018).

Rail transport enterprises carry the largest volumes of transit in comparison with other modes of transport (Luchnykova, 2016). It is also important to note that only bulk cargo is transported by rail: coal, iron and manganese ore, ferrous metals, wood, crushed stone, etc. Cargo transit is the most profitable type of international transportation, and income from such activities is the largest. The transit rate is higher than that of transportation of exports and imports, therefore, considerable attention should be paid to the problem of increasing the efficient use of the transit potential of the railway companies of JSC Ukrzaliznytsya to secure their share, role and status as a strategic transit carrier within the framework of the European integration of Ukraine.

The Association Agreement between Ukraine and the EU on 16 September 2014 (On ratification of the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other side, 2015) was an impetus for the development of the Ukrainian economy and the effective use of transit potential. By fulfilling the requirements of this Agreement, Ukraine has an opportunity to become a full member of the European Union. Therefore, it is necessary to ensure the preconditions for the improvement of the organisational and economic bases for the use of the Ukrainian transit potential to create a European model of rail transport market that would promote the competition in the market of international cargo transit. As stated in the Strategic Plan for the Development of Rail Transport (Strategic Plan for the Development of Rail Transport up to 2020, 2015), developed in accordance with the requirements of the Association Agreement with the EU, a new model for the operation of rail transport enterprises should ensure the organisational and financial distribution of infrastructure operators and

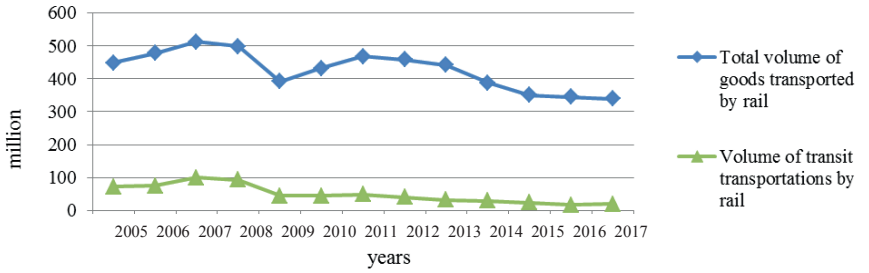

Fig. 1. Volumes of general and transit freight traffic of the JSC Ukrzaliznytsya for 2005-2017

Source: elaborated by the author based on Transportation of Freight by Railways of Ukraine, 2017.

the carrier, as well as create free access to the transportation market. This can be achieved by adopting appropriate rules and procedures for the access to the rail infrastructure (in accordance with the provisions of Directive 2001/14/EU of 26 February 2001). In order to integrate the Ukrainian and European transport systems, it is necessary to harmonise the national legislation in the transport sector with the European norms. Such coherence of legal acts regulating transit transportation and their forwarding services, as well as the implementation of the relevant EU directives that were enshrined in the relevant annexes of the Association Agreement, will create the legal preconditions for the improvement of the organisational and economic bases for the use of transit capacity by railway undertakings.

Calculations were made to compare the growth rates of freight transport by all the modes of transport with the growth rates of freight rail traffic according to official statistics (official website of the State Statistics Service, 2018; official website of the JSC Ukrzaliznytsya, 2018). The results made it possible to draw the following conclusions. Fig. 1 presents the total freight traffic by rail and volumes of transit freight traffic for 2005-2017 and illustrates a linear downward trend.

According to statistics, the Ukrainian transit potential is not used in full, and more than 80% of potentially possible cargo transit volumes are lost. These data confirm that the Ukrainian railway network has an unused transit reserve.

The structural and dynamic analysis of the volumes of cargo transit by railways in Ukraine was carried out for the period from 2005 to 2017, focusing on 18 types of cargo categories according to official data of the JSC Ukrzaliznytsya (Transportation of Freight by Railways of Ukraine, 2017). In terms of volumes of rail transit traffic, 2016 was the worst of the 13 studied years with 16.93 million tons. Compared to the largest volumes of 2008, the decrease is more than four-fold. This testifies not only of the negative tendency in the field of transit traffic by the Ukrainian railways but also indicates the deterioration of the rating and position of the JSC Ukrzaliznytsya as a strategic transit carrier within the framework of the European integration of Ukraine. During 2017, 19.55 million tons of cargo transit were transported by rail enterprises, which is 2.62 million tons more than in 2016. A rather insignificant growth indicates the remaining problems of the significant reduction in transit traffic by this strategically important mode of transport. In summary, the following conclusions can be made. During the investigated period 2005-2017, there was a nonlinear trend in the change of volumes of cargo transit by the Ukrainian railways (Fig. 2). For most of the types of cargo, change in volumes was characteristic and reflected the general dynamics.

Comparing the change in the volumes of transit traffic in 2017 and 2005, growth can be observed in the transportation of coal, oil and petroleum products, iron and manganese ore, timber, automobiles, minerals and cement, while the remaining 11 cargo types demonstrate a reduction. The analysis of data particular to 18 cargo types by year revealed an uneven and unstable change. For a period 13 years, a stable trend is represented by the data on transportation volumes of half of the analysed goods: nonferrous metals and their products; cars; machinery and equipment; salt; coke; ferrous metal scrap; cement; mine construction materials; ferrous metal ores, sulphur raw materials. The transit volumes of ferrous metals, chemicals and mineral fertilisers, grains and grain products increased by almost 6 times during the investigated period. The greatest changes among the different types of goods over the past 13 years were observed for coal, oil and petroleum products, and iron and manganese ores. Their variations were in the range of 0.155 to 0.407; 0.072 to 0.318; and 0.155 to 0.390, respectively. These results demonstrate a very uneven distribution of cargo volumes transported by the Ukrainian railways both in terms

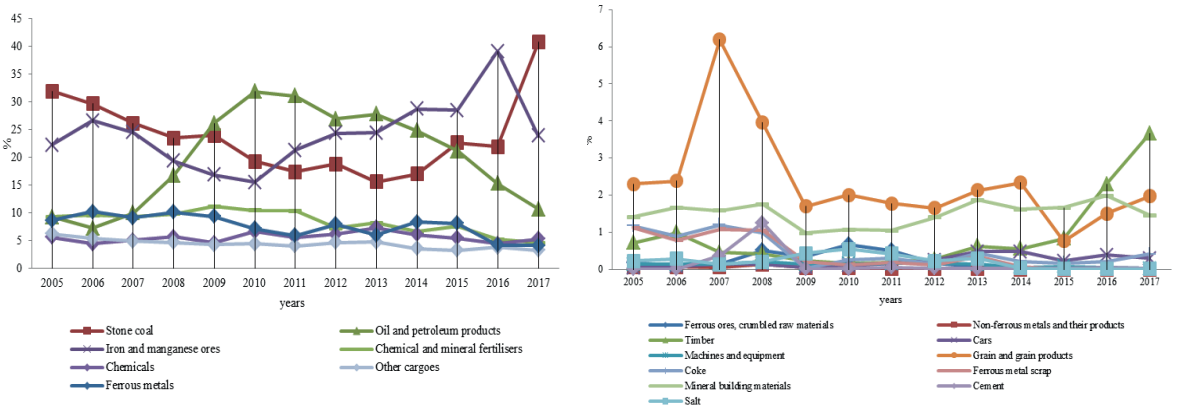

Fig. 2. Specific volumes of cargo transit by the Ukrainian railways for 2005-2017 [%]

Source: elaborated by the author based on Transportation of Freight by Railways of Ukraine, 2017.

of years and the types of goods. Consequently, the existing structure is unstable and ineffective. The persistence of such negative nonlinear trends and unreasonable policy in the field of cargo transit through Ukraine and the continued tendency for significant reductions in cargo volumes predict the loss in the Ukrainian share of cargo transit by rail in the total volumes of domestic and international freight. Aiming to identify the reasons behind the given problem as well as proposals and recommendations for strengthening the role of the Ukrainian railways within the framework of European integration of Ukraine, to study must focus on the main countries of departure and destination of the goods passing through the territory of Ukraine. The main reason for the reduction in the volumes of cargo transit is the deflection of freight flows to the ports of the Russian Federation (RF). The Russian Federation is the main source of cargo transit for Ukraine. According to the reported data, 80% of the cargo transit originates in the Russian Federation. In the structure of transit volumes of 2017, the largest share belongs to coal (40.7%). This type of cargo is sent by Russian enterprises through the territory of Ukraine to Slovakia, Turkey, Poland, Romania and the United Kingdom. The Russian Federation is the main country of transit of iron and manganese ore. The bulk of this type of transit cargo, namely about 40%, goes to Slovakia, and the remaining 60% — to Poland, the Czech Republic, Iran, Romania and Italy. In 2017, the volume of transit of this type of cargo decreased by almost 30%. The main reason for this was a partial re-routing of Russian iron ore supplies to the domestic market, increased competition from Australian and Brazilian suppliers, partial deflection of traffic in the direction of Russian seaports and reducing numbers of European construction projects. The second place in the formation of transit In 2016-2017, Kazakhstan and Belarus were the second largest source of transit cargo, sending petroleum products as energy gases via Ukrainian railways. The countries of destination for this type of cargo were Turkey and Eastern Europe.

Fuel oil is sent from Belarus via Ukraine to the Netherlands (80%) and Great Britain (20%). Hungary, Turkey, Poland, Romania, Greece, Slovakia and Croatia are recipients of Russian and Belarusian potash fertilisers. Lithuania, Finland, the Russian Federation and Belarus send other mixed mineral fertilisers to Hungary, Moldova, Serbia, Romania and the United Arab Emirates. Nitrogen fertilizers are transported from Kazakhstan and the Russian Federation to Moldova, Turkey, Romania, Hungary and Serbia. Ferrous metals come from Belarus, the Russian Federation, Hungary and Poland. Their share in the overall structure of cargo transit in 2017 was 4%. Countries of destination for this type of cargo were Israel, Egypt, Slovakia, Poland. Cast iron (Transportation of Freight by Railways of Ukraine, 2017) was also sent to the USA and Slovakia from the Russian Federation. In 2016-2017, there was a certain decrease in transit volumes from Belarus, which was mainly due to the deflection of transported petroleum products to the ports of the Baltic States. It should be noted that the main competitor of the JSC Ukrzaliznytsya is the Belarusian railway. This is due to the re-routing of significant volumes of Russian transit traffic, namely, coal to Poland and Germany and ferrous metals to the EU countries. Also, the countries of the Customs Union have been allocated benefits. As a result, the Belarusian transit by rail significantly exceeds the Ukrainian. Besides, in 2016-2017, shipments from Kazakhstan to Turkey decreased significantly (by 31.7%) due to the re-routing of cargo flows

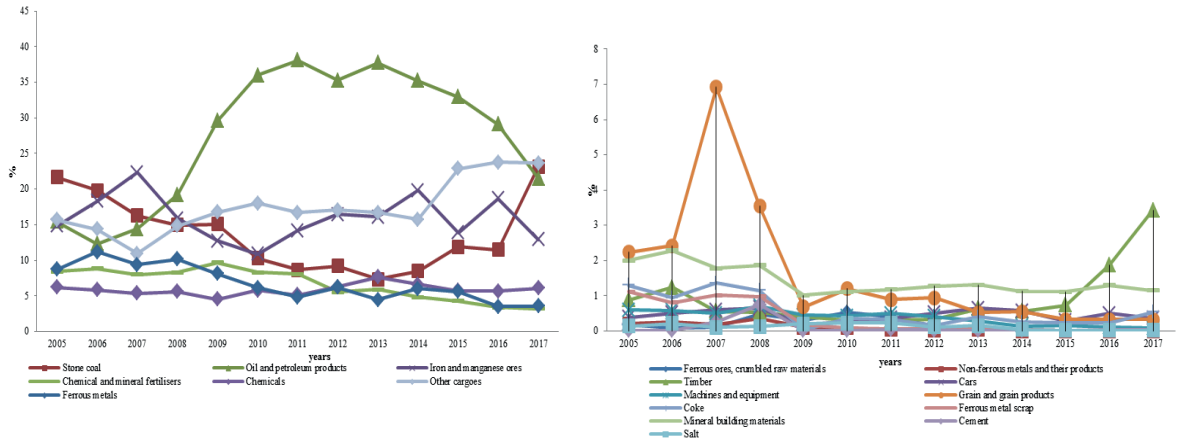

Fig. 3. Share of revenues from transit by railways of Ukraine for 2005-2017 [%]

Source: elaborated by the author based on Transportation of Freight by Railways of Ukraine, 2017.

from the Ukrainian port of Odessa to the port of Taman. The main reasons for reducing the volume of cargo transit was is the loss of a part of the Ukrainian railway infrastructure due to military actions in eastern regions.

To ensure the comparability of data on revenues from cargo transit by Ukrainian railways by type and time, it is expedient to analyse the relative values of the structure presented in Fig. 3.

The structured and systematised data on revenues for 2005-2017 indicates variations in the structure by year and type of goods. The analysis of revenues from coal transit showed that during the analysed 13 years, the share varied from 0.074 in 2013 to 0.231 in 2017. It is worth noting that the unstable structure of distribution was observed for 11 years.

The ABC analysis allowed to investigate the share of freight volumes and revenues from cargo transit by railways of Ukraine for 2005-2017. The results of calculations and their division into three groups by the contribution to the total volume by year showed a significant inconsistency in the distribution of the types of cargo based on two indicators ("volumes of transportation" and "revenues from cargo transit", %). In the distribution of cargo volumes, Group A consisted of mainly three to five types of cargo, with their total share in the range of 75.2% to 81.0%. Group B included chemicals and other cargoes. And the Group C consisted of the remaining 11 items: ferrous ores, sulphur raw materials; timber; cars; machinery and equipment; grain and grain products; coke; ferrous metal scrap; mineral building materials; cement and salt. Grouping by the indicator "revenues from cargo transit" transported by the Ukrainian railways allowed to divide the goods into three groups. Group A was mad of goods with the cumulative share of 75.0% to 85.8% in 2005-2017. Consequently, the goods in this group amounted to an average of 80% of the revenues from the total cargo transit. The distribution of Group A goods by this indicator was different for each year for 13 years. In terms of "volumes of transportation", other cargoes were a part of Group B, because their share in the total volume ranged from 3.2% to 6.1%. However, in terms of "revenues from cargo transit", they were placed in Group A, since their contribution to the total revenues from cargo transit was from 11.0% to 23.8% each year. Consequently, the traffic of other cargoes amounted to an average of 5% and contributed an average of 17% – 18% of revenues.

The calculated values of the taxonomic index for 2005-2017 presented in Table 1 showed a tendency to decrease the value of this indicator. The system of revenues from cargo transit was best developed in 2005-2008, and since 2009, including from 2017, it was average. In 2017, it was 0.45. This testifies to the inefficient and inappropriate development of the system of revenues from cargo transit by JSC Ukrzaliznytsya for 2005-2017.

Tab. 1. Dynamics of the taxonomy regarding the level of development of the system of revenues from cargo transit

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Indicator value	0.61	0.62	0.60	0.67	0.46	0.49	0.48	0.50	0.50	0.46	0.43	0.46	0.45
Standard	0.60 – 0.79				0.4 – 0.59								

4. Discussion of the results

The conducted research using the structural-dynamic analysis, the ABC method and the taxonomy method resulted in conclusions indicating the need to revise the strategy for the development of JSC Ukrzaliznytsya as a competitive carrier. The analysis of revenues from cargo transit revealed the non-conformity between the revenues from cargo transit and their volumes for 13 years. Considering the structure of transported goods, it's the system is considered unstable. In summary, such significant structural changes do not correspond to strategic goals of the European integration in respect to the JSC Ukrzaliznytsya as a transit carrier.

The ABC analysis showed inconsistencies and instability in Groups A, B and C based on indicators "volumes of transportation" and "revenues from cargo transit". Additional analyses are required to identify the causes, main threats, and opportunities, and problems and assess the situation in the context of the world market of goods to further substantiate the managerial decisions on the rational planning of the volume of cargo transit through the territory of Ukraine by domestic railways aiming to increase the volumes and the flow of cargo transit as well as maximise the profits.

Conclusions

The conducted comprehensive research allowed to propose recommendations for the development of the JSC Ukrzaliznytsya as a strategic cargo carrier under the conditions of European integration:

1. Improve the state of the domestic rail network. Much of the road network is in poor condition. The railway network has bottlenecks on the main nodes and overload areas requiring double tracks. Most of the rolling stock of the JSC Ukrzaliznytsya is already outdated or will become such soon.
2. Remove customs barriers at the borders of Ukraine. Many countries encounter problems with cargo transportation at the border, among which is the insufficient railway capacity and non-transparent tariffs for rail operations.
3. Rational use of the railway infrastructure. The railway infrastructure in Ukraine is multifunctional because it is used for both passengers and cargos. This creates difficulties in scheduling and the use of railway infrastructure.
4. Ensure a uniform distribution of rail transport. The existing railway infrastructure contains part of roads and stations that are not sufficiently used or do not work at all. At the same time, about a third of railways are significantly overloaded.
5. Improve regulatory compliance and regulation of transport issues. Ukraine is delaying the ratification of a large number of transport and border-crossing agreements supported by the United Nations Economic Commission for Europe. The volume of agreements ratified by Ukraine is very low.
6. To conduct multifaceted research of the cargo transit system. Constant systematic monitoring and study of changes in transit traffic with the use of economic and mathematical tools will allow railway enterprises to reach a qualitatively new level in the field of cargo transit, thus ensuring the JSC Ukrzaliznytsya the role of a strategic partner in the freight transport market within the framework of European integration.

Refocusing the JSC Ukrzaliznytsya strategically important cargoes will ensure greater revenues from cargo transit and the necessary strategic development of the JSC Ukrzaliznytsya in the context of the European integration.

The study makes an important contribution to the existing literature. Firstly, though this research adopts a single-country approach, analysing a Ukrainian company, it allows comparing the results with other sectors of the economy. Secondly, this detailed analysis may become a substantial advantage that allows formulating hypotheses to be verified in the context of other industries and/or countries. And thirdly, the results of this study can offer guidance to companies willing to benefits from the European integration.

Our study has several limitations, the first of which is the analysis of only one national company. Secondly, the study was qualitative, whereas a quantitative approach might be used in future research. These limitations need to be addressed in future research. Despite the limitations, the results achieved allowed to determine a true picture of the situation in the analysed sector.

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