Environmental Aspects of Product Life Cycle Management and Purchasing Logistics: Current Situation in Large and Medium-Sized Czech Manufacturing Companies

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Abstract: This paper is focused on current approaches to the environmental behavior of large and medium-sized Czech manufacturing Companies, in relation to the control of environmental aspects through the whole product life cycle and the management of environmental risks in individual phases of product life cycle. This work addresses environmental aspects of product life cycle including design, manufacturing and selected logistics activities, specifically solution for environmental risk management and levels of environmental system considering environmental activities in manufacturing companies. Based on the qualitative and quantitative research performed through the structured interviews combined with questionnaire survey, authors provide an analysis of the actual insight into managing environmental risks and aspects through the whole product life cycle in Czech manufacturing companies. Results are considered also from the viewpoint of individual elements of environmental system and relation of environmental activities to the country's legislative requirements and other system standards across the business environment. Based on the research activities, the authors found out that the final customer is the most important stakeholder influencing risk management in the individual phases of the product life cycle. Further research steps will be directed towards the comparative study of the environmental performance of medium and large manufacturing companies in other countries. Practical use of research results is focused especially on the new agreement of the environmental requirements with customers throughout the whole logistics chain.

Keywords: Level of environmental management system; product life cycle; environmental aspects; risk-based thinking; purchasing logistic

1 Introduction

Nowadays, businesses are influenced by the following trends – a Green Economy and Circular Economy. Global trends determine the future business behavior. This article is focused on the environmental performance of large and medium-sized manufacturing companies in order to identify the underlying motives for managing environmental aspects and risks from raw material purchase, product development, through logistics and manufacturing to recycling.

Sustainable development involves 17 goals to assure sustainability for future generations. The voluntary approach in business environmental area is presented by the Corporate Social Responsibilities in economic, social and environmental area (CSR) of small and medium companies in the Czech Republic. This guide involves three pillars, one of them is the environmental area with several recommended activities (Business Leaders Forum, 2004). This approach brings both the direct and indirect advantage and ensures long term competitiveness. (Amaeshi, Nnodim and Osuji, 2013). From a different point of view, Hitchens et al. (2005) prove that companies with average financial performance could be compared to high-performing competitors in environmental initiatives.

The main goal of Circular Economy (CE) is to maintain the value of materials, products and other resources as long as possible and return them back into the product cycle by reusing them and minimizing the generation of waste at the same time (Eurostat, 2018). Vranjanac and Spasić (2017) demonstrated positive and negative economic effects of waste management in their study focused on recycling of packaging waste and concluded that the presence of economic effects is not always instantly visible and have to be considered in all relevant relations. However, Leising et al. (2018) emphasize that the concept of the Circular Economy is not only about closing loops in terms of reusing waste but it includes also the concept of slowing material loops by introducing the long lasting reusable components and products. The products that become unusable at the end of their life cycles should be made predominantly of materials that can be recycled or incinerated in a waste incinerator or at least rapidly degraded to low molecular weight harmless substances in the dumping ground (Gregász et al., 2008).

Product life cycle in environmental concept was determined through the requirements of the norm ČSN EN ISO 14001: 2016, where the top management should determine risks and opportunities, which are related to environmental aspects of the company throughout the product life cycle. Siebert et al. (2017) highlight that life-cycle assessments assessing the impact of sustainability from a regional perspective have not been fully developed yet. It means assessing products' social implications as they are determined by the national and regional socio-economic conditions.

The risk assessment should be evaluated in all processes of a company and also in the environmental process (ČSN EN ISO 9001: 2016). According to the requirements the environmental activities of companies are focused on aspects in

the area of air protection, nature and landscape, water and waste management. The main external factors influencing business in the area or environmental protection is a compliance with legislative requirements of Ministry of the Environment of Czech Republic and EU environmental legislation. There are two ways to establish environmental management system in Czech Republic. The first solution is to implement the EMAS (Eco-Management and Audit Scheme) and the second possibility is the norm ČSN EN ISO (the International Organization for Standardization) 14001: 2016 – Environmental management system. Both systems integrate environmental care to the business strategy, improve the environmental performance, achieve the environmental objectives and fulfil the compliance with obligations.

Many studies point out to the positive impacts of companies' competitiveness by using environmental activities in the companies. However, none of them explains what environmental activities are being implemented in the business area. The authors of the article focused on manufacturing companies in the Czech Republic, legislative requirements, standards and other environmental regulations to analyze the current environmental behavior of selected companies. Current studies deal with the importance of re-using waste, but none of them provides information about the current approach of manufacturing companies to this issue.

The aim of this paper is to describe the current environmental behavior of medium-sized and large manufacturing companies in Czech Republic to confront this behavior with the current legislative and system requirements and to identify potential barriers in following of new environmental trends.

Based on the results of theoretical research and qualitative study, we have defined the following hypotheses:

- H1: The level of environmental system positively affects the approach of the company to the environmental aspects through the whole product life cycle.
- H2: Companies that consider environmental risks through the whole product life cycle have implemented a complex methodology for determination and measurement of environmental risks for all stages of product life cycle.

2 Literature Review

Organizations have to implement sustainable actions, particularly in the field of environmental policy and energy. The European Union agreed to reduce greenhouse gas production by 20% by 2020. Renewable energy sources seem to be a significant part of the solution to this problem. From this perspective the potential for renewable energy and pro-active environmental and energy approach do not meet the present trends in developed countries (Ministry of the Environment, 2008-2018). In the following sections we shorty discuss current studies and legislative in the field of environment and their risk for management.

2.1 Environmental Aspects and Product Life Cycle

Innovations in the field of environment clearly represent a competitive advantage. Hojnik & Ruzzier (2017) suggested some solutions how companies can be profitable on one side and environmentally friendly on the other one. They simply stated that introducing eco-innovation would result in significant positive benefits.

Salim et al. (2018) mention world trends in imposing environmental management systems, ISO 14001 in particular. The authors highlighted increasing interest in environmental research in a research dated from 2000 to 2016. Voluntary environmental management system (EMS) plays an important role in achieving sustainable production and consumption practices.

Life cycle thinking (Loiseau et al., 2017) means an evaluation of the holistic impacts of land use planning policies on the environment. It signifies that we should take into account several aspects which relate to the territorial features and consumption patterns.

It is important to consider environmental aspect already during the phase of product design. As Kramoliš and Staňková (2017) point out, product design not only leads to innovative and modern products but it can significantly influence the financial performance of enterprises which is very closely connected with environmental aspects of production process.

According to Sarkis et al. (2010), the pressure of stakeholders to apply ecological practices lead to three types of measures: eco-design procedures, resource reduction procedures, and implementation of environmental management system procedures. The concepts of eco-design and product life cycle assessment (LCA) are well implemented theoretical concepts which bring measurable practical results.

Kolotzek et al. (2017) deal with the raw materials used in final products based on the triple bottom line approach. The authors of this study suggest a corporate-oriented raw material assessment model which considers an up to date sustainability assessments as well as the recent development in the field of critical analysis, life cycle impact assessment (LCIA) and social life cycle assessment (SLCA). Recommendations are the following: using alternative raw materials or technologies and the variation in the purchase of raw material.

An emerging research field called corporate environmental behavior, on which, more and more research is focused, gives rise to new environmental theories, such as, the theory of ecologically significant behavior (Stern 2000). Both pressures from outside and individual business characteristics encourage companies to adopt active environmental behaviors (He et al., 2016). However, government regulations have the most important impact. For this reason, research on corporate environmental behavior should inform environmental policy (Clark, 2005).

Vogtlander et al. (2017) explain a method called Eco-Efficient Value Creation to analyze the costs, market value and eco-costs of innovative product and service

designs, which should be used in Business to Business (B2B) markets. The main goal of this method is to find lower eco-costs of materials depletion and pollution. However, despite the fact that situation in cost management is improving, many companies still maintain adherence to historical and conservative cost management systems (Novák & Vencálek, 2016). Therefore, the implementing of above mentioned approaches would require longer time and changing the way of thinking.

2.2 Risk Management in Environmental Area

Particularly, during an economic downturn in a country, an organization needs to determine and address its associated risks (Medic et al., 2016). As Taraba et al. say (2016) the risk-free projects and processes do not exist and therefore, it is necessary to set up measures in order to be able to identify and solve risks in any area even environmental one. Zhang et al. (2017) present a method for the application of dynamic Bayesian networks (DBNs) in conducting accident scenario analysis and dynamic quantitative risk assessment in their study. The authors used the following procedure: an accident scenario of the assessed activity is determined, the root causes, safety barriers, and potential consequences related to this activity are found, and then it is analyzed by performing a cause-consequence. Finally, uncertainties of events likely to occur are assessed. Berec at al. (2018) highlight the importance of risk assessment and risk management to achieve maximum security levels.

Khan et al. (2017) present holistic framework for environment conscious based product risk modelling and assessment. The authors assessment the product risk in following steps: establish relationship among parameters, develop relationship graph for parameters, generate risk function, evaluate the ideal value of Risk index, evaluate risk index for individual design, repeat the steps for all other alternatives, rank all the design concepts based on index and select the best alternative.

Ning et al. (2018) describe safety risk assessment models in a construction site environment. These models consist of three parts, i.e. factor identification and classification from more categories, factor analysis, and assessment function development. The factor analysis is based on quantifying the risk factors according to five ranks and evaluating the likelihood of accident occurrence.

Németh-Erdődi (2008) describes, that before starting an innovative project in value to assess the market risk and risk of product implementation and decide on the way and cost of product development taking into account the acceptable risk. Wong (2017) describes the risk-based thinking in daily operations in a practical and effective way for chemical testing. Wong recommended to use the Plan-Do-Check-Act cycle (PDCA) in a specific form: Risk assessment, planning actions, progress monitoring and reporting for review. This form of PDCA cycle shall achieve the integration of risk-based thinking into the quality management system.

3 Methodology

In the first step the authors performed a qualitative analysis in order to get a realistic general knowledge about the current state and situation in the field of environmental management system in Czech manufacturing companies. The method of structured interviews was used to gain a basic information describing the level of environmental management and related risk based-thinking and environmental aspects in the whole product life cycle. Respondents of qualitative research were precisely selected in order to cover the whole considered segment. Our sample included 3 large and 3 medium-sized companies from different industrial branches (mechanical engineering, automotive, textile, food, chemical and plastic industry). The results showed that all interviewed companies with implemented environmental system also actively attend to the management of environmental aspects through the whole product life cycle. However, the level of implemented environmental risk management system is slightly different among all interviewed companies. The same respondents were also used for testing the comprehensibility and structure of the questionnaire used for evaluating set of hypotheses.

To realize the quantitative research, authors used an electronically distributed questionnaire. Based on the questionnaire, the authors approached 5 000 large and medium-sized Czech manufacturing companies in the first half of 2018. A total of 247 large and medium-sized Czech manufacturing companies from different industrial branches answered the questionnaire and participated in our survey. The structure of our respondents includes different industrial branches - production of food products, beverages, clothes, textiles, wood processing, paper production, production of chemical substances and chemical preparations, pharmaceutical products, rubber and plastic products, repairs and installation of machinery and equipment, manufacture of machinery and equipment, production of transport and equipment, car manufacturing, engineering and electrical equipment manufacturing. The second aspect taken into account during the research was the ownership structure. The sample of respondents includes 55% of companies with domestic majority owner, 27% with foreign majority owner, 12% subsidiary companies with foreign majority owner and 6% of subsidiary company with domestic majority owner. The main goal of our study is to understand better the main barriers influencing the management of environmental risks because it becomes more and more important nowadays.

Both hypotheses were tested by appropriate statistical methods. First of all, the Pearson correlation test was applied to detect the existence of correlations between all groups of questions. It was supplemented by Cronbach Alpha test in order to prove gained results and measure the level of internal consistency of each group. After that the SPSS v.17 and AMOS v.18 software were used to test first hypothesis and parametric paired sample, Student's T-test was applied to test the second hypothesis.

A questionnaire based research was used to obtain data for evaluating the above mentioned hypotheses. Besides the initial basic identification and classification questions (industry, size of the company, owner structure etc.), the questionnaire includes 6 questions related to the level of environmental management system applied (Q1 – Q6) and the next 3 questions (Q10 – Q12) describing the risk-based thinking and environmental aspects related to the product life cycle.

Table 1
The list of questions asked via questionnaires

No.	Question	Type
Q1	The reason of implementing EMS	Closed
Q2	Interaction of TOP management in EMS	Closed
Q3	Defining the competences and responsibilities in the area of company´s environmental activities	Closed
Q4	Strategic concept for environmental policy till 2020	Closed
Q5	Training of employees in the area of EMS	Closed
Q6	Monitoring of current environmental trends	Closed
Q8	Does a company consider environmental risks through the whole product life cycle?	Closed
Q9	How does a company determine the environmental risks?	Closed
Q10	Does a company consider suppliers´ approach to environmental matters as one of their evaluation criteria?	Dichotomous
Q11	Does a company consider the environmental impact when purchasing a new machines and technologies?	Dichotomous
Q12	Does a company consider environmental aspects in a process of product design and development?	Dichotomous

Source: authors´ own

To evaluate the first hypothesis, H1: The level of environmental system positively affects the approach of the company to the environmental aspects through the whole product life cycle, we divided all related questions into two groups. The following figure (Figure 1) shows the scheme of evaluating hypothesis H1 which is more complicated and includes more questions influencing the result. According to our hypothesis, the positive answers in a group of questions related to the maturity of environmental systems cause the positive answers in a group of questions related to the management of environmental aspects through the whole product life cycle. In case of the negative results we are going to study the relations between the questions separately.

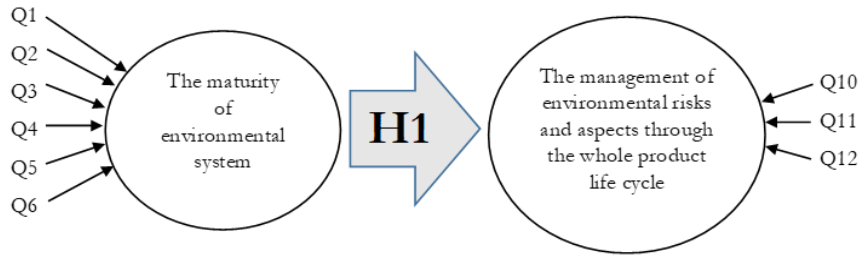

Figure 1
Scheme of evaluating the hypothesis H1 (source: authors´ own)

The second hypothesis looks at the level of environmental risk management regarding companies considering environmental risks through the whole product life cycle. The sample used for evaluation of the second hypothesis includes only respondents that answered positively to question no. 8. To confirm the hypothesis, the respondents farther had to choose both answers a) and b) in question no. 9.

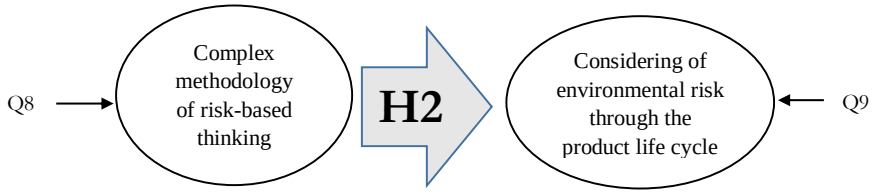

Figure 2
Scheme of evaluating the hypothesis H2 (source: authors´ own)

4 Empirical Results and Discussion

The following section provides a brief interpretation of the empirical results to both defined hypotheses. In order to get the most relevant results, we tried to keep the structure of the sample similar to the universe regarding the complexity of industrial activities included (see NACE structure in Figure 2) and owner structure.

4.1 Evaluation of the First Hypothesis

Hypothesis H1 says that the level of environmental system positively affects the approach of the company to the control of environmental aspects through the whole product life cycle. In order to prove/disprove the hypothesis, two group of questions were formulated. First group (Q1 – Q6) examines the maturity of environmental systems and the second group (Q10 – Q12) examines the level of managing environmental aspects through the whole product life cycle.

The hypothesis was tested via LISREL Structural Equation Model, where individual questions represent observed variables and group 1 (G1) and group 2 (G2) are latent variables consisting of observed ones.

In order to check whether observed variables are referred to appropriate latent variables the existence of correlations between individual questions in groups G1 and G2 were tested (Table 2). This is also important parameter which can lead to conclusion if LISREL structural equation modeling can be used to available questionnaire results. Subsequently EFA (Exploratory Factor Analysis) was performed. After reviewing the results of EFA and the correlation matrixes for both groups of questions the question Q3 is removed from further analysis due to very low correlations with other items from group. The rest of the questions from group G1 belongs to one factor with high factor loadings presented in Table 3. Reliability checked using Cronbach's α coefficient for G1 is 0.843 and it is considered as highly reliable.

Table 2
Pearson Correlation between all questions

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q10**	**Q11**	**Q12**
Q1	1								
Q2	0.498**	1							
Q3	0.215**	-0.134*	1						
Q4	0.596**	0.545**	-0.090	1					
Q5	0.532**	0.589**	-0.125*	0.847**	1				
Q6	0.414**	0.523**	-0.057	0.536**	0.536**	1			
Q10	0.366**	0.489**	-0.220**	0.399**	0.439**	0.421**	1		
Q11	-0.154*	-0.071	0.115	-0.133*	-0.088	0.020	0.069	1	
Q12	-0.087	0.055	0.154*	-0.036	0.005	0.032	0.088	0.239**	1

Correlation significance: *p<0.05, **p<0.01

Table 3
The results of Exploratory Factor Analysis

Maturity of environmental systems		**Level of managing environmental aspects through the whole product life cycle**	
Questions	Factor loading	Questions	Factor loading
Q1	0.750	Q10	-0.414
Q2	0.774	Q11	0.738
Q4	0.880	Q12	0.753
Q5	0.885		
Q6	0.736		
Eigenvalue	3.308	**Eigenvalue**	1.282
Variance explained %	55.131	**Variance explained %**	42.741

Source: authors´ own

The questions from group G2 generated one factor with factor loadings presented in Table 3. Considering all output questions (questions from G2) individually, we

can observe statistically significant correlation of question Q11 with the question Q12. It is caused by the fact that many organizations have started to consider environmental aspects during the phases of designing new processes or products. Therefore, the company that consider environmental aspects in a process of product design and development takes care also about the environmental friendly technologies used for its production. It is not the same situation in case of question Q10, which is highly influenced by the negotiating power of suppliers and this situation is changing more slowly. In case of connection between Q10 to the other output questions (Q11 and Q12), a small negative correlation occurs in the most cases. Generally, the second group seems to be inconsistent. The same results were gained also by a component matrix analysis and Cronbach Alpha test which were used to test the reliability of both groups of questions before testing the hypothesis. According to the Cronbach Alpha test we detected a negative average covariance among answers in the second group (Cronbach´s Alpha reached negative value -0.068). The reasons for all observed inconsistencies can be various. Obviously the wrong structure of questionnaire or wrong formulation of questions can lead to a negative covariance among answers. However, this is not case of presented study because the authors avoided this risk by preliminary research and testing the comprehensibility of the questionnaire during the phase of qualitative research. The main reason is explained in the following paragraph.

70% of interviewed companies is certified according to ČSN EN ISO 14001:2016. These companies declare fulfilling all requirements of this norm saying that companies should determine risks and opportunities which are related to environmental aspects of the company throughout the product life cycle. Questions Q10, Q11 and Q12 were selected based on interviews in the preliminary phase as the most often occurred ones. Just suppliers´ evaluation and purchasing of new machines and technologies in the phase of new products´ design and development must be realized with regard to their environmental impacts. However, sometimes the force of external involved sides is too strong that it does not allow companies to fulfil all set goals in the environmental area. Therefore, as the main reason of above mentioned inconsistencies among the answers in the second group of questions is considered just this external involved side, obviously customers. Customers very often highly affect decision making processes of their suppliers including also environmental aspects and they have crucial influence to their planning and control of key business processes.

After defining the conceptual model, it has to be verified whether the model appropriately describes the relations among observed and latent variables by Measurement variables analysis and evaluate hypothesis with Path analysis.

The model fit indices in Table 4 show that proposed model is valid due to the obtained values of fit indices are acceptable or above recommended values (Jovanović et al., 2018; Schumacker & Lomax, 2004).

Table 4
The fit indices of proposed model

Fit indices	χ^2	df	χ^2/df	RMSEA	RMR	GFI	CFI	NFI	AGFI	IFI
Recommended values	-	-	<3	<0.08	<0.1	>0.9	>0.9	>0.9	>0.9	>0.9
Values for structural model	37.25	17	2.21	0.07	0.03	0.96	0.98	0.97	0.92	0.98

Source: authors´ own

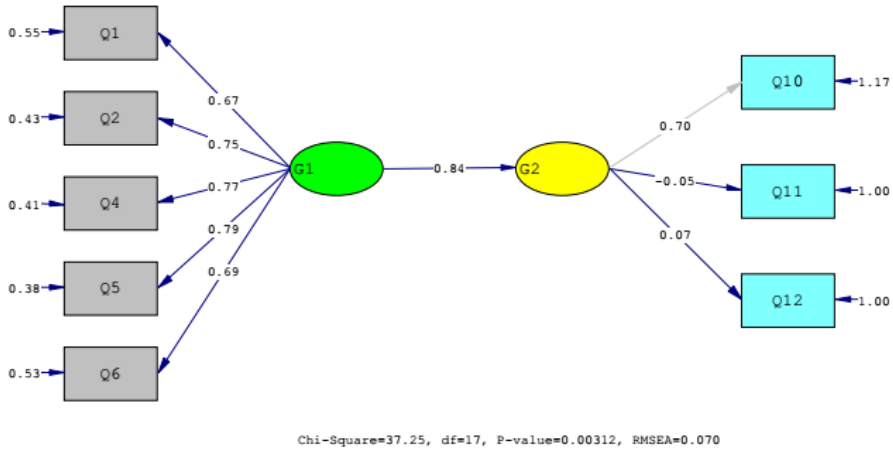

Figure 3
Final model describing correlations between two tested groups of questions based on standardized solution for the structural model (source: authors´ own)

The tested structural model presented in Figure 3 indicates that hypothesis 1 is confirmed since path analysis resulted with the β coefficient value 0.84 while t-test is 9.27 and it is statistically significant ($p<0.05$). The test is positive despite detecting a negative average covariance among answers in the second group as mentioned above. This inconsistency occurred especially in case of respondents with a low level of environmental system management and therefore it did not influenced the structural model at all.

It means that the higher level of environmental system management leads to the more serious approach of the company to the environmental aspects through the whole product life cycle.

4.2 Evaluation of the Second Hypothesis

Hypothesis H2 focuses on the management of environmental risks through the whole product life cycle. It assumes that companies considering environmental risks through the whole product life cycle have implemented a complex methodology for determining and measuring of environmental risks for all stages of product life

cycle. Regarding the fact that this hypothesis examines connection between two single questions (Q8 and Q9), it was evaluated by Pearson correlation analysis and parametric paired sample Student's T-test.

The following correlation matrix (Table 3) proves that there is a statistically significant relationship between our two considered questions Q8 and Q9 (2-tailed significance < 0.01 and Pearson correlation r = 0.213).

Table 3
Pearson Correlation for hypothesis H2

	Q8	**Q9**
Q8	1	
Q9	0.213**	1

Correlation significance: *p<0.05, **p<0.01
Source: authors´ own

Also the Student's T-test proved the relationship between both tested questions on the confidence level of 95%. However, regarding the fact that the average difference between both variables is 0.551 and the t-value is quite low (t = 16.567), we cannot state that there is a positive correlation between considered questions with adequate statistical significance.

While interviewed companies consider environmental risks in relation to the product life cycle, just the minority of them is establishing a complex methodology for determining and measuring of environmental risks for all stages of product life cycle. Such kind of a methodology is a voluntary activity of an organization which is not ordered by any norm or regulation. Therefore, hypothesis H2 was not unambiguously proven.

Conclusions

Business behavior is determined by global trends, which include, environmental aspects focusing on improving environmental sustainability, higher usage of renewable resources, clean production and protecting nature and all natural resources. Companies are very often forced to prove compliance to legislative requirements, usually EN ISO 14001. This norm leads to manage environmental aspects and risk through the whole product life cycle including design and development, purchasing logistics, manufacturing process, sales and reverse logistics and re-using of materials.

The main goal of presented study, was to examine what level of environmental system is currently used by large and medium-sized Czech manufacturing companies, how it affects the approach of the company to the environmental aspects through the whole product life cycle and what are the main barriers influencing the management and measuring of environmental risks in individual phases of product life cycle. Our results showed that environmental issues are highly influenced by the legislation and other regulations or system norms across the whole business

environment. Nevertheless, a significant player in the strategic direction of the companies within the supply chain is the customer - an external stakeholder. When evaluating the second hypothesis, we identified customer as the most crucial barrier affecting the management of environmental risks within the whole product life cycle.

Another observed phenomenon resulting from the absence of environmental strategy is the fact that some companies just try to keep minimal required compliance with relevant norms, regulation or legislation but they do not care about management of environmental aspects and risks during all phases of product life cycle in depth. Therefore, in our future research we will focusing on development of the complex framework. for better transferring requirements of EN ISO 14001 or EMAS into the individual phases of product life cycle including all relevant environmental aspects and risks. Another potential for further research is the focus on a comparative study in other countries, which are actively involved within the corporate sector, in environmental activities according to existing statistics.

Acknowledgement

The authors are thankful for the financial support received from the project Development of complexly methodology of process planning, management and organization by implementation and utilization of INDUSTRY 4.0 concept in SMEs (VaV-IP-RO/2018/03) at the Tomas Bata University in Zlín. This work was also supported by the internal grant project IGA/FaME/2017/016 - Environmental and energy risk management in relation to the triple bottom line concept within selected industrial sector in the Czech Republic and the SHAPE ENERGY project founded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 731264.

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