Management and Production Engineering Review
Volume 13 • Number 3 • September 2022 • pp. 118–126
DOI: 10.24425/mper.2022.142389

Achieving Sustainable Manufacturing and Green Organizations: Preliminary Research on Green Competencies

Magdalena GRACZYK-KUCHARSKA

Institute of Safety and Quality Engineering, Department of Marketing and Organization Development, Poznań University of Technology, Poland

Received: 13 June 2022
Accepted: 19 July 2022

Abstract
Sustainability manufacturing is crucial in many aspects in terms of environmental impact. It concerns the consumption of energy, raw materials and materials, as well as the emission of harmful substances and waste. The implementation of sustainability manufacturing requires many actions at various levels, including strategic, tactical and operational ones. In order to implement measures aimed at minimizing the negative impact of the company on the environment, employees' competencies are needed. The article presents preliminary research on key green competencies for sustainability companies. The research was carried out in the form of individual interviews with medium and large production companies. The result of the research is the division of competencies (knowledge, skills and attitudes) into three stages of the organization's development, indicating the key competencies for each stage of the development of sustainability management.

Keywords
sustainability, sustainability manufacturing, green competencies, interoperability and sustainable enterprise, green organization, management.

Introduction

In recent years, automation of production processes has contributed to resource-efficient manufacturing (Mohanty and Jagtap, 2020) and minimization of negative environmental impacts (Góralski et al., 2020). By increasing the precision of operational activities, it is possible to effectively reduce the amount of energy needed to produce a unit product, the amount of production waste, or the number of required material resources such as raw materials or intermediate products, including water and rare metals (Mohanty and Jagtap, 2020).

Manufacturing companies face the challenge of generating a high return on investment while taking into account legal aspects, including those relating to sustainability and minimising negative environmental impacts.

Shaping a sustainable industrial ecosystem and production in a circular economy, as well as improving the capacity of the industrial sector for sustainable and resource-efficient production (Machado et al., 2019) requires more than just orienting activities in line with legal requirements. It also requires the appropriate formation of competencies, understood as knowledge, skills and attitudes, for the accelerated implementation of processes related to sustainable development and minimising negative environmental impacts. To do this, it is important to define key competencies to accelerate the development of sustainable manufacturing in companies (Norström et al., 2020).

Sustainable manufacturing (SM) is one of the key strategic challenges for companies (Tseng et al., 2021, Enyoghasi & Badurdeen, 2021). SM can be defined as "the integration of processes and systems capable to producing high-quality products and services using less and more sustainable resources (energy and materials), being safer for employees, customers and surrounding communities, and being able to mitigate environmental and social impacts throughout its entire life cycle" (Machado et al., 2019). Although there are publications addressing aspects of SM in the context of Industry 4.0 (Beltrami et al., 2021) also in relation to government programes e.g. "A more sustainable manufacturing in the UK" (Manufacturing Commission, 2015), "FoF 2020 Roadmap" (EFFRA,

***Corresponding author**: M. Graczyk-Kucharska – Institute of Safety and Quality Engineering, Department of Marketing and Organization Development, Poznań University of Technology, ul. Jacka Rychlewskiego 2, 62-095 Poznań, Poland, phone: +48 61 665 34 03, e-mail: magdalena.graczyk-kucharska@put.poznan.pl*

2016), "Sustainable Production for Smart Factories" (Ministry of Enterprise and Innovation, 2016), the directions of SM development are still not being linked with the necessary competence resources, such green competencies (GC) especially. GCs can be understood as "the requisite ecological knowledge, skills and other socio-economic behaviour an individual has to help him/her behave and act rightly and responsibly towards the overall well-being of his/her immediate environment" (Subramanian et al., 2016).

This paper aims to match GCs, as defined on the basis of the literature, with the development phases of green organizations (GO) that are engaged in production for supporting SM. To this end, the following research questions have been defined:

- RQ1: What areas of operations of manufacturing companies are related to green activities?
- RQ2: What are GCs and how to define them in the context of SM?
- RQ3: How to define the development phases of green organizations?
- RQ4: What competencies are key in the different phases of GO development?

The paper is organized as follows: section two presents a review of SM, GO, GCs, and how these three concepts are linked. This chapter concludes with a summary of how variables were selected for the qualitative preliminary research carried out on ten medium and large manufacturing companies. The following chapter describes the selection of the research sample and analyses the results of the qualitative research. The following part is a discussion of the results in the context of the research questions. The final section discusses the conclusions, contributions, and implications for further research.

Literature review

The concept of sustainable development began to be addressed in the literature in the 1980s, in particular after the publication of the Brundtland Commission's report on the global environment and development in 1987. Brundtland (1987) defined sustainable development as "meeting the needs of the present generations to meet their own needs". Just a few years later, it was pointed out that the issue of sustainable development is closely linked to the depletion and degradation of natural capital resources. The rationale behind implemented projects, especially commercial and business ones, should take into account not only economic efficiency and net benefits. They should be undertaken under the condition that environmental damage (i.e. depreciation of environmental capital) is negative or zero (Barbier, et al., 1990).

In relation to manufacturing companies, the literature most often highlights issues related to materials, energy and waste management (Smith & Ball, 2012; Mueller et al., 2013). It is a typical factual approach. In a broader context, an organization means not only the material and technological equipment, but also the people, specified goals, and the structure of the organization (Gitling, 2013).

Sustainable manufacturing

Sustainable production was introduced at the 1992 UNCED conference in Rio de Janeiro as a guide to help companies and governments transition towards sustainable development. There are several definitions related to SM. For instance, SM is defined by the U.S. Department of Commerce as "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound" (Rosen and Kishawy, 2012). SM is characterised by the integration of processes and systems that can produce high-quality products and services using fewer and more sustainable resources (energy and materials) that are safer for the employees, customers and surrounding communities and can mitigate environmental and social impacts throughout the product life cycle (Mohanty and Jagtap, 2020).

Nowadays, the concept of SM is supported by advanced methods and tools in the field of Industry 4.0 including technology areas such as the Internet of Things, Big Data Analytics, Cloud Computing, Simulation and Prototyping, 3D Printing, Augmented Reality or Robotic Systems. Linked to these are outcome areas related to aspects of economics, the automation process, or environmental protection (Kamble et al., 2018). Important directions for further research include sustainable Industry 4.0 and related issues such as solutions that support customer services, supply chain optimisation, and the facilitation of sustainable practices of remanufacturing and recycling.

Waste management is also an important element in managing production processes, having been analyzed in the literature in relation to the circular economy (Blunck and Werthmann, 2017), lean manufacturing (Sanders et al., 2016) or examining impacts on environmental management (Carvalho et al., 2020).

In the context of SM, a broader, more comprehensive and integrated approach is needed in the spirit of the Tripple Bottom Line (Ahmad et al., 2018), covering economic, social and environmental issues, among other things (Rosen & Kishawy, 2012).

Green organizations

An organization is comprised of sets of elements that are separated from their environment, internally ordered and interrelated and oriented towards achieving a specific objective. GOs are thought to be those in which production, organizational, and marketing processes are carried out in line with the principles of sustainable development, using environmentally friendly technologies, waste reduction, energy efficiency, and sustainable resource management based on social, natural, and economic pillars.

In the literature, a growing number of authors have been conducting sustainability-focused research in organization. In addition to the previously explained concept of SM, research relating specifically to manufacturing companies focuses on:

1. *Closed-loop waste management is* understood as the realization of a closed-loop material cycle throughout the economic system, as well as the optimization of resource consumption (Alhawari et al., 2021) and the ecological design of the resource management system.
2. *Green Human Resource Management* (GHRM) means policies, practices and systems that help organization employees plan and implement green processes for the benefit of the individual, society, the environment and the business. These include three categories: green skills, including green recruitment and selection, green motivation, including green performance management, and green possibilities, including opportunities consisting of green employee engagement and a green culture (Cabral & Dhar, 2020).
3. *Improving employees' knowledge and awareness of ecology and sustainability* as part of training, green skills education and green GHRM motivation.
4. *Environmental management* is based on the organizational implementation of an environmental management system, i.e. the identification of the environmental aspects of activities and the development, implementation and maintenance of the company's environmental policy (Bąk, 2021, p. 10).
5. *Minimizing the use of resources*, including energy, is understood as improving the capacity of the industrial sector to manufacture in a sustainable and resource-efficient way. The concept is linked to SM (Machado et al., 2020).
6. *Green (sustainable) marketing*, which assumes that all activities to prepare, produce, promote and sell a good and maintain contact with the customer should combine the aspect of profitability and competitiveness of the company with social and ecological usefulness to improve the quality of life (Brzustewicz, 2014; Dangelico & Vocalelli, 2017).
7. *Green construction of products*, i.e., the correct choice of raw materials and intermediate products and a way of combining different materials in a disjointed manner to enable the reuse of as many product components as possible (Geda, 2020).
8. *Green Supply Chains* broadly defined as, e.g., environmental management in the supply chain, green purchasing and procurement, green logistics, reverse logistics and environmental logistics and sustainable supply network management (Tseng et al., 2019).
9. *Zero waste buildings* in which production is carried out are buildings with very high energy performance where the primary energy consumption rate expressed in kWh/m^2 is important. They are characterised by almost zero or very low amounts of required energy which should largely come from renewable energy sources, including sources of renewable energy generated on-site or nearby (Soharu et. al., 2022).

The above categories of activities help answer RQ1: What areas of manufacturing company operations are related to green activities? In each of these categories, there are important competencies that will help develop green organizations faster and more effectively, thus reducing the environmental impact and improving the quality of life of people.

Green competencies

The concept of green competencies (GC) can be understood as the knowledge, skills and attitudes that make it possible to achieve the mission of minimising negative impacts on the environment and initiating and implementing actions in line with the principles of sustainable development. The literature uses various keywords related to competencies and sustainability, such as GCs (Cabral and Dhar 2020), green skills (Vona et al., 2015) or sustainability competencies, understood as competencies in the area of sustainable development (Wiek et al., 2015).

Among the relevant studies in the area of GCs, one must mention Pedersen (1999), who conducted a factor analysis and identified six dimensions related to GCs. These six dimensions are conscientious, resource conservation, outdoor skills, practical skills, knowledge and wayfinding. Corral-Verdugo (2002), in his work on environmental psychology, proposed GC as a higher-order factor that encompasses dispositional variables such as attitudes, motives and perception. In contrast, Subramanian et al. (2016) categorized GCs into natural and acquired.

A brief review of the literature devoted to GCs helps answer RQ2: What are green competencies and how to define them in the context of SM?

It should be important to diagnose the GCs needed to achieve faster and more efficient organizational goals, especially in terms of SM. It is manufacturing companies that face the most challenges when it comes to managing waste, energy, and materials in accordance with the Tripple-Bottom Line.

Methodology

The graphic scheme of the research methodology consists of several steps, as shown in Figure 1.

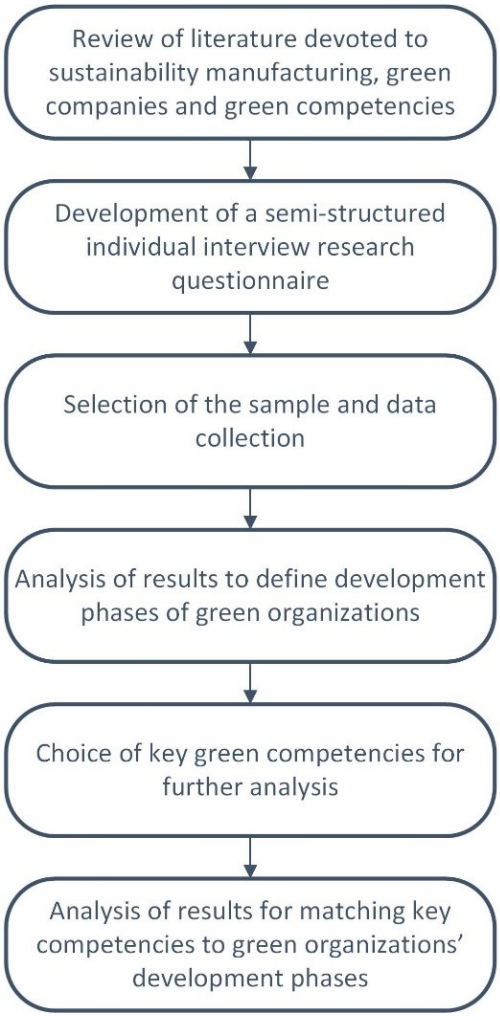

Fig. 1. Graphic scheme of research methodology

After a thorough review of the literature, two key questions were developed. The first one covered 10 areas that, for manufacturing companies, are described in the literature in relation to sustainability issues and were characterised in the previous chapter. Among them, the respondents assessed their knowledge of the following concepts: SM, GHRM, knowledge and awareness of ecology and sustainable development, environmental management, minimising the consumption of resources, including energy, green marketing, ecological product design, green supply chains, closed-loop waste management, zero waste buildings. Then, where the respondent had encountered the concept and knew or heard of it, they assessed the extent to which each category was satisfied now, that is, in 2022 and in 2017. The question was asked in one questionnaire in a study conducted in 2022. The survey used a scale from 0 to 5 where 0 meant that the category was not at all important, 1 meant that it was important to a very small extent, 2 to a small extent, 3 on average, 4 to a large extent and 5 to a very large extent.

The second group of key questions related to GCs. GCs were divided into four component groups: knowledge (K – 34 components), skills (S – 37 components), attitudes (A – 34 components) and performance-related managerial skills (MS – 33 components). The respondents made assessments similar to those for key areas related to green activities in the company but in relation to the relevance of GCs in the enterprise. It is worth mentioning that due to the large number of GCs, the paper discusses only hard competencies associated with the different development phases of green organizations. Social competencies, which the respondents mentioned most frequently as equally important for each phase for both 2022 and 2017, were omitted.

Research was conducted to identify the development phases of GO and the key competencies required. Individual semistructured interviews were conducted with representatives of 10 medium and large manufacturing enterprises located in Wielkopolska and often based on foreign capital. Participants in the survey included company representatives who held the positions of HR Manager, HR Country Manager, Sales Director, HR Administration Assistant, Owner, Senior Business HR Partner, Senior HR Specialist, HR & Personnel Development Leader, and HR & Employer Brand Manager. The data was collected between 31 March and 15 April 2022. It is worth noting that the results were presented based on 10 manufacturing companies. Therefore, statistical analyses based on such a small sample were not possible. Tables (2-4) present preliminary studies and the assumptions for the phases for GCs and GO differ. The division is due to the differing results in the GO and GC category groups.

Results

Green organizations

The division into GCs assigned to the different development phases of GO was based on:

- assessment of the importance of a given competence (satisfaction) – only competencies chosen as important (respondent assessment 4 and 5) were selected for the analyzes,
- averaged difference between the assessment of requirements in 2022 vs. 2017 (AD) – only assessments complying with the above criteria were included,
- the percentage of respondents who know and understand the assessed competence (knowledge – K) and the degree of their satisfaction in the surveyed company is at the level of 4 or 5: 40–60% is phase 1; 10–30% – phase 2; less than 10% – phase 3.

The results of the GO assessment categories and their development phases are presented in Table 1.

Table 1
GO assessment categories

GO Phase	Phase 1 of green organizations' development		
	GO assessment categories	K	AD
1	Environmental management	60%	1.22
1	Minimising the use of resources, including energy	60%	1.33
1	Closed-loop waste management	40%	1.30
2	Sustainable manufacturing	30%	1.00
2	Knowledge and awareness of ecology and sustainability	30%	1.10
2	Environmentally friendly product design	10%	0.83
2	Green supply chains	10%	0.63
2	Zero waste buildings	10%	1.00
3	Green Human Resources Management	0%	1.00
3	Green marketing	0%	0.63

The analysis shows that SM is in phase 2 of GO development. The biggest changes between 2017 and 2022 were seen in companies in relation to minimizing resource consumption, including energy and closed-loop waste management.

Green competencies

The division into GCs assigned to the different development phases of GOs was based on:

- assessment of the importance of a given competence (importance) – competencies chosen as important (respondent assessment 4 and 5) were selected for the analyses,
- averaged difference between the assessment of requirements in 2022 vs 2017 (AD) – only assessments complying with the above criteria were included,
- the percentage of respondents who know and understand the assessed competence (knowledge – K) and importance was rated at a minimum of 4 – scale: 100% is phase 1; 80 – 90% – phase 2; less than 80% – phase 3.

High requirements in relation to GC knowledge indicate an important area, which is environmental management in enterprises. It can be concluded that knowledge in the area of broadly understood sustainable development is crucial for initiating and managing change in the area of minimizing the negative impact on the environment. The results for phase 1 GOs are summarized in Table 2.

Table 2
GCs relevant for phase 1 in the development of GO

Code	Phase 1 of green organizations' development		
	Name of competence	K	AD
K7	Environmental knowledge	100%	1.43
K12	Supply chain knowledge	100%	1.67
K17	Human rights knowledge	100%	1.50
K18	Administration knowledge	100%	1.25
K32	Knowledge on how to reduce energy and resource consumption, the greenhouse effect, waste, and pollution and how to conserve and protect nature	100%	1.56
K33	Knowledge of recycling centres, renewable energy sources, used spaces, and access to sustainable services	100%	1.63
S1	Air pollution preventing skills	100%	1.43
S24	Project planning skills	100%	2.40
S26	SWOT analysis skills	100%	2.00
S27	Skills in green product development, including product development and product life cycle based on recycling, reuse and eco-design	100%	1.50
S29	Skills required for recycling and waste management	100%	1.50
S35	Leadership skills	100%	2.17
A9	Local and global responsibility	100%	1.71
A15	Attitude supporting lifelong learning	100%	1.50
A25	Process-oriented focus	100%	1.20
A28	Awareness of sustainable development, especially in environmental, social and economic terms	100%	1.50
A30	Attitudes oriented towards environmental education and education for sustainable development	100%	1.63

Table 2 [cont.]

Code	Phase 1 of green organizations' development		
	Name of competence	K	AD
A32	Attitude supported by a sense of responsibility for environmental issues, respect for nature and society and evaluation of socio-environmental conflicts	100%	1.57
A33	Preventive actions taken to protect and preserve the environment	100%	1.89
A34	Positive attitude towards the production of green products, labeling of products as environmentally safe, recycling, and recovery of packaging, and development of products that cause least environmental damage	100%	1.67
MS4	Ensuring effective communication	100%	1.71
MS5	Creating an environment of acceptance, fairness and mutual respect	100%	2.14
MS6	Transport planning	100%	1.43
MS11	Project management and prioritisation	100%	1.50
MS16	Ability to analyse data, evaluate results and recommend actions	100%	1.71
MS20	Measuring progress with indicators	100%	2.00
MS23	Waste elimination	100%	1.67
MS24	Environmental policy and planning	100%	1.56
MS27	Energy saving in transport	100%	1.86

The competency requirements for the second phase of the development of GO are presented in Table 3.

Table 3
GCs relevant for phase 2 in the development of GO

Code	Phase 2 of green organizations' development		
	Name of competence	K	AD
K3	Knowledge of the business model area	80%	1.50
K6	Knowledge in the area of economics	90%	1.13
K10	Knowledge in the area of Gross National Product	80%	1.50
K11	Knowledge in the area of social responsibility	90%	1.75
K15	Knowledge in the area of globalisation	90%	1.29
K16	Knowledge in the area of Gross Domestic Product	80%	1.25
K27	Knowledge in the area of urban planning	80%	1.50
K29	Knowledge in the area of social justice	90%	2.00
K31	Knowledge relating to environmental practices, in particular compliance with laws, rules of order and safety regulations	90%	1.56
S2	Ability to analyse environmental problems	80%	1.60

Table 3 [cont.]

Code	Phase 2 of green organizations' development		
	Name of competence	K	AD
S4	Socially responsible investment skills	90%	1.43
S5	Systemic thinking skills	90%	1.43
S6	Business case skills	90%	1.43
S7	Full cost accounting skills	80%	1.50
S10	Life cycle analysis skills	80%	1.33
S14	Indicating and indexing skills	80%	1.33
S15	Nature-conservation-based development skills	80%	1.57
S17	Resource-based community development skills	80%	1.83
S22	Negotiation and conflict management skills	90%	1.50
S32	Natural resource reuse and recycling skills	90%	1.33
S37	Sustainable development planning skills	80%	2.17
A27	Green awareness as personal awareness, curiosity and environmental skills	90%	1.44
A29	Perceiving, feeling and being aware of the environment and its problems	90%	1.57
A31	Attitude oriented toward the world view and concern for the environment and a commitment to solving environmental problems	90%	1.63
MS2	Experience in developing and presenting sustainable business concepts, training and new technologies	80%	2.14
MS7	Management based on environmental health and quality improvement	90%	1.33
MS9	Resource-conservation-based management	80%	1.71
MS14	Development of new initiatives that promote the sustainability of the organization or community	80%	2.17
MS26	Decision-making in the area of environmentally sound purchasing and supply chain management	90%	1.63
MS32	Helping departments develop indicators specific to their areas of work	80%	1.83

The results for the final third phase of GO development are presented in Table 4.

The following table (Table 5) summarises the number of competence components by categories assigned to the different phases of GO development.

It can be concluded from Table 5 that pro-environmental attitudes, increasing employee awareness, and managerial competence to manage work in the area of SM and other activities related to GO dominate in the first phase of the development of GO.

Table 4
GCs relevant for phase 3 in the development of GO

Code	Phase 3 of green organizations' development		
	Name of competence	K	AD
K1	Knowledge of the search for niches	50%	1.50
K4	Knowledge of the carbon footprint	60%	1.43
K5	Knowledge of ecological integrity	40%	1.29
K9	Knowledge of the Environmental Management System	70%	1.67
K26	Knowledge of the natural capital	70%	1.50
K30	Knowledge that integrates natural and social science disciplines to focus on aspects that reduce energy consumption, reduce environmental waste and protect ecosystems	60%	1.50
K34	Knowledge of the chain value	40%	0.83
S8	Ability to put the 4 Ps of marketing (product, price, place, promotion) into practice	30%	1.67
A2	Change agent attitude	60%	2.00
MS3	Knowledge of new sustainable business strategies	40%	2.00
MS10	Facilitation, change management and group process skills	60%	1.38
MS12	Creation and management of social partnerships	60%	1.50
MS13	Identifying sources of funding for social and sustainable development projects	60%	1.38
MS15	Understanding the meaning, process of defining and usefulness of sustainability indicators	40%	2.00
MS17	Understanding the basic principles that govern natural systems	60%	1.57
MS18	Recognising cultural, economic and political forces that influence environmental attitudes and decision-making based on an understanding of science and technology	70%	1.83
MS19	Possibility of supporting the Marshal's strategic activities in the region	40%	2.25
MS21	Life-cycle assessment	60%	1.43
MS22	Resource inventorying	70%	1.67
MS29	Ability to work with teams to evaluate decisions based on financial and sustainability goals	70%	1.38
MS33	Understanding the basic principles that govern natural systems	70%	1.71

The development of GO in phase two requires all the competencies of phase one and, in addition, the knowledge and skills of the employees in the area of indexing and indicating sustainability-related activities are key.

Phase three comprises all the key components of GCs. The most important ones that support the growth of green organizations at this stage are those linked to managerial knowledge and competencies.

Table 5
Numerical distribution of the different GC categories in the GO phases

Item	Number of competence components in GO phases					
	GO Phase	K	S	A	MS	Total
1	GO Phase 1	6	6	8	9	29
2	GO Phase 2	9	12	3	6	30
3	GO Phase 3	7	1	1	12	21

Discussion

The analysis of GO categories shows that the key areas that have gained change momentum in manufacturing companies especially include activities related to minimising resource consumption, as well as the closed-loop and circular economy. This trend is consistent with early work and issues addressed in the field of SM (Rosen & Kishawy, 2012; Blunck & Werthmann, 2017). GHRM and green marketing, on the other hand, are concepts that are not known in companies and their rate of change in recent years has been average, although important in terms of employee competence resources and research and development, also in relation to green products (Romani et al., 2021).

Average changes occurred in the areas of knowledge and awareness of ecology and sustainability, SM, zero-waste buildings and GHRM. It can be assumed that knowledge and awareness of ecology and sustainability is a kind of catalyst that drives phase 2 GO development and, at the same time, a transitional phase between phases 1 and 2.

In addition to analyzes of the respondents' familiarity with the studied concepts, the preliminary research results can also be analyzed based on the difference in importance or relevance of a given component between 2022 and 2017. As GOs develop, GCs with an increment of more than 1.7 points between the years may be key. If the concept is not understood, e.g. due to the high specialisation of the issue, these important components of competence could be omitted.

Taking into account the maximum variation of competence requirements, the following can be distinguished:

- Phase 1 GO: creating an environment of acceptance, fairness and mutual respect; measuring progress with indicators; energy savings in trans-

port; effective communication, ability to analyse, evaluate results and recommend actions;
- Phase 2 GO: development of new initiatives that promote the sustainability of the organization or community; experience in developing and presenting sustainable business concepts, training and new technologies; helping departments develop indicators specific to their areas of work; conservation of resources;
- Phase 3 GO: the possibility of supporting the Marshal's activities; knowledge of new sustainable business strategies; understanding the meaning, process of defining and usefulness of sustainability indicators; recognising cultural, economic and political forces that influence environmental attitudes and decision-making based on an understanding of science and technology; understanding of the basic principles that govern natural systems.

Conclusions and future work

It is clear from the reviewed literature that there is a lack of research relating simultaneously to GO and GC. Individual issues are addressed, e.g., in relation to SM, circular economy and other sustainability areas, but they are not linked to either the phases of development of GOs or GCs.

The results discussed in this document are based on individual interviews and the presentation of the division of organizational development into phases was mainly based on knowledge or unfamiliarity with GO concepts and the relevance or degree of satisfaction.

The nomenclature used for relevance and degree of satisfaction is an issue worth noting in further research. In the research on the GO category, the questionnaire indicated the degree of satisfaction of this category in the company. In the case of GCs, the relevance of these competencies in manufacturing companies was examined. In further quantitative studies, it is suggested to standardise the categories studied for a better and possible comparison of the affiliation of GCs with GOs.

It is also necessary to continue with quantitative research that will allow a more accurate analysis of GO development phases and the key GCs that are suitable for them.

Acknowledgments

The research was funded by the National Science Centre 2021/05/X/HS4/00974.

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