THESIS OF THE DOCTORAL (PhD) DISSERTATION

ANALYSIS OF THE SUSTAINABLE PURCHASING MANAGEMENT OF MANUFACTURING ENTERPRISES IN HAJDÚ-BIHAR AND SZABOLCS-SZATMÁR-BEREG COUNTY AND STUDY OF THEIR POSSIBILITIES FOR DEVELEOPMENT

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TABLE OF CONTENTS

1. INTRODUCTION, RESEARCH OBJECTIVES AND HYPOTHESES

Over the past decade, as demand has increased and supply chain management has evolved, driven by increased competition between businesses and in response to changes in the global economy. Simultaneously, environmental protection and sustainability are concerns increasing in significance and affecting business operations. In an accelerating world, new technologies are emerging day by day as a result of continuous improvements. However, the appropriate application of these technologies is not enough to remain competitive, as companies need to respond to other changes in the economy at the same time. Morever, there is growing social pressure in the context of environmental influences. My research aim is to present the changes affecting the purchasing practices of the manufacturing companies of the Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties in the Northern Great Plain Region. I examined the development trends in purchasing including, sustainable and green purchasing.

Questions to be answered during the research:

K1.: To investigate how the identification of green supplier performance factors works in managing relationships with suppliers in the surveyed enterprises.

> K1.1.: To conduct a comprehensive review of the national and international literature on the green supply chain. Based on the literature, I introduced a specific concept for green purchasing management.

K2.: The question is whether, a model can be created to examine the proposed green supplier rating factors which illustrate the context of supplier selection.

K3.: To examine how the model can be validated in the examined production enterprises.

> K3.1.: To evaluate the enterprises' suppliers focusing on environmental aspects.
>
> K3.2.: To determine the importance of environmental factors in the manufacturing enterprises using the analytical hierarchy process (hereinafter: AHP).
>
> K3.3.: To explore the industry specifics of the manufacturing sector using the AHP.

2. MATERIAL AND METHODS

In the preparation of my doctoral dissertation, I applied both primary and secondary research methods. After formulating my research topic and research questions, during the literature review, I analysed different environmental theories (e.g.: sustainability, circular economy) and explained the application of these environmental aspects in business practice. Morever, I examined the criteria and selection models of green supplier selection. At the beginning of my work, I became familiar with domestic and international specialized literature, articles and research on the topic during my secondary data and information gathering work. The various search engine databases (e.g.: Google Scientist, Science Direct, Elsevier, Ebscohost, UDiscover) were helpful in the collection of the literature. The basis of my search was mainly the results of secondary international research. I based my primary research on the data of the Central Statistical Office and the Education Management Information System (hereinafter: EMIS). My goal was to supplement and substantiate the secondary data with domestic primary research. As a result of my previous primary research work (case studies, articles), I developed my research model and found the applied methodology. During my qualitative research, I focused on the examination of the existence of a green purchasing chain for the examined companies, especially on the importance of the environmental factors of supplier selection. In calculating my results, I used the AHP-OS online software to evaluate the pairwise comparison matrixes, and used the Microsoft Excel program for further calculations. Furthermore, I formulated it as a research objective to establish a model which illustrates the context of purchasing management, taking into account the specific characteristics of the manufacturing sectors. In my opinion, the selection model can be of help to the manufacturing companies under investigation opportunities to improve their green purchasing process and increase its efficiency.

2.1. Collection of data and its evaluation system

The basis of my research was Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties, within the Northern Great Plain region. The main aim of my dissertation is to carry out supplier evaluation using the analytical hierarchical methods and to analyse sectors according to their industry specifics and to make proposals for future improvement. To compare companies and their suppliers, I had a large amount of data that had to be narrowed primarily (primary reduction criteria: NACE (Uniform Sectoral Classification of Economic Activities), size category, and sales). The data obtained will be quantitative and qualitative and will be collected from external as well as internal sources. During the research, I identified which companies should serve as the subjects of my research and created database accordingly. The Hungarian Small and Medium-sized Enterprises and Supporting their Development Act XXXIV of 2004 (hereinafter: SME Act) includes (*Table 1*) the value limits, headcount numbers and other criteria that can be used to decide which size category a company can be classified into.

Table 1: Classification of companies under the SME Act

SME classification	**Headcount numbers (capita)**	**and**	**Annual net income (Euro)**	**or**	**Balance sheet total (Euro)**
Medium-sized enterprise	< 250	**and**	≤ 50.000.000	**or**	≤ 43.000.000
Small-sized enterprise	< 50	**and**	≤ 10.000.000	**or**	≤ 10.000.000
Micro enterprise	< 10	**and**	≤ 2.000.000	**or**	≤ 2.000.000

Source: SME Act, 2004

Micro and small-sized enterprises were not included in the scope of my study, as my primary assumption is that enterprises (including supplier selection) will continue to operate as part of an entity within a separate organization (I assumed that it is possible over a given number of employees and, in cases of micro and small enterprises, this is irrelevant). Thus, minimally medium-sized or larger manufacturing enterprises operating in Hungary were the main target group of my investigation. Its compilation is shown in *Table 2* below, which is a compilation of the county National and Tax Office (hereinafter: NTCA) and the Hungarian Central Statistical Office (hereinafter: HCSO) annual top 100 largest enterprises.

Table 2: County composition of manufacturing enterprises (2017, 2019)

Hajdú-Bihar county	EMIS total county NACE'08 C section manufacturing enterprises (2019)	326 pcs
	Top 100 largest county enterprises according to 2016 net income (HCSO and NTCA) NACE’08 C section-manufacturing enterprises (2017)	33 pcs
	EMIS =/+50 number of employees, =/+10 million EUR operating income and sales net NACE’08 C section-manufacturing enterprises (2019)	74 pcs

Szabolcs-Szatmár-Bereg county	EMIS total county NACE’08 C section- manufacturing enterprises (2019)	303 pcs
	Top 100 largest county enterprises according to 2016 net income (HCSO and NTCA) NACE’08 C section-manufacturing enterprises (2017)	37 pcs
	EMIS =/+50 number of employees, =/+10 million EUR operating income and sales net NACE’08 C section-manufacturing enterprises (2019)	75 pcs

Source: Own editing, 2020

The final actors of the research are profit-oriented enterprises of the EMIS system =/+ 50 number of employees, =/+ 10 million EUR operating income and sales net, the NACE'08 C sector in the manufacturing industry operating in Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties (*Table 3*).

Table 3: Content of the actual and investigated manufacturing enterprises (2019)

NACE’08 C manufacturing sector (10.-33.)	**Hajdú-Bihar county**		**Szabolcs-Szatmár-Bereg county**	
	Actual piece (N=74 pcs)	***Investigated piece (N=37 pcs)***	**Actual piece (N=75 pcs)**	***Investigated piece (N=30 pcs)***
10. Manufacture of food products	19 pcs	*9 pcs*	19 pcs	*9 pcs*
11. Manufacture of beverages	0 pcs	*0 pcs*	2 pcs	*0 pcs*
12. Manufacture of tobacco products	1 pcs	*1 pcs*	0 pcs	*0 pcs*
13. Manufacture of textiles	0 pcs	*0 pcs*	0 pcs	*0 pcs*
14. Manufacture of apparel	3 pcs	*1 pcs*	0 pcs	*0 pcs*
15. Manufacture of leather and related products	0 pcs	*0 pcs*	5 pcs	*3 pcs*
16. Manufacture of wood and of products made of wood and cork, (except furniture) manufacture	1 pcs	*0 pcs*	5 pcs	*3 pcs*
17. Manufacture of paper and paperboard	3 pcs	*2 pcs*	1 pcs	*0 pcs*
18. Printing and reproduction of recorded media	2 pcs	*1 pcs*	1 pcs	*1 pcs*
19. Manufacture of coke and refined petroleum products	0 pcs	*0 pcs*	0 pcs	*0 pcs*
20. Manufacture of chemicals and chemicals products	0 pcs	*0 pcs*	3 pcs	*0 pcs*
21. Manufacture of basic pharmaceutical products and pharmaceutical preparations	2 pcs	*2 pcs*	2 pcs	*1 pcs*

22. Manufacture of rubber and plastic products	8 pcs	*4 pcs*	7 pcs	*2 pcs*
23. Manufacture of other non-metallic mineral products	0 pcs	*0 pcs*	1 pcs	*0 pcs*
24. Manufacture of basic metals	2 pcs	*1 pcs*	1 pcs	*0 pcs*
25. Manufacture of structural metal products	15 pcs	*7 pcs*	13 pcs	*5 pcs*
26. Manufacture of computer, electronic and optical products	1 pcs	*1 pcs*	5 pcs	*3 pcs*
27. Manufacture of electrical equipment	2 pcs	*2 pcs*	0 pcs	*0 pcs*
28. Manufacture of machinery and equipment n.e.c.	8 pcs	*3 pcs*	1 pcs	*0 pcs*
29. Manufacture of motor vehicles, trailers and semi-trailers	1 pcs	*0 pcs*	4 pcs	*0 pcs*
30. Manufacture of other transport equipment	2 pcs	*0 pcs*	1 pcs	*1 pcs*
31. Manufacture of furniture	0 pcs	*0 pcs*	1 pcs	*0 pcs*
32. Other manufacturing	3 pcs	*2 pcs*	2 pcs	*1 pcs*
33. Repair and installation of machinery and equipment	1 pcs	*1 pcs*	1 pcs	*1 pcs*
Total:	**74 pcs**	***37 pcs***	**75 pcs**	***30 pcs***

Source: Own editing, 2020

2.2. Description of used methods

2.2.1. Systematic literature review

"A literature review is a systematic, explicit and reproducible designs for identifying, evaluating and interpreting the existing body of recorded documents" (FINK, 1998). A process model for content analysis MAYRING (2003) comprises the following steps:

- Material collection: the material to be collected is defined and delimitated and the unit of analysis defined.
- Descriptive analysis: in which the collected research should be evaluated.
- Category selection: which requires categories to be analysed for the data collected (e.g.: the single year across a time-period).
- Material evaluation, in which relevant articles for answering research questions should be analysed by category.

The systematic literature review mainly focused on green supply chain testing methods, with particular emphasis on supplier selection and evaluation methods. Further literature in the dissertation concerned the topic of the green supply chain, sustainable supply chain, circular economy and general supply chain, purchasing. In the case of the further general sections, and for the supply chain, purchasing and sustainability issues I relied on the work of major researchers.

2.2.2. Characterization of the analytic hierarchy process method

Studies to develop supplier evaluation methodologies are very colourful in terms of both their aims and mathematical tools. Supplier selection is a complex problem involving qualitative and quantitative multi-criteria. The supplier selection and evaluation method I have chosen and used, the Analytic Hierarchy Process method (hereinafter: AHP), is one of the best known and most widely used multi-criteria decision support methods. AHP has been extensively researched and used in almost all applications related to Multiple Criteria Decision Making (hereinafter: MCDM) over the past 20 years (VAIDYA–KUMAR, 2006). It is an effective tool for managing complex decision-making and can help decision-makers to prioritize and make the best choice. It helps to formulate its subjective and objective aspects by reducing complex problems to pairwise comparisons and then synthesizing results. It also provides a useful technique for checking the consistency of evaluations, thereby reducing process distortion (SAATY, 1977; 1990; 2008; 2014). AHP is a methodology that has many applications. The method is based on a series of pairwise comparisons, which renders these comparisons arranged in more transparent matrixes. These matrixes evaluate on a per respondent basis, according to their preferences (DULEBA–MOSLEM, 2018). Based on paired comparisons of user preferences, the process is to make simple pairwise comparative decisions, which then use to develop overall priorities for ranking alternatives (SAATY–VARGAS, 2012).

AHP is used for large and complex problems with multiple criteria. It has been used successfully in many areas, such as marketing, finance, management, administration or sports area. The method is usually chosen because it can handle both quantitative and qualitative criteria, is easy to understand and acceptable by managers. It helps improve the decision-making process. Additionally, the hierarchical structure in the formulation of the AHP model empowers all members of the assessment team to visualize the problem at the system level, based on criteria and sub-criteria (TAM–TUMMALA, 2001). The main reason for its popularity is its three primary functions: complexity, measurement and structuring of synthesis. Its complexity based on the idea that complex problems must be presented in a way that even “average” people can understand them. Moreover, its simplicity is structuring complexity into hierarchical homogeneous groups of factors is advantageous. A hierarchical perspective relative to AHP means that it can quickly understand the human mind, represent complex problems in an easier and more friendly way (FORMAN–GASS, 2001). The decision problem of AHP’s three-layer hierarchy model illustrates in *Figure 1* below.

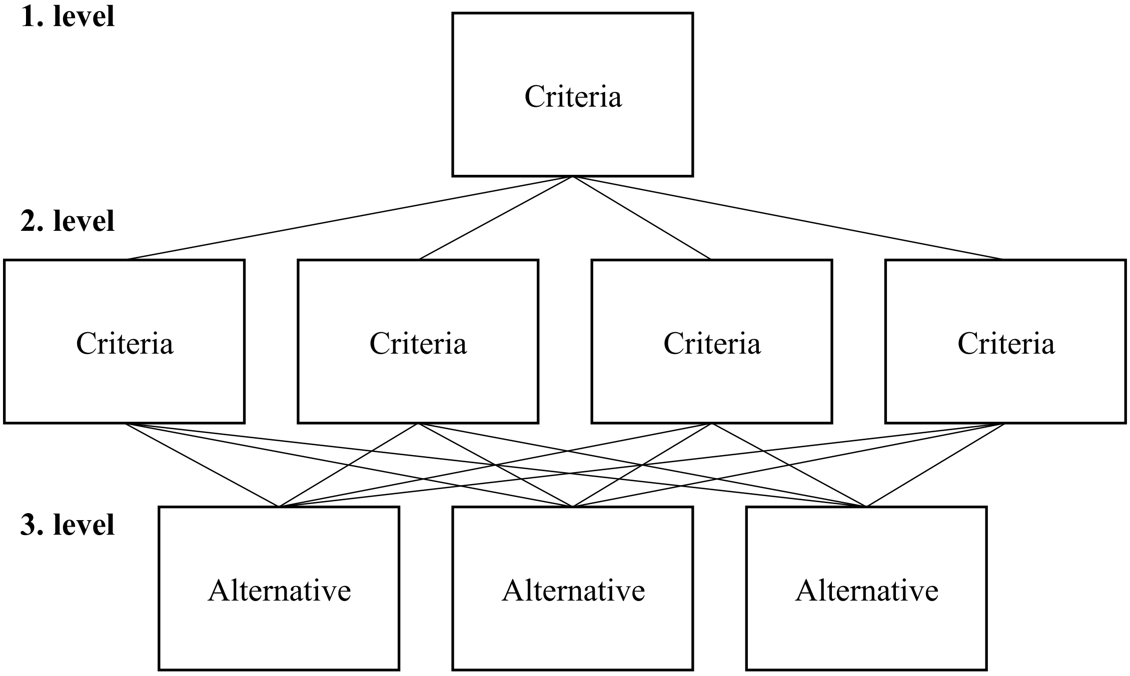

Figure 1: Illustration of the 3 levels of the AHP model

Source: SAATY, 2012

Usually, four steps are needed to set up the AHP model. The first step is to accurately identify the decision problem and establish the hierarchy, the second step is the pairwise comparison of the decision factors. The third step is to evaluate the final impact of criteria, the fourth step is to make the last procedure of selection. (DULEBA et al., 2012). The AHP method divides the elemental question into detached sections, which are easier to answer. It is much easier to evaluate if, from a certain point of view, one option compares to another rather than to all possible alternatives. In most cases, it is possible to decide which of the two alternatives is more equally advantageous for the decision-maker. Where this cannot be established, one should not use the AHP method. The final goal is to choose from alternatives (DULEBA, 2009). By dividing the problem into parts in this way in my case, which supplier one should choose based on green criteria, it is easier to understand the decision made, the used criteria and the evaluated alternatives.

2.2.3. Characterization of the own AHP model

The aspects of my model (*Table 4*) are built on domestic and mainly international literature. The model interpreted the criteria of green supplier selection on two levels from a total of 8 main aspects and 54 sub-criteria:

1. **Green quality (K1)** does not refer to essential quality, but only to those aspects that are important for the environment in question. I listed quality certifications and quality management capabilities in companies.
2. **Green technology capability (K2)** to determine the suppliers' green technology level, how they can be less burdensome to the environment in the production of their products.
3. **Total product life cycle cost (K3)** means the product life cycle cost of entering and leaving the company.
4. **Green image (K4)** whether the suppliers meet expected performance and recognize the importance of environmental and social responsibilities. In other words, how important is the image and reputation of the suppliers in the green direction.
5. **Pollution control (K5)** enterprises consider the importance of controlling environmental pollution beyond statutory regulations.
6. **Environment management (K6)** is the existence of the systems needed for environmental management that is worth associating with, and the capabilities or development opportunities that management can change.
7. **Green product (K7)** is worth considering the product that the company receives from the supplier, how "green" the product is, and how polluting to the environment it may be.
8. **Green competencies (K8)** is how much the supplier takes advantage of given opportunities, how much he/she is willing to change to go "green" to remain a supplier of the enterprise.

Table 3: Own AHP model

K1: Green quality	AK1.1.: Quality Certificate
	AK1.2.: Capability of quality management
	AK1.3.: Capability of handling abnormal quality
	AK1.4.: Management commitment to quality (degree of importance given to quality function in management and organization)
	AK1.5.: Process improvement (application of process improvement activities) continuous improvement
K2: Green technology capability	AK2.1.: Green capacity
	AK2.2.: Green technical capability
	AK2.3.: Capability of research and development
	AK2.4.: Capability of design
	AK2.5.: Capability of preventing pollution
K3: Total product life cycle cost	AK3.1.: Shipping cost
	AK3.2.: Cost of pollution effects
	AK3.3.: Rates and customs taxes (state/county/city environmental regulations)
	AK3.4.: Package disposal cost
	AK3.5.: Toxic materials disposal cost
	AK3.6.: Scrapping or dumping of waste cost
	AK3.7.: Package material cost
	AK3.8.: Disassembly cost
	AK3.9.: Cost of environmentally friendly goods
K4: Green image	AK4.1.: Market share related to green customers (Green market share)
	AK4.2.: Customer's purchasing retention
	AK4.3.: Supplier's advances in providing environmentally friendly packages
	AK4.4.: Supplier's advances in developing environmentally friendly goods
	AK4.5.: Lack of management commitment
	AK4.6.: Lack of buyer awareness
	AK4.7.: Lack of supplier awareness
	AK4.8.: Lack of company-wide environmental standards or auditing programs
K5: Pollution control	AK5.1.: Air pollution control
	AK5.2.: Water pollution control
	AK5.3.: Soil pollution control
	AK5.4.: Chemical waste control
	AK5.5.: Solid waste (scrap and components) control
	AK5.6.: Energy consumption control
	AK5.7.: Use of harmful materials control

K6: Environment management	AK6.1.: Environment-related certificates
	AK6.2.: ISO 14001
	AK6.3.: Eco-Management and Audit Scheme (EMAS)
	AK6.4.: Continuous monitoring and regulatory compliance
	AK6.5.: Green process planning (Environmental planning)
	AK6.6.: Internal control process
K7: Green product	AK7.1.: Green packing
	AK7.2.: Using of non-toxic elements
	AK7.3.: Recyclability
	AK7.4.: Reusability
	AK7.5.: Redesign/remanufacture of product
	AK7.6.: Using of low-density packaging
K8: Green competencies	AK8.1.: Materials used in the supplied components that reduce the impact on natural resources
	AK8.2.: Ability to alter process and product for reducing the impact on natural resources
	AK8.3.: Social responsibility
	AK8.4.: Ration of green customers to total customers
	AK8.5.: Green management competencies (environmental partners, training, information exchange)
	AK8.6.: The interests and rights of employee (labour relations, human rights and interest of employee)
	AK8.7.: The rights of stakeholder (the interest and rights of shareholders, consumers, communities, and related stakeholder)
	AK8.8.: Respect for the policy (comply with local regulations and policies)

Source: Own editing, 2020

3. MAIN FINDINGS OF THE DISSERTATION

The final actors of the research are profit-oriented enterprises of the Education Management Information System (hereinafter: EMIS) company information system =/+ 50 number of employees, =/+ 10 million EUR operating income and sales net, the NACE'08 C sector in the manufacturing industry, running businesses in Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties (*Table 3*). Based on age, education and professional experience, despite the low number of expert responses, I was able to draw appropriate conclusions from the survey for the two counties. The subject of my research is over 20 years (N=41 pcs), medium (N=42 pcs) and large companies (N=20 pcs), mainly under 10 million Euros (N=28 pcs) and 10-50 million Euros (N=23 pcs) operating income was also the enterprises engaged in productive activity during the examined period (total N=67 pcs) in the counties.

The evaluation of my results was analysed by the multi-criteria decision-making method using the Analytic Hierarchy Process (hereinafter: AHP), which is one of the most well-known and widely used multi-criteria decision support methods. The dissertation serves to improve the supplier evaluation scheme of the investigated companies using the AHP method. AHP is used to rank enterprises' supplier qualification criteria. It generates weights that can later be used to perform sensitivity analyses when rating suppliers. The analytical hierarchy process begins with defining the goal to be achieved. The decision problem considers green aspects to be important in supplier certifications, in the surveyed enterprises, in addition to the commonly used selection criteria (e.g.: time, price, quality).

The decision problem, which green aspects are considered important in supplier certification, is the surveyed enterprises. *Table 3* shows the AHP model, which I set up. After selecting their criteria, the experts had to evaluate the importance (priority) of the given criteria based on matrixes. Mathematically, the method is based on solving an eigenvalue problem. The results of the pairwise comparison are arranged in a matrix. The process is performed by calculating eigenvectors and then normalizing to gain weight for each measurement. Calculating the relative weight, importance, or value of the relevant factors, technically called eigenvectors. In my research, I used the Pareto-optimized right-side eigenvector of Saaty. One of the features that distinguish this methodology from other multicriteria approaches is that AHP measures inconsistency among actors. To measure inconsistencies in user judgments, for its necessary to calculate the consistency ratio. According to BRUNELLI (2015), the consistency value should remain below 10% for all matrixes, i.e. the condition CR ≤ 0.1 should meet. If the CR value is equal to or less than 0.10 (10%), this means that the evaluation within the matrix is acceptable, in the case of a higher amount, the judgment is very inconsistent. If the CR is significantly above 10%, the judgments are unreliable because they are too close to facilitate randomization and the result is worthless or has to repeat the calculation. Of course, if a person answered consistently, he or she must have a much lower consistency score, which would result from random entries. The acceptable consistency rate should be less than 10%, although less than 20% should be considered acceptable (WEDLEY, 1993). The acceptance rate is 15% for individual matrixes and 20% for aggregated matrixes. In pairwise comparisons, the CR value remained within the accepted 15%, thus the expert judgment is consistent.

From the results obtained by the manufacturing enterprises (N=67 pcs) of Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties using the analytical hierarchy process (AHP) method, I made the following statements (*Figure 3*). The two counties evaluated the aspects of the model similarly in the selection of suppliers, and they considered the criteria to be almost equally important. Only in a few cases, were there any differences. In Szabolcs-Szatmár-Bereg county (4.4%) the AK1.3. Capability of handling abnormal quality is 1.2% higher evaluated than in Hajdú-Bihar county, the highest criteria in K1 Green quality is the AK1.5. Continuous improvement. In K2 Green technology, the capability of both of them is the AK2.5. Capability of preventing pollution is the most important aspect, in Hajdú-Bihar, this is 4.4% and in Szabolcs-Szatmár-Bereg county, this is 3.5%. In the case of K3 Total product life cycle cost, in Hajdú-Bihar the most significant criteria is the AK3.1. Shipping cost (4.1%), while in Szabolcs-Szatmár-Bereg county is the AK3.5. Toxic materials disposal cost (3.5%). Compared to other criteria Green image (K4), Environment management (K6) and Green competencies (K8) were not more important in either county. In the case of K5 Pollution control and K7 Green product, the most important criteria is AK5.4. Chemical waste control and AK5.7. Use of harmful materials control in the two counties. In Hajdú-Bihar county, this is AK5.4. Chemical waste control, AK5.7. Use of harmful materials control, AK7.1. Green packing and AK7.2. Using of non-toxic elements (3.1%) while in

Szabolcs-Szatmár-Bereg county is AK5.4. Chemical waste control, AK5.7. Use of harmful materials control (3.2%) and AK7.2 Using of non-toxic elements is (3.8%).

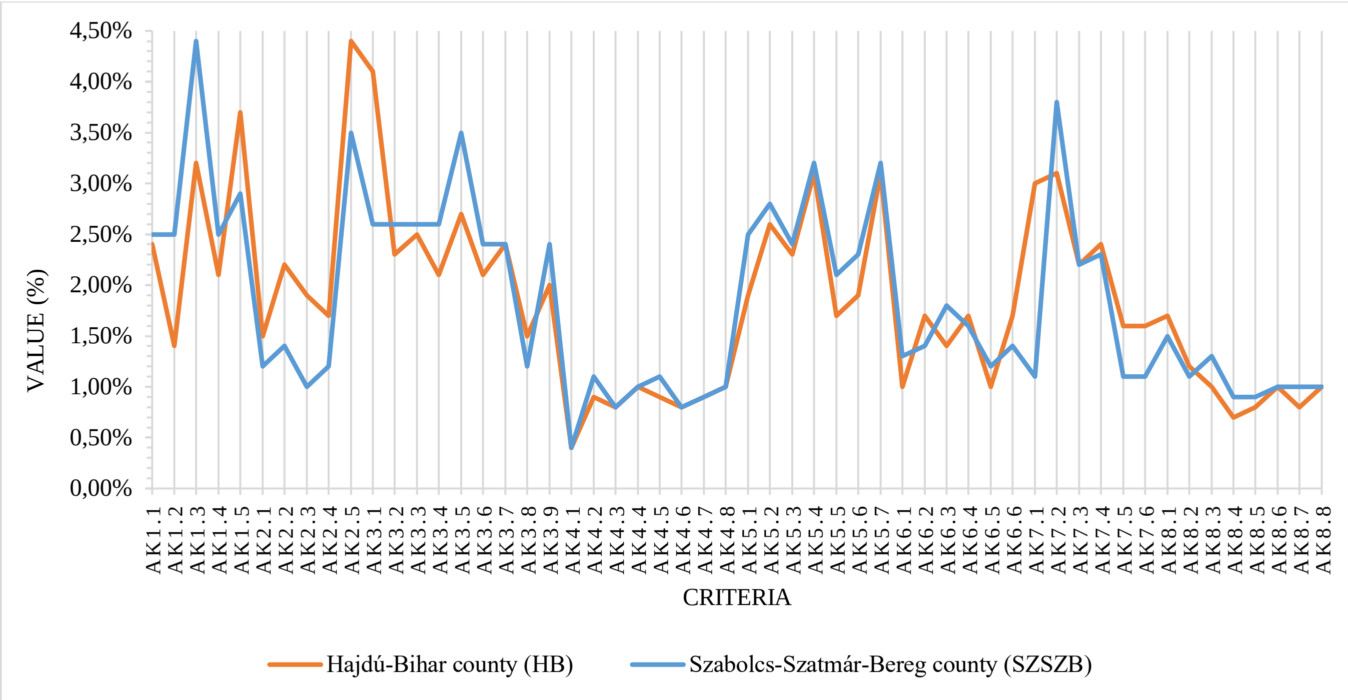

Figure 3: HB_SZSZB_results of aggregate matrix in 3 preference level (N=67 pcs)

Source: Own calculation, 2020

In summary, the most important criteria in selecting the supplier in the two counties are represented in *Table 5*. The most important green aspect for the surveyed enterprises is that suppliers should be the most favourable in terms of total product life cycle cost (K3), particularly in shipping cost (AK3.1) and toxic materials disposal cost (AK3.5). It is also important that the environmental pollution should be controlled without external influences, including the most important criteria, which are use of harmful materials (AK5.7.) and chemical waste pollution (AK5.4.), as the handling cost is expensive. In the case of green quality, the most important beyond the expected criteria, the principles of sustainability and environmental awareness is the capacity of handling abnormal quality (AK1.3.) and continuous improvement (AK1.5.). It is relevant for the enterprises that, according to our knowledge, suppliers should make green products (K7) with green technology capability (K2) namely, during manufacturing, avoid the use of toxic materials and care should be taken to prevent pollution (AK2.5.). Furthermore, I concluded, that it is not important, what kind of environment management (K6) system is used by the supplier, how conscious they are in green competencies (K8) and how well the suppliers meet the expected performance and recognize the importance of environmental and social responsibility: in other words, how important the green image and, reputation (K4) of the suppliers are.

Table 5: HB_SZSZB aggregate results (N=67 pcs)

Criteria	Priority (%)	Ranking
K3 Total product life cycle cost	**21.90%**	**1**
K5 Pollution control	**17.50%**	**2**
K1 Green quality	**13.80%**	**3**
K7 Green products	12.70%	4
K2 Green technology capability	10.00%	5
K6 Environmental management	8.70%	6
K8 Green competencies	8.55%	7
K4 Green image	6.80%	8

Source: Own calculation, 2020

I also opened up the industry specifics of the manufacturing sector using the Analytical Hierarchy Process (AHP) and came to the following:

There is a growing trend in the packaging industry to use some sort of recycled or reverse packaging solutions. This is also reflected by the sector specifics, namely the production of paper products from recycled paper. In some cases, paper is manufactured from cellulose, and industry aims to use the least amount of environmentally damaging inks in its printing activities, as its recycling costs are the most significant and these reduce the value of product reusability. Also, this is confirmed by the results I obtained it.

Hajdú-Bihar county NACE 17 Manufacture of paper and paperboard (N=2 pcs) main selection criteria:

1. K7 Green product (25.6%) in this the most important AK7.4. Reusability (8%); AK7.3. Recyclability (5.7%); AK7.2. Using of non-toxic elements (4.6%).
2. K3 Total product life cycle cost (18,8%), within this AK3.1. Shipping cost (5%).
3. K5 Pollution control (11.6%) is the third most important, within this AK5.7. Use of harmful materials (3%).

The chemical industry creates a variety of products that affect every area of our lives. The chemical industry in the broadest sense comprises 4 sectors:

- Manufacture of coke and refined petroleum products (NACE 19)

- Manufacture of chemicals and chemicals products (NACE 20)
- Manufacture of basic pharmaceutical products and pharmaceutical preparations (NACE 21)
- Manufacture of rubber and plastic products (NACE 22).

Pharmaceuticals can be released into the environment at all stages of the product life cycle, and the industry is also actively involved in minimizing the environmental impact of pharmaceutical activities. The pharmaceutical industry is a highly regulated industry, and all products must be produced using a good manufacturing practice. (PLUMB, 2005; FEDERSEL, 2006; EFPIA, 2018).

Hajdú-Bihar county NACE 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations (N=2 pcs) main selection criteria:

1. K1 Green quality (24.8%) within this AK1.2. Capability of quality management (6.5%), AK1.4. Management commitment to quality (5.5%), AK1.1. Quality Certificate (4.8%) and AK.1.5. Continuous improvement (4.3%).
2. Second most important factors are K5 Pollution control (20.8%), AK5.5. Solid waste (scrap and components), AK5.6. Energy consumption (4.2%).
3. K2 Green technology capability (10.8%), AK.2.5. Capability of preventing pollution (2.7%), AK2.1. Green capacity (2.7%), AK.2.2. Green technical capability (2.4%).

Manufacture of rubber and plastic products represents another sub-sector of the chemical industry. Plastics production is one of the most environmentally-friendly industries, as the waste produced is not naturally decomposed. The plastics industry, and in particular plastics processing, is a typical background industry. Its growth and opportunities are closely link to the economic environment. Most of the products released do not appear as stand-alone products in our daily lives, but as parts or components (BUZÁSI, 2019).

Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties NACE 22 Manufacture of rubber and plastic products (N=6 pcs) main selection criteria:

1. K3 Total product life cycle cost (17.65%)
2. K5 Pollution control (16%)
3. K7 Green product (13.05%).

Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties NACE 24+25 Manufacture of basic metals and structural metal products (N=13 pcs) main selection criteria:

1. K5 Pollution control (22.8%)
2. K3 Total product life cycle cost (15.5%)
3. K1 Green quality (15.3%).

During the manufacture of computer, electronic and optical products, all of the products and associated by-products and wastes produced during the process are hazardous goods, their treatment, disposal and recycling are very costly and, to the best of our knowledge, are not yet solved.

Szabolcs-Szatmár-Bereg county NACE 26 Manufacture of computer, electronic and optical products (N=3 pcs) main selection criteria:

1. K5 Pollution control (25.7%) within this AK5.4. Chemical waste control (7%).
2. K3 Total product life cycle cost (20.4%), the most important in third preference level AK3.5. Toxic materials disposal cost (5.1%) and AK3.2. Cost of pollution effects (3.8%).
3. Third most important selection criteria K7 Green product (15.5%) within this in third preference level AK7.2. Using of non-toxic elements, AK7.3. Recyclability and AK7.4. Reusability (3.1%).

Waste of manufacturing of electrical and electronic equipment is one of the major world-wide wastes, for which there is a need to develop new environmental strategies. Environmental regulations, closed-loop supply chain activities, eco-design practices, and environmentally friendly strategies implemented by the government and industry all help to integrate environmental and sustainability considerations into the industry. Recently, waste from electrical and electronic equipment has emerged as one of the major wastes in the world due to the market expansion and the trend for electronic products of shortened lifecycles (EU 2019/63 HATÁROZATA, GEORGIADIS–BESIOU, 2009).

Hajdú-Bihar county NACE 27 Manufacture of electrical equipment (N=2 pcs) main selection criteria:

1. The main important criteria are K3 Total product life cycle cost (28.6%) within AK3.1. Shipping cost (6.8%); AK3.3. Rates and taxes (4.9%) and AK3.7. Package material cost (5.8%).

2. The second most important criteria are K1 Green quality (25%) within this the most important is K.1.5. Continuous improvement (10.9%); AK1.1. Quality Certificate (4.6%); AK.1.2. Capability of quality management (4.3%).
3. The third is K2 Green technology capability (14.2%) within this the most important is AK7.2. Using of non-toxic elements (4.4%).

Hajdú-Bihar county NACE 28 Manufacture of machinery and equipment (N=3 pcs) main selection criteria:

1. K3 Total product life cycle cost (31.6%) within this are the most important AK3.5. Toxic materials disposal cost (7.7%), AK3.1. Shipping cost (6.2%), AK3.3. Rates and taxes (3,3%) and AK3.6. Scrapping or dumping of waste cost (3.2%).
2. In K7 Green product (25%) the most important criteria are AK7.4. Reusability (6.4%), AK7.3. Recyclability (6%) and AK7.2. Using of non-toxic elements (5.7%).
3. The third most important criteria in manufacture of machinery and equipment are K5 Pollution control (10.4%), in the third preference level. In addition to the sub-criteria, AK5.2. Water pollution control (2.9%) is the most important.

4. MAIN CONCLUSIONS AND NOVEL FINDINGS

The overall research aim is to present green purchasing practices, including supplier selection, using the AHP method in the practice of manufacturing enterprises of the Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties in the Northern Great Plain Region. Using this method, a ranking system of criteria and a green supplier selection criteria system for the two counties will be set up, taking into account the industry specifics of the manufacturing sectors. The realization of main and sub-research questions, I made the following new and novel results:

Findings and results of the research questions to be answered:

- **K1.: To investigate how the identification of green supplier performance factors works in managing relationships with suppliers in the surveyed enterprises.**
    - K1.1.: To conduct a comprehensive review of national and international literature on the green supply chain. Based on the literature, I introduced a specific concept for green purchasing management.

My definition of "green purchasing management" is a strategic tool that contributes to the competitive achievement of environmental, sustainability, social and economic goals within an enterprise. To this end, they integrate environmental considerations (partly as a result of CSR policy, growing consumer demand, stricter enforcement of laws) into their purchasing policies, programs and actions bearing in mind the principles of the circular economy. The goal is to use green environmental management tools to continuously provide green products and services and minimize negative environmental impacts throughout the whole purchasing chain.

The concept of green purchasing is not yet understandable in the case of the examined enterprises, although the interpretation I have introduced is partly acceptable to them. The concept, which I introduced can be considered a new result.

- **K2.: The question is whether, a model can be created to examine the proposed green supplier rating factors which illustrates the context of supplier selection.**

The aspects of my model (*Table 4*) are based on domestic and mainly international literature. The model interpreted the criteria of green supplier selection on two levels on a total of 8 main aspects and 54 sub-criteria. I formulated more factors than the same cluster in the model, so it was very confusing and time-consuming for experts to make pairwise comparisons. The research provided practical usability for the surveyed enterprises to consider green criteria in supplier selection, but the implementation of such a separate evaluation model would not be applied.

My research question is partially answered. Only green supplier selection is not typical in corporate practice, in this form, companies would not use my model as a stand-alone green purchasing selection model, and thus not all parts of the model could be put into practice.

K3.: To examine how the model can be validated in the examined production enterprises.

- K3.1.: To evaluate the enterprises' suppliers focusing on environmental aspects.
- K3.2.: To determine the importance of environmental factors in manufacturing enterprises using analytical hierarchy process (hereinafter: AHP).
- K3.3. To explore the industry specifics of the manufacturing sector using AHP.

I examined the importance of the aspects of the model I created based on the literature by analytical hierarchy with the help of experts from the manufacturing enterprises of Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties (N = 67 pcs). The survey, which I conducted is a subjective examination, which can be made objectified. By assigning quantitative data to the aspects of the model, I would have obtained a more reliable answer from the experts, as this would have made it easier for them to weight and decide between them. I confirmed SAATY's (1980) definition of the number of factors and WEDLEY's (1993) work on consistency ratio. The AHP model with fewer factors (up to 6 criteria) and with a 15% CR threshold is suitable for supplier evaluation and selection. The AHP method is also useful for supplier certification, but it is not practicable in business practice, as it is too complex and time-consuming.

Table 5 summarizes the most important criteria of supplier selection in the two counties:

- Among the examined enterprises (N=67 pcs), the most important of the green criteria in supplier evaluation is viewed in terms of total product life cycle cost (K3), especially shipping cost (AK3.1) and toxic materials disposal cost (AK3.5).

- Environmental pollution should be controlled without external influences, and the most important criteria are the use of harmful materials (AK5.7.) and chemical waste pollution (AK5.4.), because the handling cost is expensive.
- In addition to the expected criteria of their green quality (K1), the principles of sustainability and environmental awareness have reflected the capability of handling abnormal quality (AK1.3) and continuous improvement (AK1.5).

It is relevant for the enterprises, that according to our knowledge, suppliers should make green products (K7) with green technology capability (K2), namely during manufacturing, they should avoid the use of toxic materials and take care to prevent pollution (AK2.5.). Furthermore, I concluded, that it is not important, what kind of environment management (K6) system is used by the supplier, how conscious they are in green competencies (K8) and how well the suppliers meet the expected performance and recognize the importance of environmental and social responsibility: i.e. how important the green image, reputation (K4) of the suppliers is.

I explored the industry specifics of the manufacturing sector using the AHP method. Industry priorities aligned with county priorities. There were no major differences. In those industries, which are closely monitored, there has been a major paradigm shift and consumer trends under consumer pressure, in these (e.g.: Manufacture of paper and paperboard or manufacture of rubber and plastic products), there is a policy towards adapting to environmental and sustainability trends. In these industries, the most important criteria are the K3 Total product life cycle cost, K5 Pollution control and K7 Green product. In other words, the goal is to produce a green product with the least environmental impact throughout the whole supply chain. In other industries, green criteria tend to align with county priorities.

- During the manufacture of paper and paperboard (NACE 17), there is a growing trend in the packaging industry to use some sort of recycled or reverse packaging solutions. This also reflects the sector specifics, namely the production of paper products from recycled paper. In some cases, paper is manufactured from cellulose, and it aims to use the least amount of environmentally damaging inks in its printing activities, as its recycling costs are the significant costs and reduce the value of product reusability.

- Pharmaceuticals (NACE 21) can be released into the environment at all stages of the product life cycle, and the industry is also actively involved in minimizing the environmental impact of pharmaceutical activities.
- Manufacture of rubber and plastic products (NACE 22) represents another sub-sector of the chemical industry. Plastics production is one of the most environmentally-friendly industries, as the waste produced is not naturally decomposed. The plastics industry, and in particular plastics processing is a typical background industry. Its growth and opportunities are closely link to the economic environment.
- During the manufacture of basic metals and structural metal products (NACE 24+25), metal recycling has many potential benefits, but this is an industry, where no major environmental and sustainability changes can be seen. Also, in this sector, purchasing activity is exclusive due to the specific nature of its industries. Therefore, in many cases, there are no selected suppliers, because enterprises only buy from whoever they can in the market and is not important at what price or under which circumstances.
- During the manufacture of computer, electronic and optical products (NACE 26), all of the products and associated by-products and wastes produced, during the process are hazardous goods, their treatment, disposal and recycling are very costly and, to the best of our knowledge, are not yet solved.
- The waste of manufacturing of electrical and electronic equipment (NACE 27) is one of the major world-wide waste streams triggering the emergence of environmental strategies. Environmental regulations, closed-loop supply chain activities, eco-design practices, and environmentally friendly strategies implemented by government and industry all help integrate environmental and sustainability considerations into the industry.

For the last two industries "Manufacture of computer, electronic and optical products" and "Manufacture of electrical equipment" the most important criteria are Green product (K7) and Green technology capability (K2), with at the least Chemical waste (AK5.4.) pollution. They also consider the AK3.3. Rates and taxes cost, because all products are dangerous goods, handling them is very expensive, so suppliers expect to comply with environmental regulations during product manufacture.

- The manufacture of machinery and equipment (NACE 28) is a modern industry not only of the automotive industry but also of other sub-sectors of the manufacturing industry. Thus, in this industry, it showed a high degree of alignment with county priorities.

In summary, the integration of environmental and sustainability guidelines into supplier selection and compliance with the circular management guidelines mainly found in sector NACE 17 Paper and paper product manufacturing and NACE 22 Manufacture of rubber and plastic products. During the manufacture of computer, electronic and optical products NACE 26 and Manufacture of electrical equipment NACE 27, all of the products and associated by-products and wastes produced during the process are hazardous goods, their treatment disposal and recycling are very costly and, to the best of our knowledge, are not yet solved. Also, this was confirmed by the results, I obtained it. NACE 24+25 During the manufacture of basic metals and structural metal products waste and metal recycling have many potential benefits, but this is an industry where no major environmental and sustainability changes can be seen. In NACE 28 Manufacture of machinery and equipment as a background industry, it showed mainly the characteristics of the county.

My research questions (K3.; K3.1., K3.2., K3.3.) were partially answered. The model is suitable for supplier selection with the reduced set of criteria, either individually or in combination with the existing one and by assigning quantitative data to a value in medium or large-sized manufacturing enterprises existing over 20 years, with 10-50 million Euros in operating income, in Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties. The revealed industry specificities only partially reflect the integration of environmental and sustainability guidelines. Within a company, in order to integrate environmental considerations (partly as a result of CSR policy, growing consumer demand and stricter enforcement of laws) into their purchasing policies and programs, there is an overriding need to achieve competitive environmental, sustainability, social and economic goals, so I could not draw conclusions for entire manufactory industry; thus, my research question was only partially answered.

5. PRACTICAL USE OF THE RESULTS

Limitations and practical utilities of my research:

- Each of the examined enterprises uses some kind of environmentally conscious enterprise management tool but rather used it more at the user level due to, its obligatory nature. At the same time enterprises have insufficient skills in environmental and sustainability issues.
- The study has provided practical utility for enterprises to consider green considerations when selecting their suppliers, but their enforcement is still not solved for some companies (e.g.: metal production). They could expect to operate more efficiently by using the environmentally-based AHP supplier selection method and even make forecasts, as using this method allows for easier and more efficient supplier selection.
- One of my limitations is that it is not representative research, because I only conducted surveys in two counties. Although county and industry results may be similar to those of other similar countries, I have not made comparisons with other companies in other countries; thus, my results do not show the sustainability development of several counties of Hungary or even other Member States and industries of the European Union.
- Another limitation is that, in case of industry characteristics, there are similarities between companies doing similar activities in other counties and countries, but there are no conclusions that can be drawn for the industry as a whole.
- In the future, it would be appropriate to carry out investigations in certain sub-sectors (e.g.: metal production). The model can be simplified more objectively by having experts choose between the quantitative values of the criteria assigned to the characteristics of a particular industry.
- Furthermore, it would be appropriate to examine the interaction between the three actors, not just the relationship between the two (supplier-buyer), so that we could move from bilateral to triple (supplier-company-buyer) relationships. In two-player studies, two supplier-customer relationships can investigate, with one being in the

role of a customer and the other in a supplier role or vice versa, so measuring the performance of one's suppliers can be compared to that of a company as a supplier. In other words, what I expect from my suppliers, I can also provide as a supplier to my customers.

6. LIST OF PUBLICATIONS RELATED TO THE DISSERTATION

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List of publications related to the dissertation

Articles, studies (6)

1. **Horváth, A.**: Körforgásos gazdálkodás eszméi, a körkörös ellátási lánc menedzsment. *Logisztika Trendek és Legjobb Gyakorlatok. közlésre elfogadva*, 1-10, 2020. ISSN: 2416-0555.
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