

SZENT ISTVÁN UNIVERSITY

**COMPLEX ANALYSIS OF GREEN SUPPLY CHAIN  
MANAGEMENT IN HUNGARIAN AUTOMOTIVE  
INDUSTRY**

THESES OF DOCTORAL (PHD) DISSERTATION

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# **1. Introduction**

## **1.1. Relevance of the topic**

The topic of environmental impacts of human activities is receiving growing attention in the media, politics, in business organizations and among academics. Parallely, Corporate Social Responsibility (CSR) appeared and became more and more popular. Involving environmental aspects in corporate strategy is an important part of CSR.

Most of the negative environmental impacts of businesses are considered to be caused by procurement, production and logistics – the main supply chain processes. Therefore companies have to make increased efforts to measure and decrease the environmental impact caused by the value creation process in the supply chain. The role of supply chain management is extended by a new element: the management of environmental impacts. Involving environmental thinking into supply chain management led to the Green Supply Chain Management (GSCM) concept, which produced an increasing number of scholarly researches and publications from the second part of the 2000s. These researches were made predominantly in the far east, no remarkable researches were done in Hungary so far. Therefore, the GSCM topic has a smallish Hungarian literature. In some cases even the translation of the GSCM terminology is missing or it is not widely accepted. The topic has several aspects to be exploited and offers several research questions.

The subject of my primary research is the Hungarian automotive industry. Automotive industry is a good choice to research supply chain management topics, thanks to its outstanding level of SCM practice. I focus on the upstream section of the supply chain, so the research sample is composed of Original Equipment Manufacturers (OEMs) and their supplier networks.

## **1.2. Research objectives and main research questions**

Based on the literature and the results of prior GSCM researches I have set four main research topics:

- 1. Motivation for green supply chain management, enabler and barrier factors.*  
Motivation involves the effects that influence companies, change their attitude towards GSCM and inspire them to apply GSCM methods. I consider these factors important for researching the penetration of GSCM in Hungarian automotive industry. My research objective is to build a systematic, clear motivation model and the analysis of the effect of the separate motivating/barrier factors. I analyse motivation not only

for the whole sample but separately for each supply chain level (OEM, and the different supplier levels).

2. *Green supply chain management methods applied by companies and the development level of green supply chain management fields.*
  - How developed is GSCM in the Hungarian automotive sector? How many companies apply the different fields of GSCM? Which are the most popular methods and techniques from the toolsets of the GSCM fields? My research objective is to map the toolset applied by the focus industry.
  - My second objective is to analyse GSCM fields along the supply chain: define the typical toolset for each supply chain role, find the most popular methods and the most developed fields for each level of the supply chain.
3. *The relationship between traditional and green supply chain, the effect of traditional supply chain management on the application of green supply chain management.*
  - Is there a correlation between the traditional SCM and GSCM toolset of the companies? Which supply chain strategies are the most favourable for GSCM? What effect do the supplier-buyer relationships have on the applicability and success of the different GSCM techniques?
4. *Performance measurement for green supply chain management and perceived GSCM performance.*
  - What expectations have companies expressed, which aspects of performance do they consider as important and what do they measure?
  - What effects of green supply chain management do companies perceive? How strong are these effects? On which fields of operation do these results appear?
  - One of the most important research questions is the correlation between the application of green supply chain management and performance. The correlation between GSCM activity and the possible results is already confirmed in the literature but only in general. It is not analysed which GSCM field has an effect on which performance category. My objective is to reveal these correspondences.

### **1.3. Research hypotheses**

#### **Hypotheses on motivation for green supply chain management**

**H1: Primary motivation** of focus companies for the application of GSCM techniques is compliance with regulations. Proactive behaviour is not typical.

**H2: Motivating and barrier factors of GSCM are different in the focus group based on the supply chain role of the company.** I assume that OEMs and Tier1 suppliers (integrators) are motivated primarily by „green” customer requirements. By fulfilling these requirements, company image can be improved and competitive advantage can be reached. I assume that Tier2-4 suppliers are influenced primarily by customer requirements (needed for staying in the supplier network) and also by financial possibilities.

#### **Hypotheses on GSCM activity**

**H3: Level of development and the applied GSCM techniques are different in the focus group based on the supply chain role of the company.** I assume that OEMs and Tier1 suppliers are on a significantly higher level of GSCM, while this level decreases as we go backwards in the supply chain.

**H4: Applied GSCM fields and techniques are different in the focus group based on the supply chain role of the company.** I assume that at OEMs and Tier1 suppliers green design and green purchasing will be dominant, while at Tier2-4 suppliers green manufacturing will dominate.

#### **Hypotheses on cooperation in the supply chain**

**H5: The more developed traditional supply chain management is in a company,** and the closer cooperation exists between partners, **the more developed GSCM can be.** Traditional SCM methods help the application of GSCM techniques.

#### **Hypotheses on the outcomes and performance of GSCM**

**H6: Attitude towards GSCM performance measurement and measured performance categories are different in the focus group based on the supply chain role of the company.** I assume that performance measurement is significantly more developed in the OEMs and Tier1 suppliers than Tier2-4 suppliers. At the supplier end of the supply chain operative performance will be emphasised, while at the OEM side environmental performance will have greater importance. The reason for this assumption is that consumers’

environmental requirements arrive to the OEMs, and they feel the consequences of meeting or not meeting these requirements.

**H7: The more developed the GSCM fields are, the more perceptible the positive changes are in the different GSCM performance categories.**



## 2. Material and method

### 2.1. Research sample

The subjects of my primary research are automotive companies operating in Hungary. The research questionnaire was sent to more than 350 companies of the focus group between July 2014 and November 2015 by the following channels:

- I used the database of <http://www.autopro.hu/> for selecting relevant companies based on their activity (product). The service ceased to be free in the middle of 2015 but the selection of companies was already done. I have sent the questionnaire directly to 79 companies between July 2014 and November 2015.
- The Association of Hungarian Automotive Component Manufacturers (MAJOSZ, <http://www.majosz.hu/>) helped to send the questionnaire to its nearly 220 members in August 2015.
- I collected data on the Automotive Hungary exhibition in October 2015, where 17 exhibitors answered the questionnaire and some of them forwarded it to their partners.
- I questioned 33 companies directly, through personal relationships.
- I collected and validated general company data using the open database of <http://ceginformacio.creditreform.hu/>.

I received 75 answers out of which 72 were complete and suitable for statistical processing. This means a respond rate of 21%.

48 out of the 72 respondent companies were owned by Hungarian owners, the other 24 were affiliates of foreign companies. This means 66.6% Hungarian and 33.3% foreign ownership.

The sample includes small, medium and large companies as well. 22 companies (30.6%) employ 50 employees or less, 25 companies (34.7%) have employees between 51 and 250, and 25 companies (34.7%) are large enterprises with more than 250 employees.

The role that sample companies play in their supply chain has key importance in the research. The respondents had to classify themselves into one of the following categories:

<i>OEM</i>	<i>4 companies</i>	<i>5,6%</i>
<i>Tier1</i>	<i>12 companies</i>	<i>16,7%</i>
<i>Tier2</i>	<i>15 companies</i>	<i>20,8%</i>
<i>Tier3-4</i>	<i>41 companies</i>	<i>56,9%</i>

The ratio of the sample and the population is important for the interpretation and generalisation of research results. Since most of the research questions are based upon the supply chain role, representativity of the sample must be checked. This raises some issues regarding the test of representativity:

- There is no available true and up-to-date data on the size of the population. There is no exact calculation on the number of automotive manufacturer and supplier companies in Hungary. Since the final product is very complex, suppliers come from different industries, and the classification of their economic activity is diverse. Therefore searches based upon TEÁOR (NACE) codes cannot be successful.
- The OEM – Tier1-4 classification is not self-evident either. The complexity of supplier networks cause that a company can play more than one role in the supply chain in the same time. A supplier delivers several different products to their customers. The company can be categorised for example as Tier3 based on one product and Tier2 based on another product. This is quite common in automotive supply chains.

Due to these issues I asked for empirical data regarding the size of population and the number of companies in each supply chain role from three automotive organisations, which were the following:

- HIPA (Hungarian Investment Promotion)
- MAGE (Association of the Hungarian Automotive Industry)
- MAJOSZ (Association of Hungarian Automotive Component Manufacturers).

I calculated the average of the estimated data they provided. The estimation of the population size and the sample size are shown in Table 1.

**Table 1. Population and sample size**

	<b>Population</b>	<b>Sample</b>	<b>Sampling rate</b>
<b><i>Total</i></b>	<b><i>~700 companies</i></b>	<b><i>72 companies</i></b>	<b><i>10,3%</i></b>
OEM	~5 companies	4 companies	80%
Tier1	~50 companies	12 companies	24%
Tier2	~100 companies	15 companies	15%
Tier3-4	~550 companies	41 companies	7,5%

**Source: HIPA, MAGE, MAJOSZ, own research**

Table 1 shows that approximately 10% of the population was selected to the sample. The sampling rate is not the same for each supply chain role – it is above the average in OEM – Tier1 – Tier2 groups and below average in Tier3-4

group. Proportional sampling would not have been suitable because the sample size for OEMs and Tier1-2 suppliers would not have been enough for statistical analyses. Therefore these groups are intentionally overrepresented.

## **2.2. The research questionnaire**

The questionnaire involves two questions on the basic data of the company and four question groups on motivation, activities, cooperation and performance. The question groups and the questions were created using the results from the literature and aiming the research questions (hypotheses).

### **Question group on motivation (Questions 3-5)**

The purpose is to assess the factors that influence companies in applying GSCM. I test hypotheses H1 and H2 using this question group.

### **Question group on green supply chain management activity (Questions 6-8)**

This question group aims the mapping of the GSCM practice of the sample companies. The answers provide data for testing hypotheses H3 and H4. The most important element of the group is question 6, a complex set of 27 sub-questions, including GSCM techniques found in the literature.

### **Question group on cooperation in the supply chain (Questions 9-19)**

The purpose is to assess the forms and intensity of cooperation between members of the supply chain. I use the results for testing hypothesis H5.

### **Question group on green supply chain management performance (Questions 20-21)**

The application of green supply chain management techniques have tangible results for companies, these performances can be measured in different categories (environmental, economical, operational and other). The aim of this question group is to assess the performances expected and measured by companies. I use the answers to test hypotheses H6 and H7, and to analyse the correspondence between GSCM techniques and GSCM performance.

## **2.3. Methods of analysis**

I analysed the GSCM practice of the sample companies by **descriptive statistics**. I described the application of GSCM techniques by calculating frequencies, relative frequencies and averages.

For the analysis of the relationship between the development of GSCM and the supply chain role I prepared **chi-squared test of a contingency table**. It was

possible because both variables are nominal. In this type of independence test, the null hypothesis states that the two variables are independent, while the alternative hypothesis expresses that they are dependent. Preparing a chi-squared test requires a big sample, providing that the distribution of the sample converges to  $\chi^2$  distribution. The sample is big enough when the expected values in all cells of the contingency table are at least five. (Hunyadi et al. 2000, Keller 2005). To reach the required number of values, I merged some of the original categories. I took care that merging categories would not affect the answer on the research question.

For the analysis of the correspondence between traditional and green supply chain management methods, I prepared **analysis of variance**. Analysis of variance technique determines whether differences exist between population means. In case of no difference the variables are independent, while in case of difference there is dependence between the variables (Hunyadi et al. 2000). The grouping variable was the way of application of traditional SCM methods, while the examined variable was a GSCM development index. According to the statistical sources I used, when preparing an F-test the group variances should be equal (see for example Keller 2005). However, Hill and Lewicki (2006) point out that the F-test is quite resistant against the violation of this condition. Since this, I prepared the analyses even in the cases where the group variances were not equal. For finding groups that show significant difference in GSCM development, I used post-hoc tests. To choose the appropriate post-hoc test, I checked the equality of variance with Levene test. In case of equal variances I used LSD test, in the other case I used Games-Howell test.

I analysed the motivation of companies with **cluster analysis** (Ward method). The methodological background of cluster analysis was provided by the statistical books of Romesburg (2004) and Kaufman and Rousseeuw (2005).

For descriptive statistics I used Excel, for the other analyses I used SPSS 15.0 for Windows and MINITAB softwares.

### 3. Results

My primary and secondary research is focused on a relatively new topic: green supply chain management. I have reviewed the literature of GSCM that – being a relatively new topic – includes publications of about 15 years’ time. I organised the existing research results, and created new models where the existing ones were not clear enough. I conducted the primary research based on these new models. I assessed the green supply chain practice of Hungarian automotive companies from four aspects.

#### 3.1. Results on motivation

One of the problematic topics of the secondary research was motivation. The systematization of motivation factors was incomplete and the aspects of evaluation – their origins and effects – were not clear. As a solution to this problem I created a two-level motivational model that separates hard (coercive) factors from soft ones, and groups the latter based on their origin and effect. The model is shown in Table 2.

**Table 2. Green supply chain management motivation model**

<b>Motivation level 1: Pressure for GSCM</b>		
<b>Regulations</b>	<b>Pressure from market</b>	<b>Other</b>
Local National EU / International	Consumer requirements Investors’ requirements Creditors’ requirements Parent company’s requirements Growing energy and product prices	NGOs Other
<b>Motivation level 2: Enabler and barrier factors</b>		
<b>Internal enablers</b>		<b>External enablers</b>
Management commitment Green corporate culture Existing green strategy Existing green competences Existing environmental management system Big company size Great environmental risk of core activity Improvement of company image		Potential subsidies Environmentally conscious customers Supplier cooperation

Internal barriers	External barriers
Cost-based strategy Traditional performance measurement system Small company size Lack of financial resources Slow return Lack of knowledge on customer requirements Lack of management commitment Lack of GSCM knowledge Non-green SCM priorities	Pressure on prices Low supplier commitment Lack of supplier capacity Low industry standards

**Source: own research**

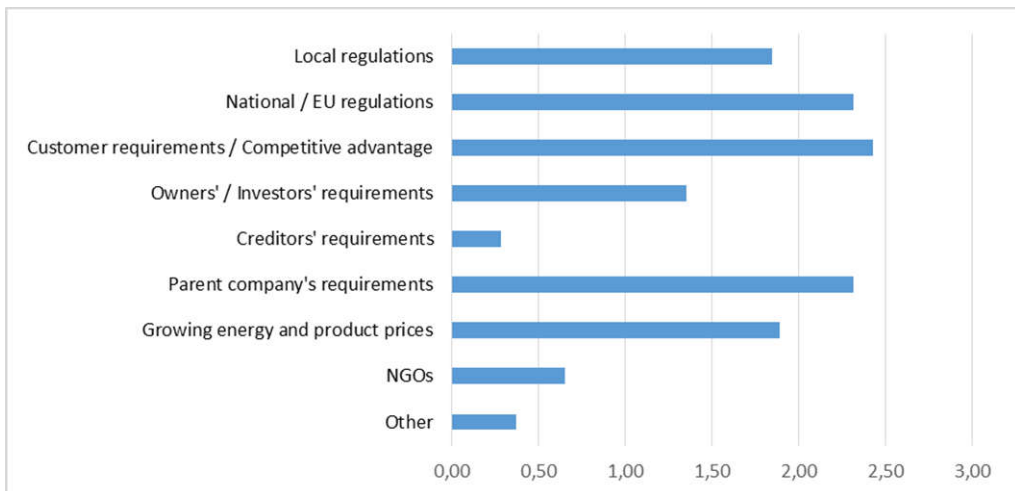
I performed cluster analysis based on GSCM motivation (pressure, enabler and barrier factors), and created five groups with different motivational patterns. The members of the different groups feel different intensity of pressure towards GSCM and faces with different enabler and barrier factors (see Table 3). Due to these differences they give different answers on motivational effects.

**Table 3. Motivation factors perceived by the motivational clusters**

Cluster	Pressure	Enablers	Barriers
<b>The Motivated</b>	strong	strong	weak
<b>The Competent</b>	medium	strong	weak
<b>The Ones in the Press</b>	strong	strong	strong
<b>The Unready</b>	medium	weak	strong
<b>The Wordly</b>	weak	weak	strong

**Source: own research**

I assessed the relevance and strength of the motivational factors in the sample of Hungarian automotive companies. All companies perceived the pressure for GSCM – 63% of them intensively and 37% of them moderately. According to the differences in perceived pressure, companies consider the importance of environmental issues differently. The main objective of the companies that feel only moderate pressure is compliance to environmental regulations (37%). Companies facing stronger pressure go beyond compliance. Some of them build the expectations of stakeholders (owners, customers, NGOs, etc.) into their environmental policy (41%). The other part of them improves their environmental policy proactively, going beyond expressed expectations (22%). The importance of sources of pressure are shown in figure 1 (0 – not perceptible, 3 – very intensive).



**Figure 1. Average strength of pressure factors in the sample**

**Source: own research**

An important observation on enabler and barrier factors is that respondent companies perceive enabler factors quite strongly. All enablers contribute to their GSCM improvement at least in a small degree. The existing environmental management system has the strongest positive effect, management commitment, potential subsidies and environmentally conscious customers have a medium-strong effect. There is no significant difference between the strength of internal and external factors on 95% confidence level.

Barrier factors were considered weaker than enablers, none of them reached medium strength. The most important barriers are of financial type: the slow return of GSCM investments, lack of financial resources, pressure on prices (customers are not willing to pay more for a more environment-friendly product) and cost based strategy, where there is little emphasis on environmental aspects. Internal barriers are significantly stronger than external ones (on 95% confidence level).

### **3.2. Results on GSCM activity**

The second question to be cleared during the secondary research was the system of GSCM fields, principles and techniques. Here I separated the GSCM fields and GSCM principles, and assigned the techniques mentioned in the literature to the fields/principles. I created a systematized toolset of GSCM, its main elements are shown in Table 4.

**Table 4. Green supply chain management fields and principles**

<b>FIELDS</b>	<ul style="list-style-type: none"> <li>- <b>green design</b></li> <li>- <b>green purchasing</b></li> <li>- <b>green manufacturing</b></li> <li>- <b>green logistics</b></li> </ul>
<b>PRINCIPLES</b>	<ul style="list-style-type: none"> <li>- cooperation in the supply chain</li> <li>- different forms of reuse</li> <li>- lifecycle management</li> <li>- organisational/management commitment</li> <li>- <b>investment recovery</b></li> </ul>

Source: own research

I involved the selected the fields and principles marked with bold in the research questionnaire. The selection was based on the number of techniques each field or principle involve and their applicability for using them in a questionnaire. I used the answers for determining the application rate of the fields, principles and each GSCM technique.

The techniques of **green design** are the less common in the sample – only 46% of the respondent companies use it (for more or less than 1 year). The reason for the relatively low level of application can be that green design does not result quick wins. The positive effect appear later, years after the launch of green design projects. Companies have to take the costs and the risk that makes green design less attractive. Otherwise, there is a reasonable progress potential, shown by answers „I don't use it but I plan to” and „Under launch/implementation”.

The most popular technique is Design for resource efficiency, which includes the reduction of material and energy consumption, the use of renewable energy and the reduction of waste. This method not only helps to reduce environmental impact but at the same time it means cost reduction at the same time. The other two methods with no cost reduction possibilities are less popular, their rate of application is around 40%.

**Green purchasing** has a large toolkit, and the popularity of the different techniques is very different. The average application rate is 54%.

Some of the techniques are administrative ones that requires certain documents or certificates from the supplier. The application of these techniques does not require big effort from the buyer company, so these are the most popular ones (applied by 70-90% of the companies).

Setting environmental requirements for purchased items and replacing material with a more environment-friendly alternative are more time-consuming, applied by half of the companies for more than 1 year. Sharing product design plans with the supplier, which requires high level of trust, shows similar patterns.



The least popular techniques aim the development or support of the supplier. These methods are very costly and require specific investment to the supplier. This can be the reason for the low application rate, which does not exceed 20%. Evaluation of second-tier suppliers is also not popular.

The average popularity of **green manufacturing** methods is high, 71%. Techniques aiming the reduction of material or energy usage have the highest application rate. The reason can be that both techniques have a positive side effect on costs, and it can be realised in the short run.

Integrating the different forms of reuse into the manufacturing process is less popular but the number of planned and underway implementations is remarkable (19%).

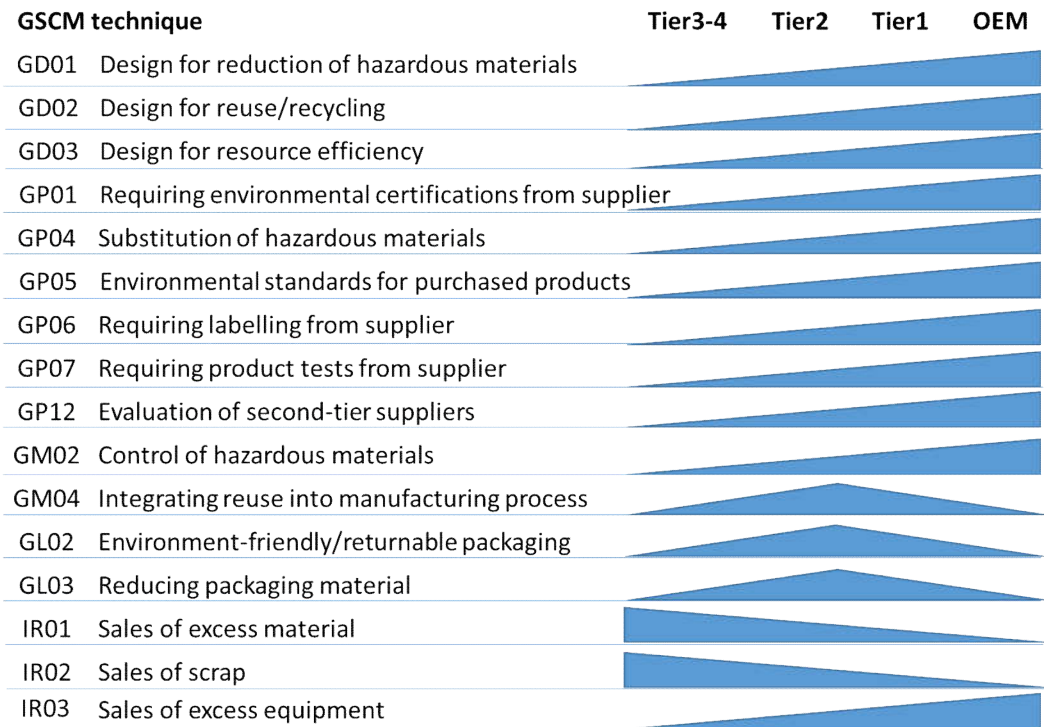
**Green logistics** techniques show big differences in the rate of application. The average rate is 58%. The most popular techniques aim the reduction of the environmental impact of packaging and the increasing efficiency of transportation. The application rate of these methods is between 72 and 78%, with a remarkable rate of recent introductions.

Reverse logistics is applied by no more than one third of the companies, and half of them do not plan its introduction. Environment-friendly modes of transport are also less popular, but it is not only an environmental consideration: it depends also on the logistics characteristics of the product, on the distances and on the timing of deliveries.

The techniques of **investment recovery** and better equipment usage are quite popular, an average of 72% of the respondents apply them. Most companies sell the scrap material but very few additional companies plan it. Sales of excess equipment and material is performed by 70% of the sample companies and the potential progress is also high.

I analysed the differences in the advancement of GSCM along the supply chain. I proved that supply chain members that are closer to the consumer apply GSCM on a higher level than members of the supplier end of the chain. I assessed the pattern of the advancement of GSCM techniques, these patterns are shown on Figure 2.

For 16 out of the 25 GSCM techniques I proved that they are applied on a significantly higher level in certain sections of the supply chain. Green design and green purchasing are significantly more popular in companies on the customer end (OEM and Tier1 supplier). Green manufacturing is most applied in the middle of the chain (Tier1-2-3), although control of hazardous substances has an important role also in OEMs. The environment friendly packaging techniques of green logistics are applied the most intensively in the middle of the chain too. Sales of excess material and scrap (techniques of investment recovery) are popular in Tier3-4 suppliers.



**Figure 2. Intensity of use of GSCM techniques in the different parts of the supply chain**  
Source: own research

### **3.3. Results on the correspondence between traditional and green supply chain management**

I grouped the companies into categories based on the answers given to questions on supply chain management methods, then used ANOVA to compare the GSCM-intensity of groups. The analysis was prepared using LSD and Games-Howell post-hoc tests.

According to the ANOVA results, 45 out of the 90 SCM method – GSCM area pairs, i.e. in 50% of the cases, there is significant difference in GSCM intensity among groups created based on SCM methods. Table 5 shows the pairs where this difference was significant at a 95% confidence level (marked with ticks).

**Table 5: Relationship between traditional and green supply chain management techniques**

SCM field	SCM technique	Green design	Green purchasing	Green manufacturing	Green logistics	Investment recovery
Information sharing	Partners inform each other of changing needs		✓	✓	✓	✓
	Partners hold regular personal consultation	✓	✓	✓	✓	
	Partners give each other feedback on performance		✓		✓	
	Partners share all information that may help the other					
	Partners share information even when it is sensitive from a business point of view					
Cooperation	There is consensus in the management that the supplier needs to be involved in the design process	✓	✓	✓	✓	✓
	Cooperation in planning and solving operative issues	✓	✓	✓	✓	✓
	The supplier take part in product design	✓	✓	✓	✓	
	Establishing joint workgroup(s) with partner company	✓	✓	✓	✓	
	Partners consolidate their decisions in the interest of cost efficiency	✓	✓		✓	
Investment into partnership	The company has made significant financial investment in order to improve cooperation	✓	✓	✓	✓	
	The company has made HR-investment in order to improve cooperation	✓	✓	✓		
	The company has shared their protected know-how or technology with their partner in order to facilitate cooperation	✓	✓			
Commitment to partnership	The company is planning to maintain the cooperation for the long-term	✓	✓			
	The company's partner is planning to maintain the cooperation for the long-term	✓	✓			
	Purchasing decisions are typically not based on price		✓		✓	
	The company shares the jointly realized profits with the supplier					
	The company typically makes hedge contracts with suppliers to protect its own interests					

Source: own research

According to the table, the most differences between the intensity of GSCM methods between groups based on SCM are measured the area of **green purchasing**: it affects 14 out 18 SCM methods. The post hoc tests show that the more intensive use of SCM methods correspond to a higher intensity rate for

green purchasing, which means that generally well-developed supplier-customer relationships can be effectively utilized in green purchasing.

The area of *green design* also shows significant differences between the groups for several (11) SCM methods, which typically affects the areas of cooperation and investment in partnerships.

Another area that showed significant differences for several (10) SCM methods was *green logistics*, where post hoc tests matched the results of the two areas presented above.

Fewer (8) SMC methods showed significant differences between the groups for *green manufacturing*. This result is surprising, given the fact that manufacturing is an internal process, meaning that suppliers have a lesser impact on it than on other elements of the supply chain that are closer to them, such as purchasing or logistics.

The study of *investment recovery* did not give relevant results, which corresponds to our expectations given the lack of logical connection.

The *importance of cooperation* is exceptional among traditional SCM areas. All methods discussed in the questionnaire showed significant differences in all GSCM areas. It can be concluded that companies using forms of cooperation more intensively in their partnerships have a higher development rate in GSCM areas.

### 3.4. Results on GSCM performance

I revealed the differences in GSCM performance measurement along the supply chain. I used the following performance categories:

Environmental performance (8 indices)

Economic performance (11 indices)

Operative performance (7 indices)

Other performance (4 indices)

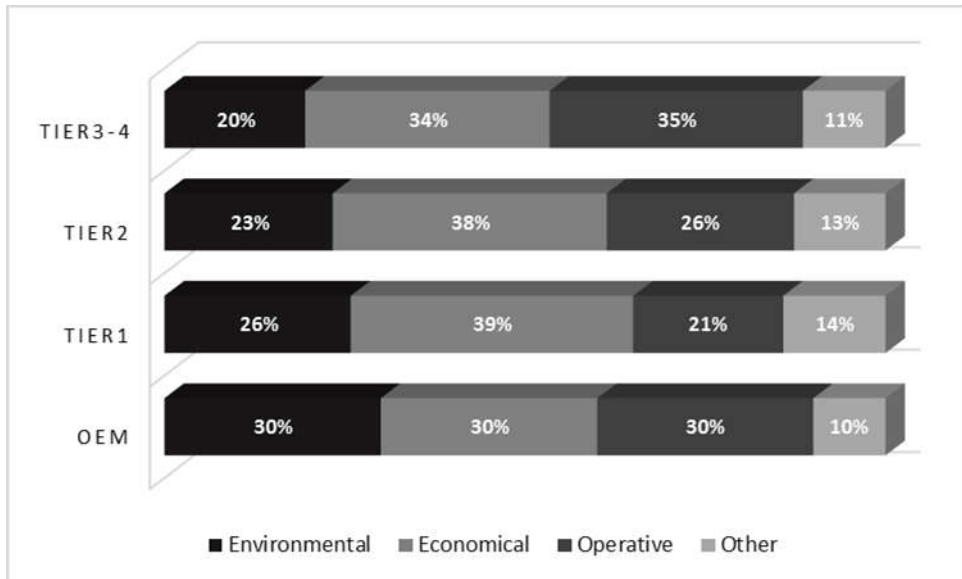
The OEMs have the most improved performance measurement system, since they measure all indices listed in the questionnaire. The supplier levels show differences in performance measurement: the number of measured indices decrease as we move on from Tier 1 to Tier 3-4. The average number of measured performance indices for each supply chain role is shown in Table 6.

**Table 6. Average number of regularly measured performance indices along the supply chain**

	Average number of indices
OEM	29,0
Tier1	26,5
Tier2	26,9
Tier3-4	22,1

Source: own research

The importance of performance categories are different in the supply chain roles: Environmental performance has decreasing importance, while operative indices have increasing performance as we move on from the OEM to Tier 3-4 suppliers (see Figure 3):



**Figure 3. Importance of performance categories along the supply chain**  
Source: own research

When analysing the relationship between GSCM practice and performance I was looking for the correspondence between the applied GSCM techniques and the changes in performance perceived by sample companies. I tested if company groups that measured different changes in performance had different GSCM intensity. I did analysis of variance (one-way ANOVA) together with LSD and Games-Howell post-hoc tests. The post hoc tests showed the groups with significant difference in GSCM intensity. The plots of the group averages showed how the groups differ from each other.

According to the results, except for some cases, the company group that perceived improvement in performance had significantly higher GSCM intensity index than the groups that perceived no or negative change in performance. Consequently, more developed GSCM fields coincided with better performance. This tendency applied the most to environmental performance, where is 32 out of 40 cases (8 indices  $\times$  5 GSCM fields) the more intensive GSCM activity concurred better performance. This means 83% of index-field pairs. This ratio was 56% in the case of economic performance and only 29% for operative performance. For 53% of the index-field pairs were performance better in the GSCM-intensive group in the case of other performance category. From the point view of the GSCM fields, green purchasing excels with being in

correspondence with the most performance indices. Investment recovery has the least connection with performance.

### **3.5. New scientific results**

The importance of my research is that green supply chain management is a lesser-researched topic in Hungary for the present.

#### **1.**

I created a **new, complex and structured model of motivation for GSCM**, based on the research results published in international literature. The model includes and systematizes the factors that motivates or hampers companies in applying green supply chain management methods. The novelty of the model is that it groups factors based on their power: the first level involves the coercive factors, the influencing but not coercive factors compose the second level. I grouped the latter ones into internal-external and enabler-barrier factor groups. The new motivational model helps the better understanding the effects on companies, finding their sources and assess their power. With the help of this model managers can have better insight of the factors they can rely on or they have to eliminate when improving their green supply chain management toolset. The model can also be used in further academic research: it helps the comparison of GSCM motivation between industries and/or countries, regions.

#### **2.**

**I created five groups of sample companies that have significantly different motivational background using cluster analysis.** The grouping was based on the pressure for GSCM, and the power of enabler and barrier factors.

Managers can position their company easily by assessing the motivation factors that describe their company. The results I presented for each cluster regarding GSCM techniques and performance measurement can help the evaluation of the present status of the company and decision-making on green supply chain management. The clusters can be used to further academic research.

#### **3.**

In the secondary research **I assessed and systematized the fields of green supply chain management, the related techniques and the general green supply chain management principles.** Separation of fields and principles helps to clear the role, aim and general or activity-specific nature of GSCM techniques. This system of GSCM techniques can be used in further empirical studies.

4.

**I assessed the green supply chain management practice of the Hungarian automotive sector.** I assessed the application rate of the GSCM fields and techniques along the supply chain (T3, see chapter 4.1). I defined

- the application rate of each GSCM technique in the sample;
- the development potential (expected introductions in the near future) of each GSCM technique in the sample;
- the differences in application rate of each GSCM technique along the supply chain;
- the differences in application rate of each GSCM technique between groups with different environmental objectives.

By these analyses I presented a complex picture of the current situation of GSCM in the focus industry.

5.

**I proved the relationship between traditional and green supply chain management** (T4, see chapter 4.1). The analyses of variance verified that in companies with a higher level of supply chain management practice the GSCM fields (principally green purchasing, green design and green logistics, in smaller scale also green manufacturing) are more developed. Forms of cooperation in the supply chain proved to be in the strongest relationship with GSCM, but information sharing and dedicated investments had also remarkable strength of relationship with some GSCM fields. My results confirm the hypothesis that companies which cooperate intensively with supply chain partners, and are willing to share information and make dedicated investments, are more likely to apply green supply chain management techniques successfully.

6.

**I assessed the performance measurement system of green supply chain management and its differences along the supply chain.** I confirmed that there are differences in the development stage and in the importance of the different performance categories between supply chain roles (T5, see chapter 4.1). I proved that in the Hungarian automotive sector

- performance management system includes an increasing number of performance indices;
- the importance of environmental performance is increasing;
- the importance of operative performance is decreasing

as we move on from the Tier3-4 suppliers to the OEM in the supply chain.

7.

**I assessed the relationships between** green supply chain management fields and GSCM performance indices. I confirmed that the more developed the GSCM fields are, the more perceptible the positive changes of the performance

indices are (T6, see chapter 4.1). I defined which performance indices correspond to the development (intensity of application) of which GSCM field.



## 4. Conclusions and recommendations

### 4.1. Conclusions, theses of the research

*H1: Primary motivation of focus companies for the application of GSCM techniques is compliance with regulations. Proactive behaviour is not typical.*

The hypothesis was **not confirmed** by the research results. Compliance was the primary motivation of less than one third of sample companies, for two thirds fulfilling stakeholder or own internal expectations was the primary motivation. Proactive behaviour was present at a reasonable part of the sample. I modify the statement of the hypothesis according to the results, and accept the modified statement as thesis.

***T1: Primary motivation of focus companies for the application of GSCM techniques is compliance with expressed expectations of stakeholders, especially parent company and customers. Proactive behaviour is remarkably present.***

*H2: Motivating and barrier factors of GSCM are different in the focus group based on the supply chain role of the company.*

The hypothesis was **not confirmed** by the research results. Supply chain role didn't determine motivation, there was no noticeable pattern that could describe the relationship between motivation and supply chain role. Further analyses (motivational clusters) implied the correspondence between motivation and role but only together with other factors (company size, ownership) was it applicable to describe the characteristics of the clusters. Therefore, I do not formulate any thesis based on hypothesis H2.

*H3: Level of development and the applied GSCM techniques are different in the focus group based on the supply chain role of the company.*

The cross-tabulation analysis showed significant relationship between supply chain role and the ratio of applied GSCM techniques. I compared the number of applied techniques in each group based on supply chain role, and confirmed that the number of GSCM techniques is significantly higher at the OEM end of the chain than at the supplier end. The most improved group turned out to be the integrators (Tier1 suppliers), followed by OEMs and Tier2 suppliers at the same level, then by Tier3-4 suppliers. It is important to note that if we took into account only the results of multinational OEMs, the results would be the same as it is stated in the hypothesis – GSCM development shows a decreasing tendency as we move on from the OEM to the suppliers.

I formulate the following thesis on GSCM development in the supply chain:

***T2: The development of GSCM and the number of applied techniques is the highest at companies that are close to the consumer, and it is gradually decreasing as we move backwards in the supply chain.***

*H4: Applied GSCM fields and techniques are different in the focus group based on the supply chain role of the company.*

The results confirmed the relationship between supply chain role and the development level of GSCM but the direction of the relationship is different for each GSCM field:

<i>Green design</i>	<i>More developed: OEM end of chain</i>
<i>Green purchasing</i>	<i>More developed: OEM end of chain</i>
<i>Green manufacturing</i>	<i>More developed: middle of the chain</i>
<i>Green logistics (packaging)</i>	<i>More developed: middle of the chain</i>
<i>Investment recovery</i>	<i>More developed: supplier end of the chain</i>

I **accepted the hypothesis**, since in case of 16 out of the 25 GSCM techniques the application rate was significantly higher in a given section of the supply chain. I formulate the following thesis based on hypothesis H4:

***T3: Applied GSCM fields and techniques are different in the focus group based on the supply chain role of the company: green design and green purchasing is the most intensively applied at the OEM end of the chain, green manufacturing and green packaging is characteristic to the middle of the chain and investment recovery is mostly applied at the supplier end of the chain.***

*H5: The more developed traditional supply chain management is in a company, and the closer cooperation exists between partners, the more developed GSCM can be.*

Results show that the different GSCM fields show different rate of correspondence with traditional supply chain methods. The closest relationship with traditional SCM was found in the case of green purchasing, than follows green design, green logistics and green manufacturing in decreasing order. Investment recovery showed no correspondence with supply chain management methods.

From the point of view of the traditional SCM methods, cooperation had the strongest relationship with GSCM. Only some techniques of information sharing were in significant relationship with GSCM, while the dedicated investments corresponded only to certain GSCM fields.

Based on the results I **accepted hypothesis H5**, and formulated the following thesis:

***T4: Companies with more developed traditional supply chain management have higher level of green supply chain management.***

*H6: Attitude towards GSCM performance measurement and measured performance categories are different in the focus group based on the supply chain role of the company.*

The analysis of the importance of the GSCM performance categories confirmed that environmental indices have the greatest importance for OEMs, and their importance gradually decreases as we move towards Tier3-4 suppliers in the supply chain. At the supplier end of the chain operative performance was considered as most important by companies. Based on the results **I accepted hypothesis H6**, and formulated the following thesis:

***T5: The development level of green supply chain performance measurement (the number of regularly measured indices) shows a growing tendency as we move from Tier3-4 suppliers towards the OEM in the supply chain. Environmental performance has greater importance for the OEM and integrators, operative performance is considered as most important at the supplier end of the supply chain.***

*H7: The more developed the GSCM fields are, the more perceptible the positive changes are in the GSCM performance categories.*

The analysis of variance confirmed the existence of relationship between perceived change in performance indices and the development of GSCM fields. **I accepted hypothesis H7** and formulated the following thesis:

***T6: The more developed the GSCM fields are in a company, the more perceptible the positive changes are in the GSCM performance categories.***

#### **4.2. Limitations of the research and further research possibilities**

The greatest limitation of the research is the low response rate and the consequently small sample size. The low response rate applied especially to Tier 3-4 suppliers. This supplier level has the most members in the population and in the same time it is the most heterogeneous group (as it is perceptible in the sample as well). Extending the survey to more Tier3-4 suppliers offer further research possibility. Reaching the sample number that provide representative sample composition would allow the researcher to draw general conclusions regarding Hungarian automotive supply chains. By larger sample size further analyses would be possible based on other characteristics (e.g. company size, ownership, served markets) of the supplier companies in each level. The importance of these characteristics turned out during present research, for example in the case of motivation. A larger sample would give a chance to understand supplier characteristics better, and create relevant supplier groups with cluster analysis.

Another research option is doing the survey on selected supply chains. In the present research I analysed the companies of the supplier levels as groups, but the sample companies are not necessarily partners, they can belong to different supply chains. Doing the survey along selected supply chain, using snowball sampling technique could reveal the effects that the partners have on each other.

The research question in this case could be that how the environmental attitude and green supply chain management practice of the dominant chain members (OEMs and possibly the integrators) influence the same characteristics of their suppliers.

The research could also be extended to the downstream branch of the automotive supply chains. Although the literature concentrates on the upstream side when researching green supply chain management methods and other aspects, but some fields (for example green logistics) could be studied also in the distribution network.

Another research possibility is to assess the hierarchy of GSCM techniques, the typical order of their introduction in companies. It could be realised by preparing detailed case studies on some selected companies with developed GSCM practice. The results could be compared with previous research results from other geographical areas (for example Zhu et al. 2007, Diabat and Govindan 2011, Lin 2013), see also in Gábriel (2013).

## 5. Related publications

### Academic book, book chapter

#### In foreign language

1. **Gábrriel Monika** – Miskolczi Mátyás (2012): A synthesized model of development of logistics organization and company lifecycle. In: Csaba Bálint Illés (editor): SMEs' Management in the 21st Century – Challenges and Solutions (Monograph). Częstochowa, 2012. pp.41-53. (ISBN 978-83-63500-16-0)
2. **Gábrriel Monika** (2014): Motivations and barriers of Green Supply Chain Management – A literature review. In: Csaba Bálint Illés – Anna Dunay – Anna Słocińska (editor): New trends in management in the 21st century (Monograph). Częstochowa, 2014. pp.61-72 (ISBN 978-83-63500-78-8)

### Papers in scholarly periodicals

#### In foreign language

1. **Monika Gábrriel** (2016): Green Supply Chain Management – Motivation, Methods and Expectations - in Hungarian Automotive OEMs. *Theory Methodology Practice – Club of Economics in Miskolc* 12:(01) pp.37-45 ISSN 1589-3413 (Print) DOI: 10.18096/TMP.2016.01.05
2. Mátyás Miskolczi – **Monika Gábrriel** (2008): Finding the logistics organization that fits using fuzzy logic. *Acta Technica Jaurinensis Series Logistica* Vol. 1. No. 2. pp.343-354. Széchenyi István University Győr 2008. ISSN 1789-6932
3. Mátyás Miskolczi – **Monika Gábrriel** (2010): Logistics focused cluster analysis of Hungarian SMEs. *Acta Technica Jaurinensis Series Logistica* Vol. 3. No. 3. pp.355-366. Széchenyi István University Győr 2010. ISSN 1789-6932

#### In Hungarian

1. Miskolczi Mátyás – **Gábrriel Monika** (2003): A Rendszerintegrátor az ellátási láncban. *Logisztikai Évkönyv* 2003. Magyar Logisztikai Egyesület Budapest. 2003. pp.89-95. ISSN 1218-3849
2. Miskolczi Mátyás – **Gábrriel Monika** (2008): A logisztikai szervezet és a vállalatirányítási rendszer szerepe a vállalati növekedésben. *Logisztikai Évkönyv* 2007-2008. pp.123-128. Magyar Logisztikai Egyesület Budapest 2008. ISSN 1218-3849

## **Presentation or paper published in scientific conference proceedings**

### **In foreign language**

1. Mátyás Miskolczi – **Monika Gábrriel** (2005): System integrating factors in supply chains corresponding with certain factors of Porter's Five Forces Model. In: „MendelNet 2005” című konferencia kiadványa, Mendelova zemědělska a lesnická univerzita v Brně, Brno 2005. ISBN 80-7302-107-2 (abstract) p.77, ISBN 80-7302-107-2 (full paper CD)
2. Mátyás Miskolczi – **Monika Gábrriel** (2005): Identification of the dominant member of the supply chain using Porter's Five Forces Model. In: „MendelNet 2005” című konferencia kiadványa, Mendelova zemědělska a lesnická univerzita v Brně, Brno 2005. ISBN 80-7302-107-2 (abstract) p.78, ISBN 80-7302-107-2 (full paper CD)
3. **Monika Gábrriel** – Mátyás Miskolczi (2012): Logistics organization in the company lifecycle. In: Proceedings of the International Conference on Management of Human Resources, Szent István Egyetem, Gödöllő, 2012. pp. 227-234. ISBN 978-963-269-294-4
4. **Monika Gábrriel** (2015): Green Supply Chain Management in Hungarian Automotive OEMs' practice. In: Proceedings of the 5th International Conference on Management 2015: Management, Leadership and Strategy for SMEs' Competitiveness, Szent István Egyetem, Gödöllő, 2015. pp.432-438. ISBN 978-963-269-492-4; DOI: 10.17626/dBEM.ICoM.P00.2015.p080
5. **Monika Gábrriel** – Zoltán Szegedi – Gábor Nick (2017): Environment Conciousness in the Hungarian Automotive Supply Chains – An Empirical Study. International Symposium on Logistics. Ljubljana, 9-12. July 2017. (befogadott publikáció)

### **In Hungarian**

1. Miskolczi Mátyás – **Gábrriel Monika** (2004): Ellátási láncok a hazai agrárszektorban In: XLVI. Georgikon Napok, “Új kihívások, új lehetőségek a mezőgazdaságban” című konferencia kiadványa, Veszprémi Egyetem, Georgikon Mezőgazdaságtudományi Kar, Keszthely. ISBN 963 9096 0920 X (abstract) p.165; ISBN 963 9096 962 (full paper CD)
2. **Gábrriel Monika** (2013): Alapkonceptiók és kutatási lehetőségek a zöld ellátási lánc menedzsmentben. In: "Felelős Társadalom Fenntartható Gazdaság. Nemzetközi tudományos konferencia. Tanulmánykötet/Proceedings." Nyugat-magyarországi Egyetem Kiadó, Sopron. pp.400-417. ISBN: 978-963-334-144-5

## Other articles

### In foreign language

1. Mátyás Miskolczi – **Monika Gábríel** (2012): Método de Clasificación con Lógica Difusa para los Modelos de Crecimiento de la Empresa y la Investigación de una Muestra de Empresas Húngaras.  
<http://www.monografias.com/trabajos91/clasificacion-logica-difusa-modelos-crecimiento-y-investigacion-empresas-hungaras/clasificacion-logica-difusa-modelos-crecimiento-y-investigacion-empresas-hungaras.shtml>