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Use of Quantitative and Qualitative Methods for Modelling Green Supply Chains

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ABSTRACT

Interest in the field of the development and implementation of the principles of green supply chains is increasing. Among theorists and practitioners of management, they are seen as a new trend and an innovative strategy. Ever-increasing customer requirements, the development of economies in the direction of closing the loop and the depletion of resources lead to a situation in which innovative solutions (including green supply chains) should be implemented. Qualitative and quantitative tools are used to assess their operations. This paper focuses largely on aspects of quantitative statistical methods that are used to assess individual elements of a supply chain, as well as a holistic approach to the evaluation of the entire chain. The methods that were chosen are an attempt to build a framework for a model and determine which of the tools are used in practice. The analysis includes an indication of the advantages, as well as the limitations, of the use of particular instruments. The second part of the paper includes an analysis of qualitative tools, devoting particular attention to tools and instruments from the area of management.

Keywords: *green supply chain, qualitative and quantitative methods, management tools*

1. INTRODUCTION

Study of the barriers and determinants of the functioning of green supply chains and their processes is a relatively new research field. Various methods, techniques, principles and concepts are used in the research process. A taxonomic approach, which organizes knowledge, as well as the presentation of the most common methods reported in the literature, is one of the main objectives of this work. It is important to present assessment models of green supply chains that include both quantitative and qualitative methods.

The integration of environmental factors into the framework of the supply chain is becoming increasingly important, in light of factors including managerial decisions. Regardless of the level (strategic, tactical or operational), the modeling methods and techniques presented support their application in supply chains. Quantitative and qualitative methods are used in practice and are implemented in order to assess the functioning of individual processes, cells and components, as well as the entire supply chain. The activities undertaken and the use of these types of tools have an impact both on the strategic management of the entire supply chain, and on those actions in the framework of operational management.

Considerations beyond the cognitive and ordered goals are also supported by the results of empirical studies relating to the use of qualitative methods (with particular emphasis on those in management) in the modeling and management of green supply chains in the Polish context.

The research methods used to evaluate green supply chains are qualitative and quantitative. By processes modeling, as well as to the assessment of individual processes and decisions in the chain are used a different approach and model types.

2. AIM AND RESEARCH QUESTIONS

This research has two principal objectives: (I) to identify the mathematical, statistical and operations research tools used to assess the activity, performance and level of the greening of the supply chain. This is possible on the basis of an analysis of the literature. The second goal (II) is to identify the management tools that can be used, as part of research on the greening of the supply chain. This process has been accompanied by practical verification, on the basis of empirical research conducted in business units in Poland. The goals are accompanied by specific objectives, which allowed for the achievement of the main objectives. These include: (1) classification of knowledge, including identification of the various methods and techniques for evaluating the functioning of green supply chains; (2) assignment of tools and techniques to specific processes and management levels; (3) an indication, based on empirical research, of which tools are used in Poland to evaluate supply-chain activities.

The stated purposes accompanied the following research thesis: (a) a large number of methods which are used to study the relationships in a supply chain are benefits / barriers to creating a supply-chain evaluation model; (b) standard methods of analysis of the supply chain could be dedicated to research on green supply chains; (c) a green supply chain requires dedicated and specific tools for the evaluation model; (d) analysis of selected industries showed that the knowledge and range of tools used by management to assess the functioning of a green supply chain are dependent on various considerations. In this regard, the sector, company size and role in the supply chain have great importance.

This approach allows us to indicate ways of modeling green supply chains and the variety of tools available for research on them, as well as showing the solutions that can be used to evaluate the usefulness of the available tools. Both

elements may give rise to the creation of a conceptual model for assessing green supply chains, in which the elements typically associated with operations research are combined and reflect a holistic approach to evaluation of green supply chains.

3. RESEARCH PROCESS

The research process was divided into several stages, and describes two areas (empirical research and identification of qualitative and quantitative tools). In the first stage, a review of literature related to supply chains (with particular emphasis on green supply chains) was conducted. The review was performed in the context of identifying the quantitative tools in the area of operations research that are used to evaluate and measure processes in the chain. These analyses were based on literature studies. This phase also included analysis of the qualitative tools, with particular emphasis on management tools, in the context of their use for research related to green supply chains. A general assessment was made on the basis of the literature in order to show the extent to which various quantitative methods are most useful in the various processes. The next stage was the construction of a preliminary model – using tools for evaluating green supply chains (divided into levels of management: operational, tactical, strategic and process approaches). The next stage analyzed responses to a questionnaire on the use of tools to evaluate green supply chains. The questions were directed to three selected industries: Food Industry – Conventional, Food Industry – Organic, Clothing manufacturing, Home appliance manufacturers, Grocery and general merchandise retail networks, Home appliance retail networks, Apparel retail networks. On the basis of a randomly selected sample, 332 companies were examined. The research process is shown in **Figure 1**.

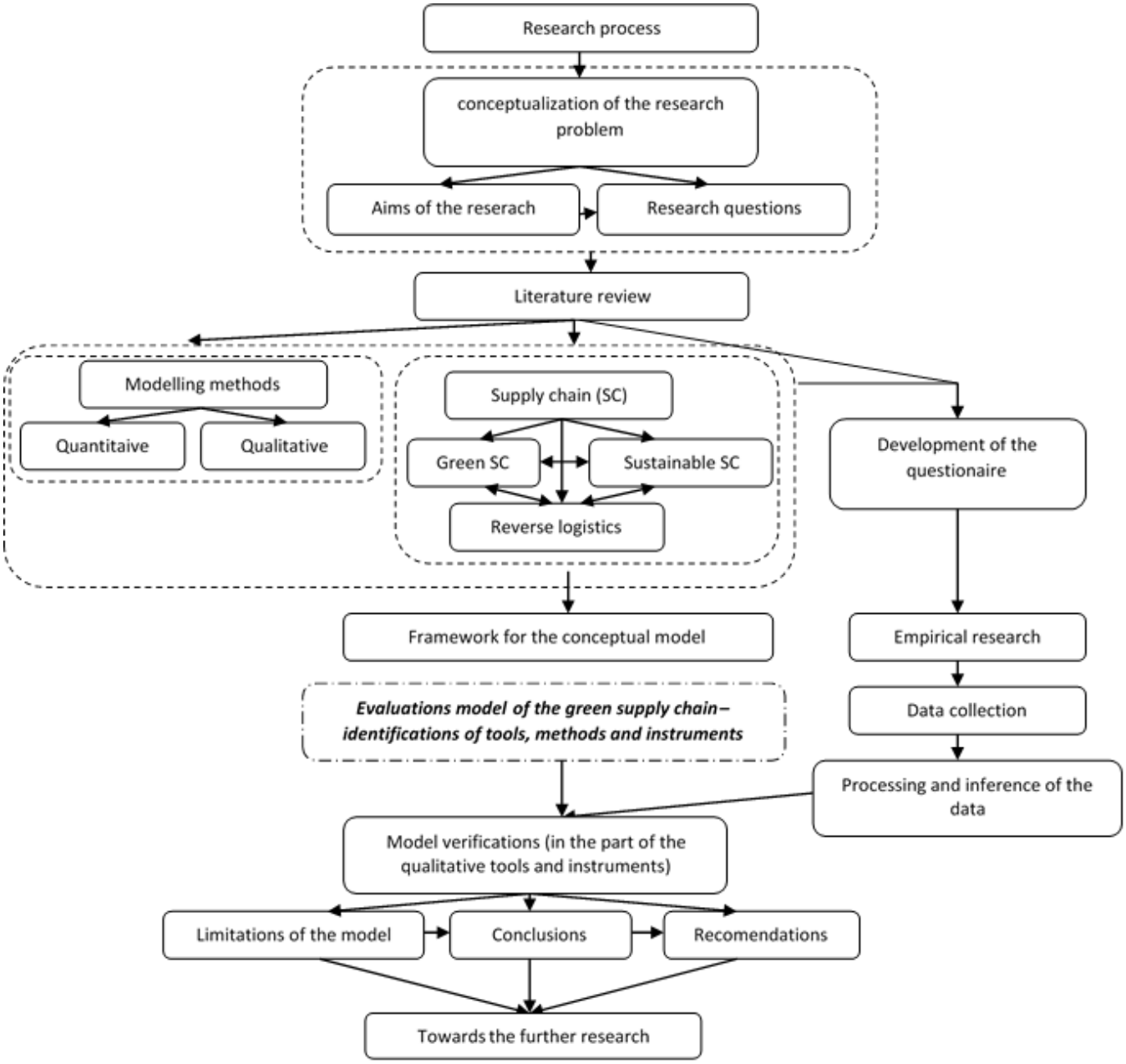

Figure 1 Research process

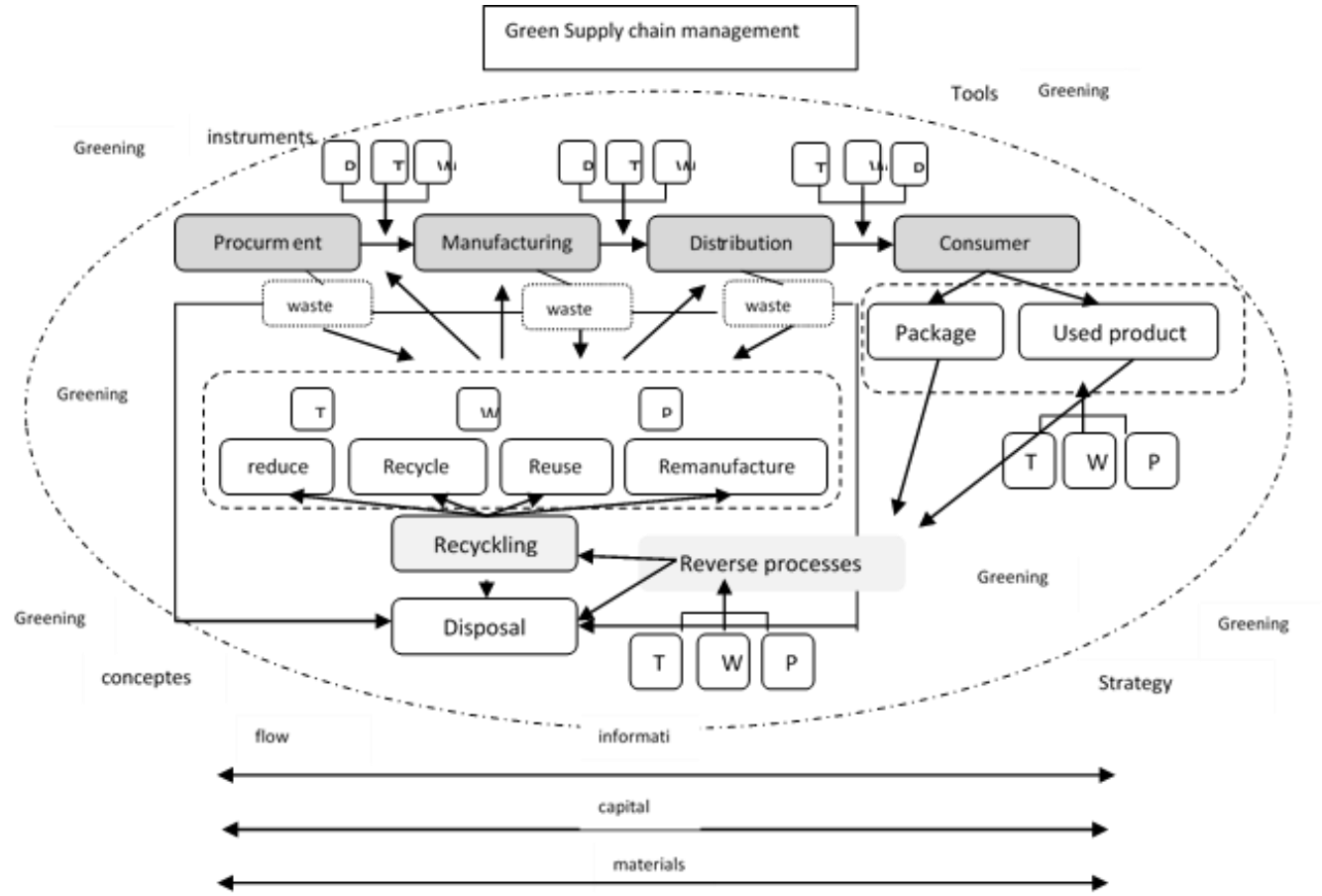

Figure 2 Green holistic approach in the supply chain

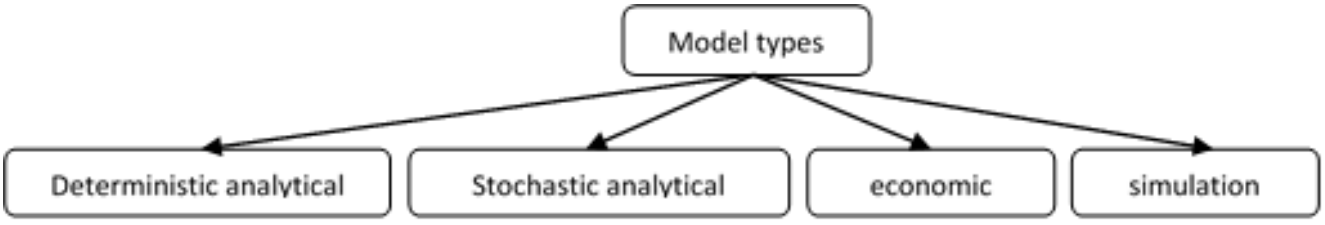

Figure 3 Model types

Source: On the basis on: Beamon, B. M. (1998)

Conclusions were drawn on this basis, and limitations were identified both in the study and in the use of particular tools. On the basis of the literature, the quantitative methods most often used in practice were identified. On the basis of empirical research conducted by the author, the tools and concepts related to management and their usefulness in Polish conditions were identified. The part of the model relating to the use of management methods was identified. The second area of the model and its verification is a further part of the research on green supply chains in Poland.

It should be noted that the literature is one of the most important bases for further empirical research. The literature allows us to find the ideas, concepts and methods used in the research field without having to rely on data collected in person by the author. It allows the review, identification, critical evaluation and resumption of studies already carried out, giving pointers to identify problems and adapt them to the needs of detailed research. Additionally, it helps to identify the conceptual content of the field (Fink, 1998) and develop the theory.

An overview of the literature allows the identification of the basic concepts, but also of the items whose identification is the most important goal of this article: the tools (qualitative and quantitative) that can be used to build a model for assessing a green supply chain. Here it was important to verify a model based on empirical research. This research is conceptual, and part of the conceptual model has been empirically verified. The structure of the model should take into account a different paradigm in connection with the use of mixed research methods. It should be a quantitative paradigm based on all stages of the research process for the quantification of the observed reality. In the qualitative paradigm, quantitative elements are largely ignored, and the effect of such research is the interpretation of the test subject and the verbalization of real-world experience (Bortz, Döring 2002).

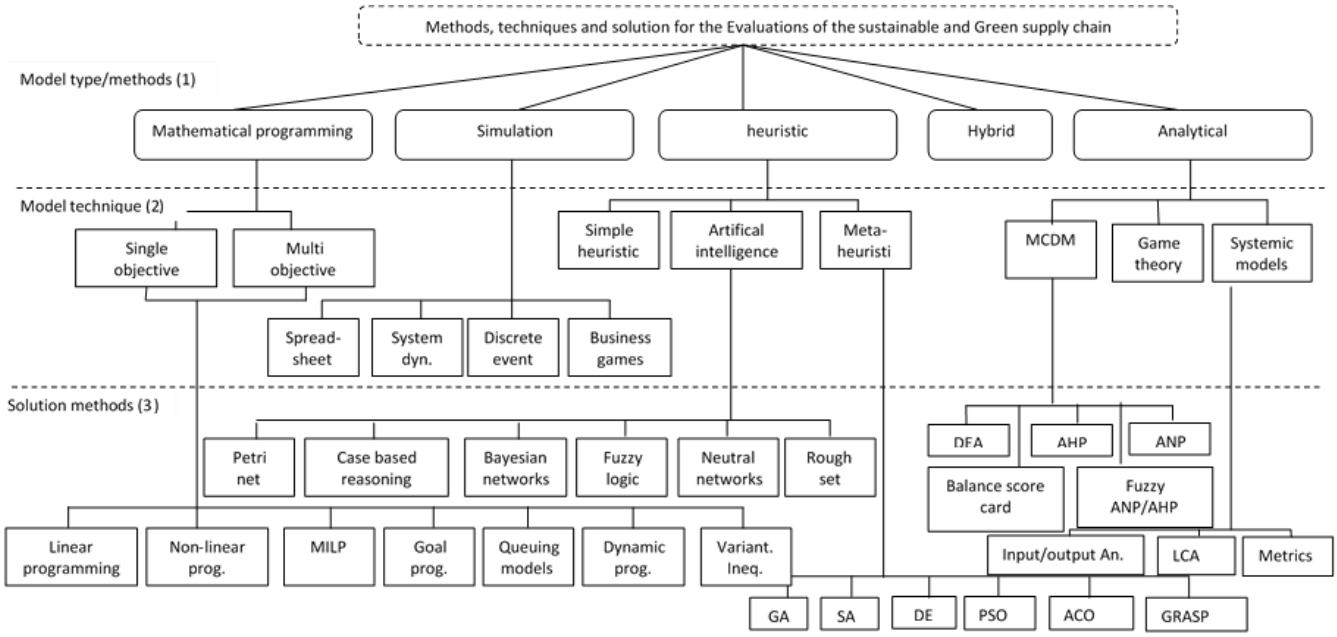

Figure 4 Methods, techniques and quantitative tools used to assessment of the sustainability and green supply chain
Source: based on: Sasikumar & Kannan (2009) and Brandenburg et al. (2014).

4. LITERATURE REVIEW

a. Green Supply Chain

The literature in this area is extremely rich. It should be noted that the greatest contribution to the literature came from: Zhu, Q., Sarkis, J. (2004, 2006), Beamon (2008) and S. K. Srivastava, (2007) Vachon & Klassen (2006), Carter & Jennings (2004), Salam, (2009), Lee, (2008); Walker et al., (2008), Sarkis et al. (2011), Capgemini Consulting (2011), Carter & Dresner (2001), Lamming & Hampson (1996), Welford & Frost (2006), Rao & Holt (2005), Carter & Carter (1998); Hall, (2000), Preuss, (2001). Kleindorfer et al. (2005); Rothenberg et al. (2001); Simpson & Power (2007), Guide & Van Wassenhove (2009); Wu & Dunn (1995), Seuring (2012), Brandenburg et al. (2014), Seuring, & Müller (2008) Yakovleva et al. (2012).

This subject has been identified as a research field for more than 20 years. However, at this point it should be noted that there are visible deficiencies both in the literature and in the practice of business in Poland. Therefore, the construction of the model and its verification in management methods and qualitative factors was based on empirical research conducted in Polish enterprises.

In the context of this discussion, it is important to indicate that this is a holistic approach, as well as a redesigned way of thinking and using the current method to analyze supply chain management, which takes into account environmental aspects.

In particular, it seeks to identify the organization of logistical processes that is the least burdensome and harmful to the environment. The resources of the literature offer the ability to appreciate that the essence of a green supply chain (in the context of projects, practical solutions, new management systems) is integration of processes, operations and environmental activities, while simultaneously increasing the standards of logistics and implementation of modern concepts - redesigning the supply chain. Improving green supply chain practices covers the area of product lifecycle management, the implementation of specific tools and components in the processes taking place in the chain: procurement, production, distribution, recycling, packaging, transportation and storage; paying attention to aspects of time, quality, cost and flexibility. In addition to the definition of a green supply chain and the processes included in its scope, the concept of holistic management of a green supply chain must be defined. "Green SCM is defined as an integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life" (Srivastava, 2007)

Guided by a holistic approach, it should be indicated that the greening of processes must occur at every stage of the life cycle of the product and the processes related to reverse logistics (including recycling). Thus, specific methods and tools can be used to assess the functioning of the supply chain. The holistic approach is presented in **Figure 2**.

An approach that takes into account the greening of processes, which is to form the basis and framework for a green supply chain, must address all processes; it must include a redesign of strategy and alignment of the appropriate tools and instruments. "Greening" refers to processes as well the choice of the strategy and tools to support them. Green supply chains differ from traditional ones in that green supply chain management is integrated into the entire process, including planning, procurement, production, consumption and reverse logistics. The entire supply chain is managed as a green system, and every process focuses on environmental management and risk control. (Sulistio, & Rini, 2015).

Table 1 Methods and techniques using in the evaluations of the supply chain

Criteria				
Management approach	External and social aspect	Organizational change	Technical aspects	Performance measuerment
Sub-criteria				
• Top management commitment and support • Environmental policy • International, governmental and domestic environmental agreements and legislations	• Effective communication within companies and suppliers • Environmental auditing for suppliers • Green image	• Environmental education and training • Manpower involvement	• Green purchasing • Green design • Green and cleaner production • Green packaging • Green labels • Reuse, recycle and recovery of material • Reduce energy consumption	• Cost • Flexibility • Time • Consumer Responsibility • Quality
Methods and techniques				
Value and supply chain model M.E. Porter, Seuring and Goldbach matrix, quality filter mapping, supply chain response matrix, physical structure mapping, decision point analysis, Method Eraned Value, Model SCOR, Model GSCF, Model APQC, Process mapping, Balanced score card, production variety funnel, demand amplification mapping, CPM, PERT, CCPM, SixSigma, cause and effect diagram (Ishikawa), TQM, value stream analysis, ERP, SCM, process activity mapping, matrix diagram, Organization and standardization of the workplace, Ecoaudit, accreditation and certification EU, ISO certificates (ISO1400x), ISO 14031, ISO 14001, Meters and indicators of eco-efficiency, LCA, Evaluation of the carbon footprint, Evaluation of the water footprint, TQEM, Just in time, Tools of the Certification of suppliers, Regulations consistent with the protection of the environment, Environmental Management System, Environmental methods for supplier selection, Environmental method of selection of business partners, Planning with partners, Informations sharing, Process orientation, SMART, Model ROF, Models of diffusion of innovation, The ability of models of organizational learning, Model SERVQUAL, Process quality model (PQM) , Methods for pollution prevention, KPI, green procurement, Eco labelling, LCC, EU directive, EU ordinance, Sustainable development tools, green supplier selections, Partnership with suppliers for sustainable development, matrix EPRA, Eco-QFD, Analysis of material flow (MFA), Total consumption of materials (TMC), ESCOR, Value stream mapping – VSM , Social life cycle assessment (SLCA), Indicatos of the chattiness of products and services (MIPS), Ecological baggage, Ecoauditing, ecological balance, inventory of sources of pollution, Good practice in the implementation of green supply chain management, Assessment process in terms of environmental, Periodic verification and evaluation of the results of environmental programs, Eco-vehicles, Control of emissions occurring in manufacturing processes, Control of emissions occurring in logistics processes, Implementation of the Ecoinnovation, Eco investment, Eco-patents, Supplier selection (only with green certificates), Having a mission of environmental protection, The environmental reports, Green taxes, demand of the organic products, Benchmarking, TBM (time based Management), BPM (business process Management), LM (lean Management), AM (agile Management), Quick response (QR), ECR, Outsourcing, SWOT – Analysis.				

Source: Witkowski (2012), Ciesielski (2009)

b. Test Methods Used to Evaluate Green Supply Chains

Research methods can be divided into several types, primarily quantitative and qualitative methods. Quantitative research is based on measurement of quantity or amount and is applicable to phenomena that can be expressed in terms of quantity. Qualitative research, on the other hand, is concerned with qualitative phenomenon, i.e., phenomena relating to or involving quality or kind (Kothari, 2004).

A supply chain can be assessed from various points of view, and taking into account various approaches, and thus different methods and techniques. For this research it is important to identify the qualitative and quantitative tools useful for assessing a green supply chain. Research using various kinds of models can be utilized (**Figure 3**).

Quantitative methods are usually based on operations research, mathematical models and econometrics. Meanwhile, qualitative methods are based on "soft" concepts and techniques, including test methods, techniques and management tools to assess the functioning of a green supply chain.

Based on the literature, it should be noted that quantitative methods are a large group, and are used to evaluate the activities of the supply chain in the context of the greening of processes. Based on: Brandenburg, et al. (2014), Sasikumar & Kannan (2009), a wide range of methods, techniques and quantitative tools used to assess sustainability and green supply chains may be present (**Figure 4**).

Also on the basis of the literature, concepts and tools related to more qualitative research may be identified, including management concepts that evaluate the functioning of a green supply chain. Selected methods are presented in **Table 1**. Certainly, an important element will be the introduction into the chain of an environmental management system. These tools and methods are chosen based on a quantitative survey (by percentage) and included the use of new strategies, concepts and tools for the development and evaluation of supply chains.

Criteria and sub-criteria as a basis to build models for green supply chain evaluation can also be identified (**Table 1**). For these criteria, it is possible to adjust the appropriate methods and verifiable techniques, and on this basis to build models for qualitative research, including management concepts, which evaluate the functioning of a green supply chain.

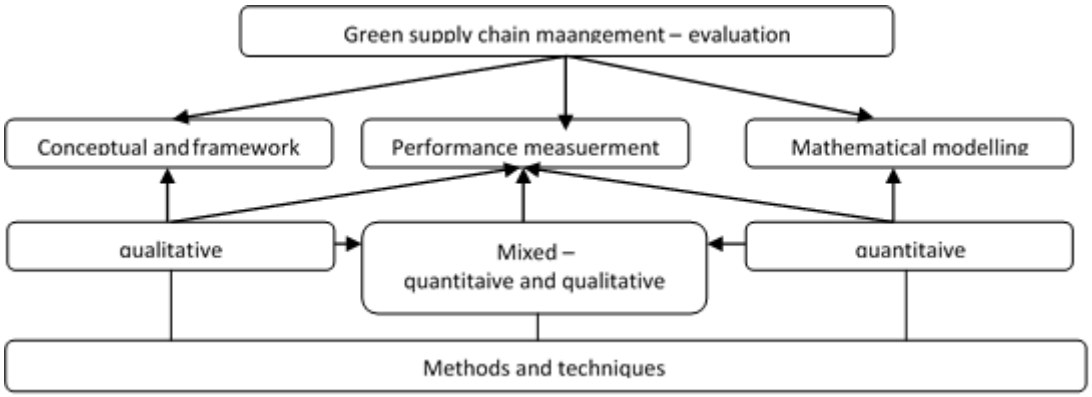

Figure 5 Evaluation model - framework

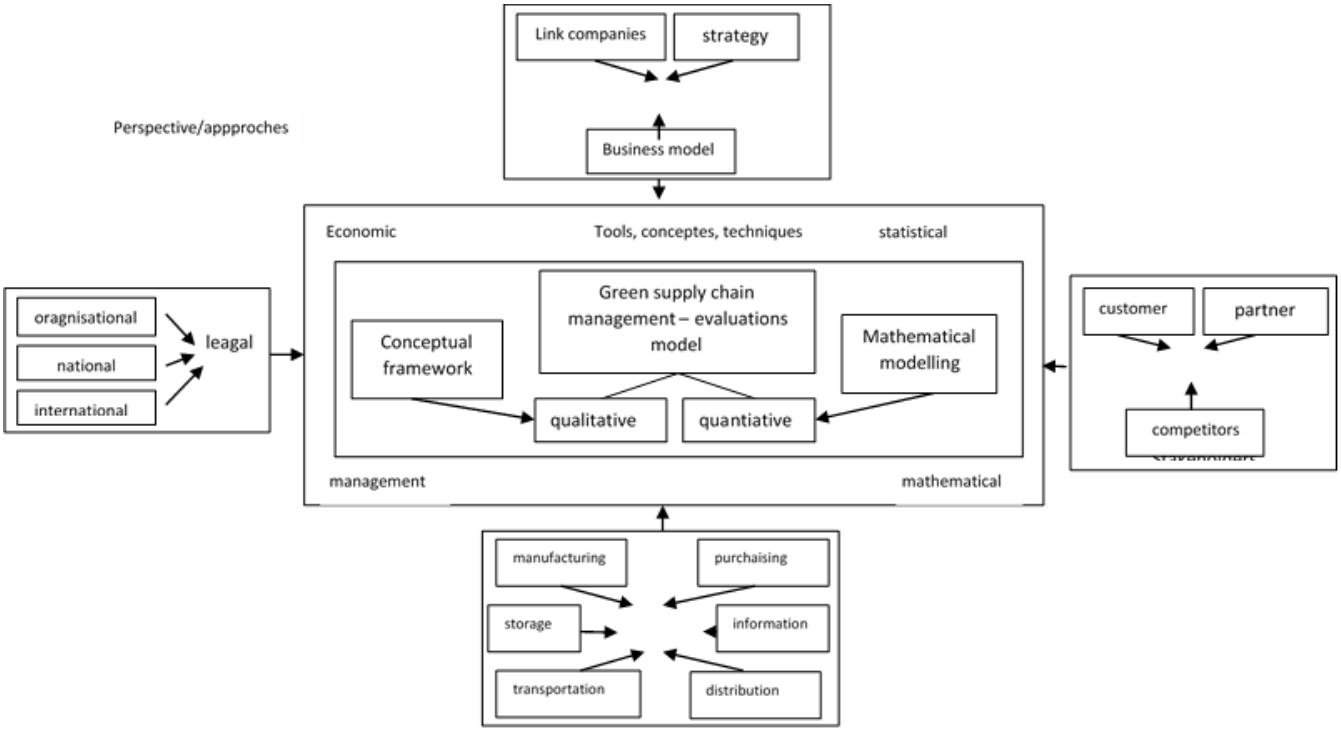

Figure 6 Evaluation model of the green supply chain

5. EVALUATION OF GREEN SUPPLY CHAINS – MODELLING AND PRACTICAL VERIFICATIONS

An evaluation model (**Figure 5**) can be created taking into account various processes. The most common methods in the literature are classified as: (1) Framework and concepts; (2) performance measurement; (3) mathematical modeling. The various techniques and parameters may be used in methods of quantitative and qualitative assessment as the basis for testing the functioning of a green supply chain.

A framework model has been developed (**Figure 6**), showing areas and perspectives that are taken into account to create an evaluation model using quantitative and qualitative tools.

On the basis of empirical research, it can indicate which of the methods and techniques were used to evaluate and parameterize a green supply chain. Another important element is indicating relationships, and whether there are correlations between certain factors and the methods used.

A survey using a questionnaire was conducted throughout Poland, using the CATI method. The survey was directed to these sectors: Food Industry - Conventional, Food Industry - Organic, Apparel manufacturing, Home appliance manufacturers, Grocery and general merchandise retail networks, Home appliance sales networks, Clothing retail networks. The parameters of the study were: number of employees > 99 people; responders were middle to senior levels of management: supply chain manager, logistics manager, head of logistics or supply chain, procurement and purchasing manager. The sample was designed to have statistical significance. The respondents were asked to answer using a five-point Likert-type scale (1- never/very rarely, 5 – very often/always). Some respondents did not

reply to the questions, but this did not invalidate the outcome. The number of companies selected was 332. The respondents had a choice of 96 criteria, including general tools, tools used to evaluate the supply chain and tools dedicated to green supply chains. The spectrum was broad and included: tools, management concepts and instruments, legal aspects and organizational and financial activities (**Tables 2 and 3**). The results do not always add up to 100%, because the total includes respondents who did not reply to all questions.

The results of the study are quite surprising, especially if we consider the sectoral approach. The tables clearly show that tools related to dedicated solutions for green supply chains are often used. Presented tools and concepts are also dedicated to each chain. This wide range indicates that not all tools are known, which is one reason why they are not used. The most important fact is that virtually all sectors indicated the use of performance assessment and the functioning of the chain SCOR model, but Green SCOR is not popular. This may result either from its area of operation, or from knowledge of the procedures and the popularity of this tool. Regardless of the industry, the largest percentage of "yes" and "always yes" responses appeared for the following tools: quality filter mapping, supply chain response matrix, GSCF model, PERT, balanced scorecard, production variety funnel, cause and effect diagram (Ishikawa), Organization and standardization of the workplace, Ecoaudit, EU accreditation and certification, ISO 14031, ISO 14001, Evaluation of the carbon footprint, Evaluation of the water footprint, ROF model, EU directives and EU ordinances, green supplier selections, Partnership with suppliers for sustainable development, Material flow analysis (MFA), Ecological baggage, ecological balance, supplier selection (only with green certificates), benchmarking and outsourcing, KPI.

An interesting observation is the lack of interest in LCA and in concurrent study of carbon and water footprints (more by networks than by the producers themselves, but this is already apparent from the very specific nature of the structure of the supply chain). A lot of interest in LCC is associated with costs throughout the life cycle. Then dedicate a well-known tool which is QFD to assess from the point of view of Eco also is not popular. When interpreting the results, it should be pointed out that among the surveyed companies representing manufacturing, in each of the groups the following were used to evaluate the supply chain (including evaluation of its greening): M.E. Porter value and supply chain model, quality filter mapping, supply chain response matrix, GSCF model, balanced scorecard, production variety funnel, PERT, cause and effect diagram (Ishikawa), value stream analysis, SCM, matrix diagram, Organization and standardization of the workplace, Ecoaudit, EU accreditation and certification, ISO 14031, ISO 14001, Evaluation of the carbon footprint, Evaluation of the water footprint, Supplier certification tools, Environmental method of selection of business partners, ROF model, organizational learning models, LCC, EU ordinances, green supplier selections, Partnership with suppliers for sustainable development, Social life cycle assessment (SLCA), Benchmarking, Outsourcing.

These elements can be used as an indication for the construction of an assessment model, and the elements which are already used can be the basis for an expansion of the evaluation model of a green supply chain. As we can see, not all elements are dedicated to the assessment of greening in the chain; general tools are also used. The location and role in the chain (manufacturer, seller) also have an influence on the specific nature of the tools used.

Referring to the sales network, and thus another link in the supply chain, it can be demonstrated that similar methods are used as at the manufacturing stage. The differences are in the percentage range, and in actions that are typically used in production processes. The most common methods include: quality filter mapping, supply chain response matrix, GSCF model, Process mapping, balanced scorecard, production variety funnel, PERT, cause and effect diagram (Ishikawa), value stream analysis, ERP, SCM, Organization and standardization of the workplace, Ecoaudit, EU accreditation and certification, ISO 14031, ISO 14001, Evaluation of the carbon footprint, Evaluation of the water footprint, Information sharing, ROF model, LCC, EU directives, green supplier selections, Partnership with suppliers for sustainable development, material flow analysis (MFA), Ecological baggage, Ecoaudit, ecological balance, Periodic verification and evaluation of the results of environmental programs, Eco-vehicles, Control of emissions occurring in manufacturing processes, Control of emissions occurring in logistics processes, Eco-patents, Supplier selection (only with green certificates), Green taxes, Benchmarking, Outsourcing. Increasingly important here are: green taxes, possession of eco-patents, the use of clean vehicles, calculation and awareness of environmental baggage and ecological balances, as well as exchanging and sharing information, and partnership for joint environmental action.

The most frequently occurring elements, taking into account all the surveyed companies and generalizing the considerations, are presented in **Table 4**. They can provide a framework directory for the basic assessment model of a green supply chain, including methods, tools and instruments for the assessment of supply chain management and legal and administrative regulation.

Table 2 Analysis of the methods, tools and concepts – empirical verifications – general and manufacturing

Methods, instruments and concepts	general			Manufacturing													
				Food Industry – Conventional			Food Industry – organic			Wearing apparel manufacturing			Home appliance manufacturers		
	No/ not use	no opinion	Yes/ always use	No/ not use	no opinion	Yes/ always use	No/ not use	no opinion	Yes/ always use	No/ not use	no opinion	Yes/ always use	No/ not use	no opinion	Yes/ always use
Value and supply chain model M.E. Porter	30,49	14,80	43,48	34,35	16,67	48,98	30,49	14,80	43,48	32,43	14,85	43,24	33,33	16,67	33,33
Seuring and Goldbach matrix	21,03	53,45	11,15	24,56	62,42	13,02	21,03	53,45	11,15	20,00	52,94	10,00	0,00	100,00	0,00
quality filter mapping	22,27	6,05	52,07	27,71	7,52	64,77	22,27	6,05	52,07	19,23	5,96	53,85	25,00	0,00	50,00
supply chain response matrix	25,71	13,69	32,58	35,72	19,01	45,27	25,71	13,69	32,58	25,71	13,30	31,43	20,00	20,00	40,00
physical structure mapping	38,17	8,54	40,19	43,93	9,82	46,25	38,17	8,54	40,19	37,84	8,45	40,54	40,00	0,00	40,00
decision point analysis	57,19	0,24	33,79	62,70	0,26	37,04	57,19	0,24	33,79	55,88	0,24	35,29	50,00	0,00	50,00
Method Eraned Value	42,87	24,85	29,38	44,15	25,59	30,26	42,87	24,85	29,38	42,50	24,40	30,00	40,00	20,00	40,00
Model SCOR	37,70	22,74	12,13	51,95	31,34	16,71	37,70	22,74	12,13	36,84	23,66	15,79	33,33	33,33	0,00
Model GSCF	2,99	0,37	76,80	3,73	0,46	95,81	2,99	0,37	76,80	0,00	0,37	78,26	0,00	0,00	75,00
Model APQC	34,27	17,05	26,32	44,14	21,96	33,90	34,27	17,05	26,32	33,33	17,17	26,67	33,33	16,67	33,33
Process mapping	10,45	20,56	44,89	13,77	27,09	59,14	10,45	20,56	44,89	10,87	20,41	45,65	16,67	16,67	33,33
Balanced score card	34,73	5,02	58,72	35,27	5,10	59,63	34,73	5,02	58,72	35,00	5,12	60,00	50,00	0,00	50,00
production variety funnel	6,93	14,50	47,04	10,12	21,17	68,71	6,93	14,50	47,04	9,09	14,55	45,45	0,00	0,00	50,00
demand amplification mapping	31,96	25,89	29,63	36,53	29,59	33,87	31,96	25,89	29,63	30,77	26,48	30,77	20,00	20,00	40,00
CPM	44,96	4,35	38,95	50,94	4,92	44,13	44,96	4,35	38,95	44,44	4,43	40,74	50,00	0,00	50,00
PERT	28,27	21,16	42,51	30,75	23,02	46,24	28,27	21,16	42,51	27,08	20,91	43,75	33,33	16,67	33,33
CCPM	32,59	31,06	17,00	40,41	38,51	21,08	32,59	31,06	17,00	33,33	31,30	18,18	25,00	25,00	25,00
SixSigma	36,42	13,08	33,60	43,98	15,74	40,28	36,19	13,33	33,33	36,67	13,33	33,33	36,36	18,18	27,27
cause and effect diagram (Ishikawa)	21,69	15,66	36,45	29,92	21,26	48,82	21,43	15,71	37,14	22,03	15,25	35,59	14,29	14,29	42,86
TQM	30,17	19,57	32,45	36,71	23,81	39,48	30,17	19,57	32,45	30,00	20,34	32,00	33,33	16,67	33,33
value stream analysis	27,58	22,05	46,53	28,68	22,93	48,39	27,58	22,05	46,53	26,32	22,79	47,37	25,00	25,00	50,00
ERP	12,40	35,72	34,76	14,96	43,10	41,94	12,40	35,72	34,76	12,50	35,85	33,33	0,00	33,33	33,33
SCM	26,46	10,85	37,10	35,56	14,58	49,87	26,46	10,85	37,10	27,59	10,47	37,93	50,00	0,00	25,00
process activity mapping	41,20	25,72	26,90	43,91	27,41	28,67	41,20	25,72	26,90	41,67	26,95	25,00	66,67	33,33	0,00
matrix diagram	21,71	23,49	31,73	28,22	30,53	41,25	21,71	23,49	31,73	21,74	23,46	30,43	20,00	20,00	40,00
Organization and standardization of the workplace	8,18	26,52	48,84	9,79	31,75	58,46	8,18	26,52	48,84	8,82	26,32	47,06	0,00	25,00	50,00

Table 2 Analysis of the methods, tools and concepts – empirical verifications – general and manufacturing (Con't)

Ecoaudit	22,47	14,47	47,51	26,60	17,14	56,26	22,47	14,47	47,51	23,53	14,00	47,06	20,00	20,00	40,00
accreditation and certification EU	7,75	34,84	36,19	9,84	44,22	45,94	7,75	34,84	36,19	5,26	36,42	36,84	0,00	33,33	33,33
ISO certificates (ISO1400x)	34,56	14,23	28,86	44,50	18,33	37,17	34,56	14,23	28,86	35,42	13,93	29,17	33,33	16,67	33,33
ISO 14031	7,96	0,42	48,23	14,06	0,74	85,21	7,96	0,42	48,23	8,00	0,41	48,00	0,00	0,00	50,00
ISO 14001	11,69	16,41	38,07	17,66	24,80	57,54	11,69	16,41	38,07	10,00	16,46	40,00	0,00	25,00	50,00
Meters and indicators of eco-efficiency	34,22	20,10	25,11	43,08	25,31	31,61	34,22	20,10	25,11	33,33	20,03	26,19	25,00	12,50	50,00
LCA	41,90	10,80	37,53	38,32	21,60	40,08	41,46	10,98	37,80	42,03	10,14	37,68	40,00	10,00	40,00
Evaluation of the carbon footprint	14,10	22,08	44,30	17,53	27,43	55,04	14,10	22,08	44,30	13,89	21,81	44,44	20,00	20,00	40,00
Evaluation of the water footprint	21,75	23,24	40,32	25,50	27,24	47,26	21,75	23,24	40,32	21,62	23,11	40,54	20,00	20,00	40,00
TQEM	41,92	5,26	14,06	68,45	8,59	22,96	41,92	5,26	14,06	44,00	5,36	12,00	50,00	0,00	0,00
Just in time	31,61	16,37	34,75	44,31	23,35	32,34	36,14	18,07	26,51	35,21	18,31	26,76	30,00	20,00	30,00
Tools of the Certification of suppliers	23,08	23,65	39,84	26,66	27,32	46,02	23,08	23,65	39,84	21,88	23,75	40,63	20,00	20,00	40,00
Regulations consistent with the protection of the environment	56,09	16,56	11,68	66,51	19,64	13,85	56,09	16,56	11,68	56,52	17,15	8,70	50,00	25,00	0,00
Environmental Management System	18,32	39,18	23,83	22,52	48,18	29,30	18,32	39,18	23,83	18,52	39,53	22,22	14,29	14,29	57,14
Environmental methods for supplier selection	43,60	27,63	22,91	46,31	29,35	24,34	43,60	27,63	22,91	44,44	27,55	22,22	50,00	25,00	25,00
Environmental method of selection of business partners	16,59	22,51	34,28	22,61	30,68	46,72	16,59	22,51	34,28	16,67	23,35	33,33	25,00	25,00	25,00
Planning with partners	35,39	20,70	28,56	41,81	24,45	33,74	35,39	20,70	28,56	35,29	20,57	29,41	33,33	16,67	33,33
Informatiosn sharing	43,94	2,36	34,11	54,64	2,93	42,43	43,94	2,36	34,11	42,42	2,39	33,33	40,00	0,00	40,00
Process orientation	33,48	19,94	25,02	42,68	25,43	31,89	33,48	19,94	25,02	34,21	19,81	23,68	40,00	20,00	20,00
SMART	28,53	30,64	34,25	42,46	17,37	40,17	28,53	30,64	34,25	29,41	30,82	35,29	33,33	33,33	33,33
Model ROF	32,74	3,01	41,75	42,24	3,89	53,87	32,74	3,01	41,75	32,50	3,15	42,50	40,00	0,00	40,00
Models of diffusion of innovation	46,87	2,84	19,38	67,84	4,11	28,05	46,87	2,84	19,38	45,45	2,86	18,18	33,33	0,00	33,33
The ability of models of organizational learning	27,62	28,32	38,83	29,14	29,89	40,98	27,62	28,32	38,83	27,59	28,78	37,93	33,33	33,33	33,33
Model SERVQUAL	48,40	7,61	29,69	56,48	8,87	34,65	48,40	7,61	29,69	48,65	7,77	29,73	50,00	0,00	25,00
Process quality model (PQM)	21,00	25,10	26,02	29,12	34,80	36,08	21,00	25,10	26,02	21,43	25,87	25,00	25,00	25,00	25,00
Methods for pollution prevention	43,18	6,98	39,84	47,98	7,76	44,27	43,18	6,98	39,84	42,86	6,83	39,29	33,33	0,00	66,67
KPI	36,40	26,81	24,55	41,48	30,55	27,97	36,40	26,81	24,55	38,24	27,36	23,53	20,00	20,00	40,00
green procurment	43,90	8,13	26,60	55,83	10,34	33,83	43,90	8,13	26,60	45,24	8,27	26,19	60,00	0,00	20,00
Eco labeling	42,46	3,06	31,26	55,30	3,98	40,72	42,46	3,06	31,26	42,86	3,03	30,95	50,00	0,00	25,00
LCC	12,09	23,33	44,09	15,20	29,34	55,45	12,09	23,33	44,09	10,00	24,32	46,67	0,00	25,00	50,00

Table 2 Analysis of the methods, tools and concepts – empirical verifications – general and manufacturing (Con't)

EU directive	44,37	11,74	42,14	45,16	11,95	42,89	44,37	11,74	42,14	43,90	11,57	41,46	33,33	16,67	50,00
EU ordinance	25,08	16,43	41,56	30,19	19,78	50,03	25,08	16,43	41,56	25,81	16,91	41,94	20,00	20,00	40,00
Sustainable development tools	41,16	28,33	16,89	47,65	32,80	19,55	41,16	28,33	16,89	42,86	28,44	14,29	50,00	25,00	0,00
green supplier selections	21,98	23,30	33,57	27,88	29,55	42,57	21,98	23,30	33,57	20,93	23,48	34,88	20,00	20,00	40,00
Partnership with suppliers for sustainable development	30,69	17,37	48,96	31,63	17,90	50,46	30,69	17,37	48,96	30,95	17,21	50,00	25,00	25,00	50,00
matrix EPRA	28,68	16,53	34,56	35,95	20,72	43,33	28,68	16,53	34,56	28,26	16,76	34,78	33,33	16,67	33,33
Eco-QFD	29,16	23,17	32,26	34,48	27,39	38,13	29,16	23,17	32,26	29,03	23,72	32,26	20,00	20,00	40,00
Analysis of material flow (MFA)	17,99	21,59	45,56	21,13	25,36	53,51	17,99	21,59	45,56	17,78	21,71	44,44	20,00	20,00	40,00
Total consumption of materials (TMC)	50,97	7,22	31,64	56,74	8,04	35,22	50,97	7,22	31,64	51,52	7,47	33,33	50,00	0,00	50,00
ESCOR	66,50	9,28	15,75	72,65	10,14	17,21	66,50	9,28	15,75	65,63	8,98	15,63	75,00	0,00	25,00
Value stream mapping – VSM	34,30	18,41	34,94	39,13	21,01	39,86	34,30	18,41	34,94	35,14	18,10	35,14	40,00	20,00	20,00
Social life cycle assessment (SLCA)	26,30	12,54	48,27	30,19	14,39	55,41	26,30	12,54	48,27	26,32	12,58	47,37	33,33	16,67	33,33
Indicatos of the chattiness of products and services (MIPS)	34,00	55,38	10,25	34,12	55,59	10,29	34,00	55,38	10,25	33,33	55,77	11,11	50,00	50,00	0,00
Ecological baggage	37,22	17,85	34,22	41,68	20,00	38,32	37,22	17,85	34,22	34,78	18,53	34,78	33,33	33,33	33,33
Ecoauditing	42,38	2,76	40,89	49,26	3,21	47,53	42,38	2,76	40,89	41,94	2,71	41,94	40,00	0,00	40,00
ecological balance	19,58	7,93	56,33	23,35	9,46	67,19	19,58	7,93	56,33	18,75	7,96	56,25	25,00	0,00	50,00
inventory of sources of pollution	40,59	15,75	23,35	50,93	19,76	29,30	40,59	15,75	23,35	40,00	15,75	24,44	40,00	20,00	20,00
Good practice in the implementation of green supply chain management	40,77	12,77	24,21	52,44	16,42	31,14	40,77	12,77	24,21	40,43	12,95	23,40	40,00	20,00	20,00
Assessment process in terms of environmental	62,82	2,29	10,79	82,77	3,02	14,22	62,82	2,29	10,79	66,67	2,37	11,11	66,67	0,00	0,00
Periodic verification and evaluation of the results of environmental programs	43,11	11,95	41,12	44,82	12,43	42,75	43,11	11,95	41,12	42,50	11,77	40,00	40,00	20,00	40,00
Eco-vehicles	53,60	8,06	32,12	57,16	8,59	34,25	53,60	8,06	32,12	54,05	7,87	32,43	50,00	0,00	50,00
Control of emissions occurring in manufacturing processes	22,26	45,23	30,33	22,76	46,24	31,01	22,26	45,23	30,33	23,81	48,75	28,57	0,00	50,00	50,00
Control of emissions occurring in logistics processes	41,86	1,25	36,67	52,47	1,57	45,97	41,86	1,25	36,67	41,46	1,26	36,59	50,00	0,00	33,33
Implementation of the Ecoinnovation	39,14	8,49	28,76	51,24	11,11	37,65	39,14	8,49	28,76	38,71	8,29	29,03	50,00	0,00	25,00
Eco investment	22,94	29,13	24,78	29,85	37,90	32,25	22,94	29,13	24,78	22,58	29,70	25,81	25,00	25,00	25,00
Eco-patents	33,31	14,18	32,45	41,67	17,74	40,59	33,31	14,18	32,45	33,33	14,01	33,33	33,33	16,67	33,33
Supplier selection (only with green certificates)	41,68	12,86	42,69	42,87	13,23	43,90	41,68	12,86	42,69	42,50	13,33	42,50	37,50	12,50	50,00

Table 2 Analysis of the methods, tools and concepts – empirical verifications – general and manufacturing (Con't)

Having a mission of environmental protection	59,79	23,23	5,02	67,91	26,39	5,70	59,79	23,23	5,02	61,54	23,67	3,85	66,67	33,33	0,00
The environmental reports	43,21	6,12	23,30	59,49	8,43	32,08	43,21	6,12	23,30	43,75	6,07	21,88	50,00	0,00	25,00
Green taxes	28,58	22,46	29,39	35,53	27,93	36,54	28,58	22,46	29,39	28,57	21,94	28,57	20,00	20,00	40,00
demand of the organic products	41,11	10,65	34,26	47,79	12,39	39,83	41,11	10,65	34,26	41,46	10,75	34,15	33,33	16,67	33,33
Benchmarking	26,48	0,93	51,42	33,59	1,17	65,23	26,48	0,93	51,42	27,27	0,91	50,00	25,00	0,00	50,00
TBM (time based Management)	43,44	13,95	20,82	55,55	17,83	26,62	43,44	13,95	20,82	44,44	14,49	19,44	40,00	20,00	20,00
BPM (business process Management)	36,62	11,24	36,08	43,63	13,39	42,98	36,62	11,24	36,08	36,11	11,12	36,11	33,33	16,67	33,33
LM (lean Management)	54,12	19,04	10,65	64,57	22,72	12,71	54,12	19,04	10,65	54,55	19,59	12,12	50,00	25,00	0,00
AM (agile Management)	33,36	31,21	27,34	36,30	33,95	29,75	33,36	31,21	27,34	33,33	29,58	27,27	50,00	25,00	25,00
Quick response (QR)	34,13	19,50	25,64	43,05	24,61	32,34	34,13	19,50	25,64	34,04	19,14	25,53	33,33	16,67	33,33
ECR	29,61	26,65	36,89	31,78	28,62	39,60	29,61	26,65	36,89	29,03	27,65	35,48	25,00	25,00	50,00
Outsourcing	20,84	8,32	47,10	27,33	10,91	61,76	20,84	8,32	47,10	21,05	8,51	47,37	40,00	0,00	40,00
SWOT	33,88	14,73	29,73	43,24	18,81	37,95	33,88	14,73	29,73	32,35	15,12	29,41	40,00	20,00	20,00

Table 3 Analysis of the methods, tools and concepts – empirical verifications – sales network

Methods, instruments and concepts	Sales network								
	of home appliances			of grocery and general merchandise retailer			of retail-clothing		
	No/not use	no opinion	Yes/always use	No/not use	no opinion	Yes/always use	No/not use	no opinion	Yes/always use
Value and supply chain model M.E. Porter	40,00	20,00	40,00	27,27	18,18	18,18	25,00	25,00	50,00
Seuring and Goldbach matrix	0,00	100,00	0,00	66,67	50,00	50,00	0,00	100,00	0,00
quality filter mapping	0,00	0,00	50,00	16,67	0,00	0,00	0,00	0,00	50,00
supply chain response matrix	20,00	20,00	40,00	30,00	10,00	10,00	25,00	0,00	50,00
physical structure mapping	40,00	0,00	40,00	22,22	11,11	11,11	50,00	0,00	50,00
decision poion analysis	50,00	0,00	50,00	30,00	0,00	0,00	66,67	0,00	33,33
Method Eraned Value	50,00	25,00	25,00	50,00	30,00	30,00	50,00	25,00	25,00
Model SCOR	50,00	0,00	0,00	50,00	16,67	16,67	50,00	0,00	0,00
Model GSCF	0,00	0,00	66,67	0,00	0,00	0,00	0,00	0,00	100,00
Model APQC	40,00	20,00	20,00	33,33	16,67	16,67	40,00	20,00	20,00
Process mapping	20,00	20,00	40,00	23,08	23,08	23,08	0,00	25,00	50,00
Balanced score card	50,00	0,00	50,00	20,00	0,00	0,00	0,00	0,00	100,00
production variety funnel	0,00	0,00	50,00	16,67	16,67	16,67	0,00	0,00	50,00
demand amplification mapping	25,00	25,00	25,00	36,36	27,27	27,27	33,33	33,33	33,33
CPM	50,00	0,00	50,00	37,50	0,00	0,00	50,00	0,00	50,00
PERT	25,00	25,00	50,00	28,57	21,43	21,43	25,00	25,00	50,00
CCPM	33,33	33,33	0,00	50,00	30,00	30,00	33,33	33,33	0,00
SixSigma	30,00	20,00	30,00	32,00	12,00	12,00	33,33	11,11	33,33
cause and effect diagram (Ishikawa)	14,29	14,29	42,86	23,53	11,76	11,76	14,29	14,29	42,86
TQM	33,33	16,67	33,33	26,67	20,00	20,00	33,33	16,67	33,33
value stream analysis	50,00	0,00	50,00	20,00	20,00	20,00	0,00	0,00	100,00
ERP	0,00	50,00	50,00	42,86	28,57	28,57	0,00	50,00	50,00
SCM	0,00	0,00	50,00	25,00	12,50	12,50	0,00	0,00	50,00
process activity mapping	50,00	50,00	0,00	57,14	28,57	28,57	50,00	50,00	0,00
matrix diagram	20,00	20,00	40,00	41,67	25,00	25,00	20,00	20,00	40,00
Organization and standardisation of the workplace	0,00	25,00	50,00	22,22	22,22	22,22	0,00	25,00	50,00
Ecoaudit	20,00	20,00	40,00	37,50	12,50	12,50	25,00	0,00	50,00
accreditation and certification EU	0,00	50,00	50,00	40,00	40,00	40,00	0,00	50,00	50,00
ISO certificates (ISO1400x)	40,00	20,00	20,00	30,77	15,38	15,38	40,00	20,00	20,00
ISO 14031	0,00	0,00	50,00	0,00	0,00	0,00	0,00	0,00	50,00
ISO 14001	0,00	25,00	50,00	12,50	12,50	12,50	0,00	0,00	50,00
Meters and indicators of eco-efficiency	40,00	20,00	20,00	36,36	18,18	18,18	40,00	20,00	20,00
LCA	50,00	16,67	33,33	26,32	10,53	10,53	50,00	16,67	33,33
Evaluation of the carbon footprint	0,00	25,00	50,00	20,00	20,00	20,00	0,00	25,00	50,00
Evaluation of the water footprint	20,00	20,00	40,00	30,00	20,00	20,00	20,00	20,00	40,00
TQEM	50,00	0,00	0,00	42,86	0,00	0,00	50,00	0,00	0,00
Just in time	20,00	0,00	40,00	40,00	20,00	20,00	33,33	16,67	16,67

Table 3 Analysis of the methods, tools and concepts – empirical verifications – sales network (Con't)

Tools of the Certification of suppliers	25,00	25,00	50,00	30,00	20,00	20,00	25,00	25,00	50,00
Regulations consistent with the protection of the environment	100,00	0,00	0,00	33,33	16,67	16,67	100,00	0,00	0,00
Environmental Management System	33,33	33,33	0,00	42,86	42,86	42,86	0,00	50,00	0,00
Environmental methods for supplier selection	50,00	25,00	25,00	50,00	25,00	25,00	50,00	25,00	25,00
Environmental method of selection of business partners	25,00	25,00	25,00	36,36	18,18	18,18	25,00	25,00	25,00
Planning with partners	33,33	16,67	33,33	38,46	23,08	23,08	33,33	16,67	33,33
Informatiosn sharing	40,00	0,00	40,00	22,22	0,00	0,00	40,00	0,00	40,00
Process orientation	40,00	20,00	20,00	40,00	20,00	20,00	40,00	20,00	20,00
SMART	33,33	33,33	33,33	30,00	30,00	30,00	33,33	33,33	33,33
Model ROF	40,00	0,00	40,00	16,67	0,00	0,00	40,00	0,00	40,00
Models of diffusion of innovation	50,00	0,00	0,00	40,00	0,00	0,00	50,00	0,00	0,00
The ability of models of organizational learning	33,33	33,33	33,33	37,50	25,00	25,00	33,33	33,33	33,33
Model SERVQUAL	50,00	0,00	25,00	36,36	9,09	9,09	50,00	0,00	25,00
Process quality model (PQM)	33,33	33,33	0,00	42,86	28,57	28,57	33,33	33,33	0,00
Methods for pollution prevention	50,00	0,00	50,00	22,22	11,11	11,11	50,00	0,00	50,00
KPI	50,00	50,00	0,00	40,00	30,00	30,00	50,00	50,00	0,00
Green procurement	50,00	0,00	25,00	33,33	8,33	8,33	50,00	0,00	25,00
Eco labeling	50,00	0,00	25,00	16,67	0,00	0,00	50,00	0,00	25,00
LCC	0,00	25,00	50,00	22,22	22,22	22,22	0,00	25,00	50,00
EU directive	40,00	20,00	40,00	27,27	9,09	9,09	50,00	0,00	50,00
EU ordinance	0,00	33,33	33,33	22,22	11,11	11,11	0,00	33,33	33,33
Sustainable development tools	33,33	33,33	0,00	60,00	30,00	30,00	50,00	50,00	0,00
green supplier selections	20,00	20,00	40,00	38,46	23,08	23,08	20,00	20,00	40,00
Partnership with suppliers for sustainable development	25,00	25,00	50,00	41,67	16,67	16,67	25,00	25,00	50,00
matrix EPRA	33,33	16,67	33,33	30,77	15,38	15,38	33,33	16,67	33,33
Eco-QFD	25,00	25,00	25,00	44,44	22,22	22,22	33,33	33,33	33,33
Analysis of material flow (MFA)	20,00	20,00	40,00	28,57	21,43	21,43	20,00	20,00	40,00
Total consumption of materials (TMC)	66,67	0,00	33,33	40,00	10,00	10,00	66,67	0,00	33,33
ESCOR	100,00	0,00	0,00	44,44	11,11	11,11	100,00	0,00	0,00
Value stream mapping – VSM	50,00	25,00	25,00	36,36	18,18	18,18	50,00	25,00	25,00
Social life cycle assessment (SLCA)	33,33	16,67	33,33	22,22	11,11	11,11	33,33	0,00	66,67
Indicatos of the chattiness of products and services (MIPS)	50,00	50,00	0,00	60,00	60,00	60,00	50,00	50,00	0,00
Ecological baggage	50,00	0,00	50,00	42,86	14,29	14,29	50,00	0,00	50,00
Ecoauditing	50,00	0,00	50,00	12,50	0,00	0,00	33,33	0,00	66,67
ecological balance	0,00	0,00	66,67	22,22	11,11	11,11	0,00	0,00	66,67
inventory of sources of pollution	40,00	20,00	20,00	33,33	16,67	16,67	40,00	20,00	20,00
Good practice in the implementation of green supply chain management	40,00	20,00	20,00	28,57	14,29	14,29	40,00	20,00	20,00

Table 3 Analysis of the methods, tools and concepts – empirical verifications – sales network (Con't)

Assessment process in terms of environmental	100,00	0,00	0,00	50,00	0,00	0,00	100,00	0,00	0,00
Periodic verification and evaluation of the results of environmental programs	40,00	20,00	40,00	40,00	10,00	10,00	50,00	0,00	50,00
Eco-vehicles	50,00	0,00	50,00	36,36	9,09	9,09	50,00	0,00	50,00
Control of emissions occurring in manufacturing processes	0,00	50,00	50,00	66,67	50,00	50,00	0,00	50,00	50,00
Control of emissions occurring in logistics processes	40,00	0,00	40,00	27,27	0,00	0,00	40,00	0,00	40,00
Implementation of the Ecoinnovation	33,33	0,00	33,33	37,50	12,50	12,50	33,33	0,00	33,33
Eco investment	0,00	33,33	33,33	44,44	33,33	33,33	0,00	50,00	0,00
Eco-patents	20,00	20,00	40,00	45,45	18,18	18,18	25,00	25,00	25,00
Supplier selection (only with green certificates)	40,00	20,00	40,00	36,36	9,09	9,09	40,00	20,00	40,00
Having a mission of environmental protection	66,67	33,33	0,00	50,00	25,00	25,00	66,67	33,33	0,00
The environmental reports	50,00	0,00	0,00	44,44	11,11	11,11	50,00	0,00	0,00
Green taxes	20,00	20,00	40,00	44,44	22,22	22,22	25,00	25,00	25,00
demand of the organic products	50,00	0,00	25,00	25,00	8,33	8,33	50,00	0,00	25,00
Benchmarking	0,00	0,00	66,67	16,67	0,00	0,00	0,00	0,00	100,00
TBM (time based Management)	40,00	20,00	20,00	33,33	11,11	11,11	40,00	20,00	20,00
BPM (business process Management)	33,33	0,00	33,33	40,00	10,00	10,00	33,33	0,00	33,33
LM (lean Management)	50,00	25,00	0,00	40,00	20,00	20,00	50,00	25,00	0,00
AM (agile Management)	50,00	25,00	25,00	40,00	30,00	30,00	33,33	33,33	33,33
Quick response (QR)	33,33	16,67	33,33	30,77	15,38	15,38	33,33	16,67	33,33
ECR	33,33	33,33	33,33	33,33	22,22	22,22	33,33	33,33	33,33
Outsourcing	0,00	0,00	66,67	18,18	9,09	9,09	0,00	0,00	66,67
SWOT	40,00	20,00	20,00	33,33	11,11	11,11	40,00	20,00	20,00

Table 4 Ranking of the most popular tools and methods using in polish companies in the evaluation of the functioning of the green supply chain

1.	Model GSCF	17.	LCC
2.	Balanced score card	18.	Value and supply chain model M.E. Porter
3.	ecological balance	19.	Supplier selection (only with green certificates)
4.	Benchmarking	20 .	PERT
5.	quality filter mapping	21.	EU directive
6.	Partnership with suppliers for sustainable development	22.	Model ROF
7.	Organization and standardization of the workplace	23.	EU ordinance
8.	Social life cycle assessment (SLCA)	24.	Periodic verification and evaluation of the results of environmental programs
9.	ISO 14031	25.	Ecoauditing
10.	Ecoaudit	26.	physical structure mapping
11.	Outsourcing	27.	Rating of the water footprint
12.	production variety funnel	28.	Tools of the Certification of suppliers
13.	value stream analysis	29.	Methods for pollution prevention
14.	Analysis of material flow (MFA)	30.	CPM
15.	Process mapping	31.	The ability of models of organizational learning
16.	Rating of the carbon footprint	32.	ISO 14001

6. DISCUSSION, VALUE AND LIMITATIONS OF THE STUDY

In the absence of research (including literature) regarding the use of quantitative methods in Polish conditions, this element of research and this model show a pioneering approach, especially in terms of the study of this economy. The empirical studies conducted by the author are used for presentation of methods and techniques for the assessment, parameterization and verification of the functionality of the chain, allowing the formation of conclusions related to Polish economic reality. To complete the research and building of the models, quantitative methods must be used, based not only on indications of the literature but on showing how operations research supports evaluation of green supply chains.

The value of this work consists in (1) organizing a set of tools (2) identification of the most commonly used methods and using them as the basis for the construction of green supply chains for the sectors in question; (3) proposing a model for assessing green supply chains, (4) identification, on the basis of empirical research, of the elements (in the field of management tools) used to assess supply chains in Poland. The conclusions that arise indicate broad and significant possibilities for the evaluation of green supply chains and the availability of many tools conducive to such solutions. The barrier is knowledge of the tools by those who manage and make decisions for supply chains, as well as their degree of usefulness (not all of them can be adapted to any industry). These tools, methods and instruments can definitely be used to build models, based on mathematics, statistics and operations research, as well as for a higher quality (stochastic) approach and research on the supply chain. The full picture of the evaluation system must certainly use both types of method, and combinations of them. This may indicate that there are some methods that are valid and suitable for all sectors. Models should be dedicated, but there are some basic elements that definitely must be used with this modeling.

In conclusion, and in answer to the questions of the research process, it should be pointed out that an excessive number of methods, tools and concepts can be a barrier in the assessment of a supply chain, because not all tools are useful and known for each chain. It seems that the best option is to select a maximum of about 20 elements, which will serve as a basis for research on the greening of processes and activities. Another solution is choosing a group of tools and evaluation chain based on the scope of the group.

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