SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2019
ORGANIZATION AND MANAGEMENT SERIES NO. 133

SUPPLY CHAIN QUALITY MANAGEMENT OF AUTOMOTIVE COMPONENTS

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Abstract: Inferior automotive component quality might be caused by diverse sources in the supply chain network. To compete in a highly dynamic environment, a supply chain quality management integrating quality issues of the internal and external supply chain is needed. In this paper, a supply chain quality management model for automotive components was developed on the basis of further development of ISO 9001:2015. This way, the quality within the value chain can be managed. To evolve the model, the novel concept of supply chain quality management and its dimensions were reviewed in the literature. Drawing upon the results, intersections concerning common processes of both approaches, quality management and supply chain management, were identified using ISO 9001:2015 and the SCOR model. Based on the findings, a supply chain quality management model for automotive components was developed and will be introduced. The results reflect implications for the management of supply chain quality to be implemented by companies.

Keywords: supply chain quality, automotive component industry, ISO 9001:2015.

1. Introduction

Manufacturers of automotive components have to cope with strict quality requirements. In the event of product defects leading to process disruptions and financial losses, a company's reputation can be jeopardy (Huo *et al.*, 2016). However, a company's performance does not only depend on its capabilities (Park *et al.*, 2001) but rather on the whole supply chain. In addition, quality challenges intensify with larger supply chain networks (Tang, 2008; Kang, 2010). To achieve overall optimization of supply chain quality performance, economic optimization of individual companies is insufficient (Carmignani, 2009). The internal focused quality management must be extended by the inclusion of the supply chain perspective (Carmignani, 2009; Flynn, B.B. and Flynn, E.J., 2005; Sousa and Voss, 2002). Although many research questions have been treated in literature concerning the merging of quality management (QM) and supply chain management (SCM) into supply chain quality management (SCQM), a specific application approach is still missing (Zeng *et al.*, 2013; Lin *et al.*, 2005; Chibba, 2017; Carmignani, 2009). Thus, a more detailed consideration of joint practices and their associated processes is required for the implementation of SCQM in the automotive industry.

The objective of this paper is to develop an SCQM model for automotive components based on the further development of ISO 9001:2015. This model is meant to bridge the gap many organizations are faced with during the implementation of supply chain quality in enterprises. To develop the SCQM model, an extensive literature review was initially carried out to describe the concept and identify its dimensions. In the next step, common processes between quality management and supply chain management were revealed using ISO 9001:2015 and the SCOR model. The article ends with the presentation of the developed SCQM model for automotive components.

2. Evolution of supply chain quality management

Particular importance in achieving competitive differentiation is placed on both management philosophies, QM and SCM (Talib *et al.*, 2010). SCM synchronizes processes between suppliers, manufacturers, distributors and retailers with the primary goal to meet customer requirements (Simichi-Levi *et al;* Krajewski *et al.*). In a similar way, QM requires the management of processes to produce tailor-made products according to (ISO 9001:2015; Fernandes *et al.*, 2017). However, both approaches have shortcomings concerning the management of supply chain quality. Regarding SCM, the often pursued cost-cutting and efficiency perspective is too narrowly oriented (Huo *et al.*, 2016). QM, in turn, encompasses the internal view, neglecting external operations (Robinson, and Malhotra, 2005; Foster Jr., 2008; Chibba, 2017; Zu, and Kaynak, 2012). To overcome restrictions, similarities and differences were identified by (Soltani *et al.*, 2011) between QM (see (Soltani *et al.*, 2008; Hackmann, and Wageman, 1995; Sitkin *et al.*, 1994; Soltani *et al.*, 2006) etc. according to (Soltani *et al.*, 2011)) and SCM (see (Li *et al.*, 2008; Hult, 2004; Tan, 2001) etc. according to (Soltani *et al.*, 2011)) as well as their intersection (see (Chen *et al.*, 2004; Ketchen Jr. and Hult, 2007) etc. according to (Soltani *et al.*, 2011)). The intersection is illustrated in Figure 1 by (Soltani *et al.*, 2011).

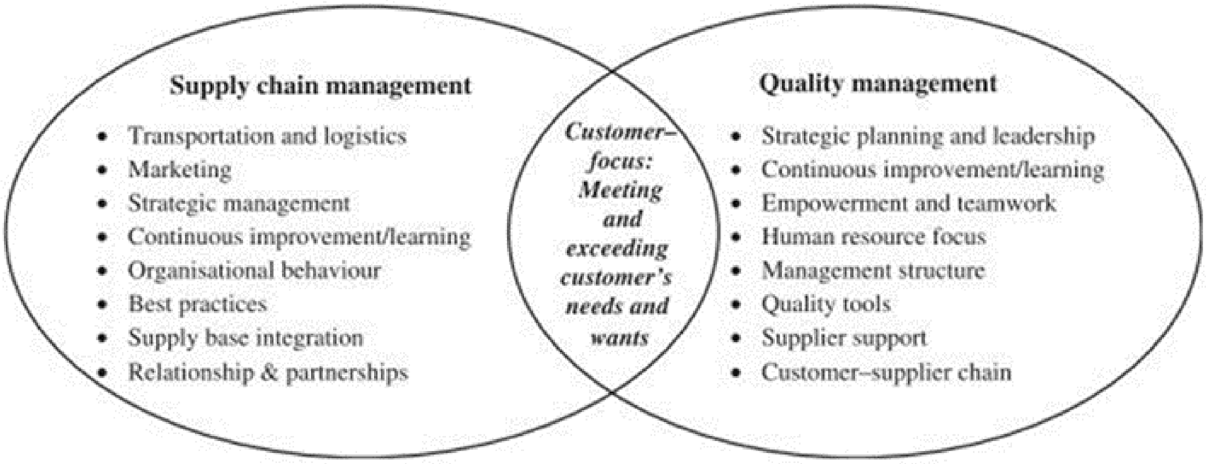

Figure 1. Intersection between SCM and QM (Soltani *et al.*, 2011) Copyright 2011 by Publisher.

Merging the complementary approaches of SCM and QM is known as SCQM (Soltani *et al.*, 2011). "SCQM is the formal coordination and integration of business processes involving all partner organizations in the supply channel to measure, analyze and continually improve products, services, and processes in order to create value and achieve satisfaction of intermediate and final customers in the marketplace." (Robinson and Malhotra, 2005, p. 319). It is not limited by a best practice like ISO 9001 certification or total quality management cf. (Carmignani, 2009; Robinson and Malhotra, 2005; Terziovski and Hermel, 2011; Zu and Kaynak, 2012; Vecchi and Brennan, 2009).

An overview of SCQM literature is given in Table 1, which discusses topics concerning synergies between QM and SCM as well as their influence on performance metrics. Following the taxonomy of (Robinson and Malhotra, 2005), the articles can be distinguished between those dealing with intra-organizational and inter-organizational issues.

Intra-organizational papers discuss traditional quality management containing aspects of cross-organizational boundary expansion of quality initiatives relevant to supply chain quality (Robinson and Malhotra, 2005). Inter-organizational papers treat topics concerning the integration of internal quality management with the supply chain environment (Robinson and Malhotra, 2005). Literature considers the upstream side, downstream side as well as quality process integration on the downstream and upstream side. Only a few papers include the integration of the external and internal view. This integration of the external and internal view consists of the following dimensions: internal practices, upstream and downstream management (Zeng *et al.*, 2013).

Table 1.
Papers regarding synergies between the separate QM and SCM approaches

Perspective	Dimension	Literature
Internal view	Internal view together with external impact (customer/supplier)	(Park *et al.*, 2001; Salvador *et al.*, 2001; Gotzamani and Tsiotras, 2001; Segars *et al.*, 2001; Mehra *et al.*, 2001; Ahire and Dreyfus, 2000; Yeung *et al.*, 2003; Romano, 2002; Rosenzweig *et al.*, 2003; Terziovski *et al.*, 2003; Tan *et al.*, 1998; Tan *et al.*, 1999; Choi and Eboch, 1998; Forker *et al.*, 1997; Kumar *et al.*, 2014)
External view	Upstream side	(Trent and Monczka, 1999; Shin *et al.*, 2000; Fynes *et al.*, 2005; Lai *et al.*, 2005; Tracey and Tan, 2001; Wu *et al.*, 2010; Hollos *et al.*, 2012)
	Downstream side	(Mukerjee, 2013; Danese and Romano, 2012; Mokhtar, 2013)
	Downstream and upstream side	(Forza, 1996; Soltani *et al.*, 2011; Salvador *et al.*, 2001; Romano and Vinelli, 2001)
Internal and external view	Integration of internal practices, upstream and downstream supplier	(Zeng *et al.*, 2013; Kaynak and Hartley, 2008; Kuei *et al.*, 2001; Lin *et al.*, 2005; Fernandes *et al.*, 2017; Quang *et al.*, 2016; Hu *et al.*, 2015)

The first generalized models were conceptualized by (Fernandes *et al.*, 2017; Quang *et al.*, 2016; Hu *et al.*, 2015). For example, (Quang *et al.*, 2016) delivered a conceptual framework covering the three core dimensions (upstream and downstream side as well as internal processes). In addition, it promotes support practices. The SCQM framework of (Hu *et al.*, 2015) consists of six critical SCQM elements comprising a strategic and operational level. The elements associated with the strategic level are supply chain leadership and supply chain design for quality. The operational level is covered by the internal, upstream and downstream QM as well as product recall strategy. The SCQM model is adjusted with the environmental factors of the individual industry (Hu *et al.*, 2015).

To sum up, there is increasing research on the integration of QM and SCM in conformance with (Chibba, 2017). However, there are a lot of issues which are insufficiently covered in literature (Zeng *et al.*, 2013; Huo *et al.*, 2014; Huo *et al.*, 2016; Sila *et al.*, 2006). Furthermore, there are various aspects and relationships considered from different perspectives. Initial research focused on modeling conceptual SCQM frameworks which is at a highly generalized level.

Towards a more application-oriented approach, common processes including the internal and external perspective need to be identified for the individual dimensions and adapted to special sectors.

3. Integration of ISO 9001 into the SCOR model

To achieve a detailed view of the generalized level, common processes including the internal and external perspective need to be identified for individual dimensions. Supporting the external and internal perspectives (Robinson and Malhotra, 2005), the Supply Chain

Operations Reference (SCOR) model will be regarded in the following to connect common issues with ISO 9001:2015.

The SCOR model, which is currently available in version 12.0, was developed by the Supply Chain Council (Li *et al.*, 2011; www.apics.org). The objective of the SCOR model is to represent the process architecture from the supplier to the end consumer stage. The SCOR model spans all customer interactions, physical material transactions and market interactions. It consists of several process levels, which are illustrated in Figure 2. At the first level, primary management processes comprise the following: plan, source, make, deliver, return and enable. These processes define the scope and content of the supply chain. At the second level, the six top-level processes are divided into process categories conforming with the operation strategies. The process categories are in turn subdivided into process elements (third level). The fourth level contains the implementation-related itemization of the individual process elements and is not part of the SCOR model (APICS Supply Chain Council, 2014; www.apics.org). The sub-division of the SCOR model into hierarchical levels enables a linkage with ISO 9001:2015 by adaption to the levels (see Figure 2). Processes in a quality management system according to ISO 9001:2015 are depicted in a process map illustrating the existing processes and their interrelationships. The processes are classified into leading, core and support processes, e.g. production belongs to core processes and interacts, for example, with procurement. On the next level, the processes can be broken down into sub-processes, e.g. production consists of several processes. According to the SCOR model, the processes in a quality management system are sub-divided into process elements, which are described in procedures, including information about input/output, expected results of the processes etc. The description of the implementation is contained in the work instructions and their references to further documents.

SCOR model	Level	ISO 9001:2015
Process Types (Scope): Plan, Source, Make, Deliver, Return	1	**Process map** Processes divided in leading, core, support processes
Process Categories (Configuration)	2	**Processes with sub processes**
Process Elements (Steps)	3	**Procedures**
Process Elements (Implementation)	4	**Work instructions**

Figure 2. Adoption of the SCOR model levels (APICS Supply Chain Council, 2014) to ISO 9001:2015.

To identify joint issues and derive joint processes, the content of the individual levels of the SCOR model and the requirements of ISO 9001:2015 were compared with each other. Based on joint topics and complementary goals, specific leading, core and support processes of the component supply chain were assigned to process types and categories of the SCOR model. Additionally, the identified processes requiring harmonization regarding the critical aspects of the supply chain are divided into processes, which are directly and indirectly influenced by the external perspective. For example, the process type plan is aimed at the development of plans concerning the supply chain (APICS Supply Chain Council, 2014). Interfaces with ISO 9001:2015 are standard sections "8.1 Operational planning and control" and "8.2 Requirements for products and services". On the basis of respective requirements, joint processes were identified, which require harmonization with the external perspective. The results are illustrated in Table 2.

Table 2.
Identification of common processes

<table>
<tr><th colspan="2">SCOR model</th><th>ISO 9001:2015</th><th colspan="3">Joint processes</th></tr>
<tr><th colspan="2" rowspan="2">Process categories</th><th rowspan="2">Standard section</th><th rowspan="2">Process type</th><th colspan="2">Processes</th></tr>
<tr><th>Direct</th><th>Indirect</th></tr>
<tr><td rowspan="3">Plan</td><td>• Plan SC
• Plan Source
• Plan Make
• Plan Delivery</td><td rowspan="3">8. Operation
8.1 Operation planning and control
8.2 Requirements for products and services</td><td>Core processes</td><td>• Request handling
• Order processing</td><td>• Procurement
• Production
• Logistic</td></tr>
<tr><td rowspan="2">Plan Return</td><td>Core processes</td><td>• Complaint management
• Logistic</td><td>• Production
• Logistic</td></tr>
<tr><td>Support processes</td><td>• Identification & traceability</td><td>• Preventive and corrective actions</td></tr>
<tr><td>Source</td><td>• Source Stocked Product
• Source Make-to-Order Product
• Source Engineer-to-Order Product</td><td>8.5 Control of externally provided processes, products and services</td><td>Core processes</td><td>• Procurement</td><td>• Production
• Logistic
• Complaint management</td></tr>
<tr><td rowspan="2">Make</td><td rowspan="2">• Make-to-Stock
• Make-to-Order
• Engineer-to-Order</td><td rowspan="2">8.5 Production and service provision</td><td>Core process</td><td colspan="2">• Production</td></tr>
<tr><td>Support process</td><td colspan="2">• Identification and traceability</td></tr>
<tr><td rowspan="2">Deliver</td><td rowspan="2">• Deliver Stocked Product
• Deliver Make-to-Order Product
• Deliver Engineer-to Order Product
• Deliver Retail Product</td><td rowspan="2">8.4 Production and service provision</td><td>Core process</td><td colspan="2">• Logistic</td></tr>
<tr><td>Support process</td><td colspan="2">• Identification and traceability</td></tr>
</table>

Cont. table 2

Return	Source Return	• Defective Product • MRO Product • Excess Product	**8.2** Control of externally provided processes, products and services	Core process	• Complaint management	• Logistic • Procurement
	Deliver Return	• Defective Product • MRO Product • Excess Product	**8.5.5** Post-delivery activities **8.7** Control of nonconforming outputs	Core process	• Complaint management	• Logistic • Core processes where the cause is identified
				Support process		• Preventive and corrective action activities
Enable	• Manage Supply Chain Business Rules		**4.** Context of the organization **5.** Leadership		• Strategy	
	• Manage Supply Chain Performance		**9.** Performance evaluation	Leading Processes	• Management review • Internal Audit	• Core processes • Leading processes • Support processes
	• Manage Supply Chain Human Resources		**7.2** Competence	Leading process	• Human resource management	
	• Manage Supply Chain Assets		**7.1.3** Infra-structure		• Maintenance management • Gauge management	

4. SCQM model for automotive components

The SCQM model, which is illustrated in Figure 3, was designed with reference to a supply chain for ready-to assemble components. The supply chain includes the production of raw materials, semi-finished products, component parts, ready-to assemble components and the assembling process.

The introduction of SCQM is a strategic choice of the supply chain leadership (Carmignani, 2009; Hu *et al.*, 2015). The implementation on the operational level takes place through the internal, downstream and upstream QM (Quang *et al.*, 2016; Hu *et al.*, 2015). Individual characteristics of the dimensions of the SCQM model are affected by the specific environmental factors of the automotive industry, which are generally classified according to (Hu *et al.*, 2015) into competitive environment, government regulations and supply chain characteristic.

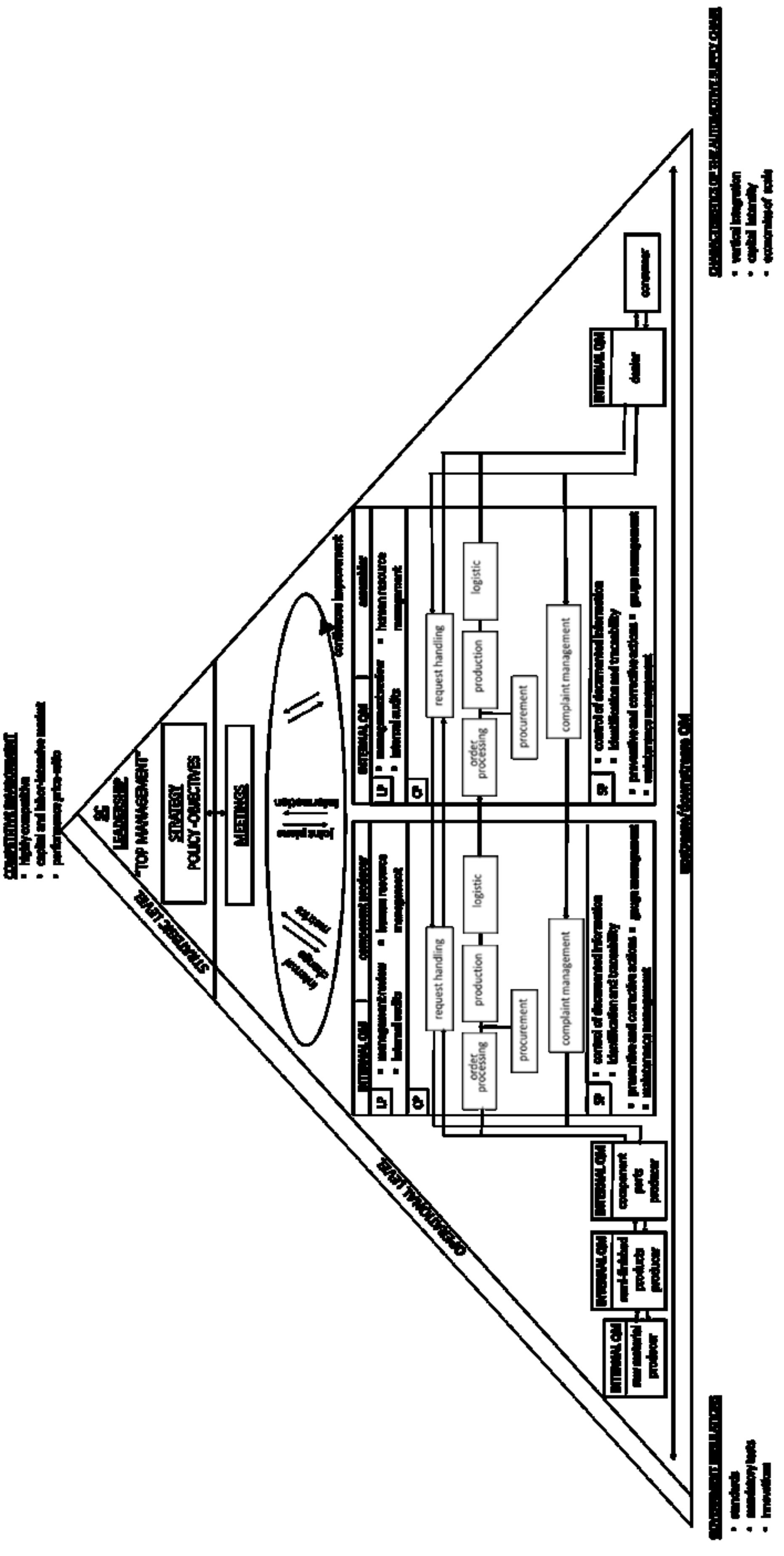

Figure 3. SCQM model for automotive components

The SCQM strategy, which is defined by the top management, harmonizes, combines and balances the requirements of the internal and external perspective. Moreover, the policy and objectives are determined.

The starting point for the introduction of SCQM at the operational level is the implementation of internal QM, which interacts with the direct supplier and customer. Based on the processes identified in the previous chapter, process maps for the individual stages, illustrated in Figure 3, were developed. The internal processes must be harmonized with the external requirements of the supply chain discussed on the strategic level, for example, specific requirements for identification and traceability for the whole supply chain.

Due to the fact that the requirements of ISO 9001:2015 are the common specifications for all industries, additional industry-specific and company-specific requirements need to be applied. Industry-specific requirements are given in respective standards like ISO/TS 16949, VDA and regulations (e.g. FMEA, APQP). Company-specific requirements relate to the corresponding field of the companies. Figure 4 shows the variety and complexity of the requirements for the component supply chain which uses aluminum strips. Company-specific requirements are given, for instance, in the standard series DIN EN 485 "Aluminium and aluminium alloys – sheet, strip and plate" defining specifications and order guidelines concerning properties, control plans etc. To ensure the quality of a semi-finished product, the standardization of the ordering process, the requirements of the raw material supplier and the raw material itself are essential. In the case of ordering ingots, the standard DIN EN 1676 "Aluminium and aluminium alloys – alloyed ingots for remelting" must be taken into account.

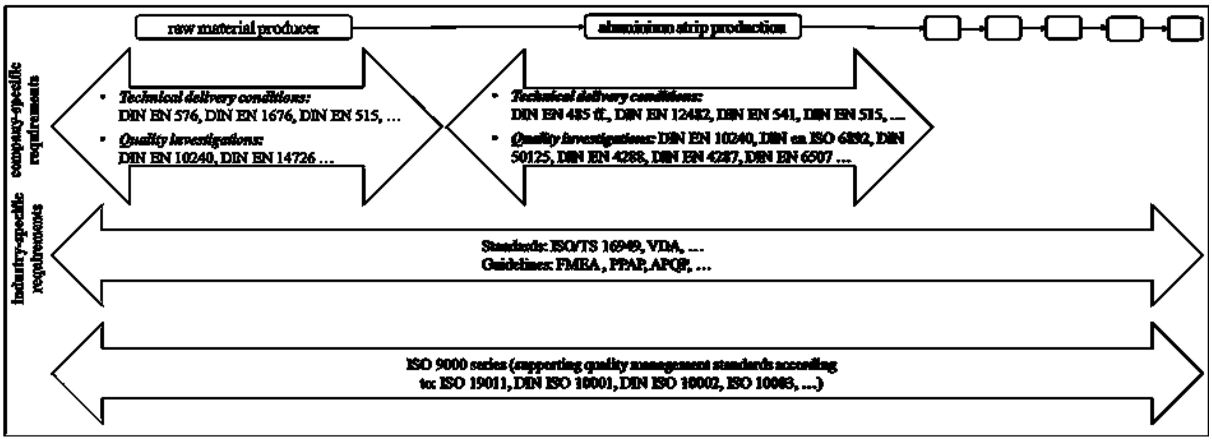

Figure 4. Requirements of the automotive industry.

Beside the interactions between the individual supply chain partners, interactions between all members of the supply chain take place at the senior level of strategic alignment. This includes meetings concerning the generation of collaborative demands, material replenishment and production plans but also additional quality issues. Based on joint plans, performance can be evaluated and improvement actions can be derived for the whole supply chain as well as for the individual stages.

5. Results and implications

The paper considered the merger of QM and SCM to SCQM. On the basis of an extensive literature review, dimensions of SCQM were identified. To achieve a detailed view of the joint processes of QM and SCM, the SCOR model and ISO 9001:2015 were checked for common features. It was illustrated that on the one hand, there are processes which are under direct impact. This means processes which need to be integrated with suppliers and customers. On the other hand, there are processes which are influenced indirectly and require a harmonization with the external conditions. Using the above-mentioned findings, an SCQM model was developed for automotive components.

The implementation takes place at the strategic and operational level. The strategic level serves the holistic supply chain perspective, including a joint policy and objectives. The operational level includes internal QM and its integration with the upstream and downstream QM. To establish SCQM, companies in the automotive supply chain should initially focus on the introduction of a stable internal QM based on ISO 9001:2015, followed by the integration of downstream and upstream QM. In this context, specific requirements which can be sub-divided into industry-specific and company-specific requirements should be gathered. Moreover, joint management should be organized on the senior level. Based on the joint management, performance could be evaluated and improvement processes can be derived.

Acknowledgments

This work was supported by the European Union (European Social Fund) and Saxonian Government under grant 100270111.

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