Postprint

Industry 4.0 technologies in the purchasing process

Industry 4.0 technologies in the purchasing process

Abstract

Purpose - To explore the possible practical impact of Big Data/Business Intelligence and Internet of Things on the purchasing process of premium automotive manufacturers, and to evaluate its theoretical impact with a transaction cost economics approach.

Design/methodology/approach - An exploratory multiple-case study was carried out, using qualitative content analysis and cross-case synthesis.

Findings - Collaborative platforms and a new purchaser role were found to impact the entire process. In the strategic purchasing 4.0 process, co-creation of specifications, automated prequalification and parameter-based negotiations are some expected changes. The operative purchasing 4.0 process is shaped by e.g. interactive call-offs. Transaction cost is expected to decrease, by reduced uncertainty and supplier specificity, and lowered information search, negotiation and monitoring costs.

Research implications - The description of a potential purchasing 4.0 process for premium automotive manufacturers.

Practical implications - Premium automotive manufacturers can develop strategies to push the existing standards of purchasing. Suppliers can create scenarios to allow for future compliance at the purchasing-sales interface.

Social implications - The consideration of new technologies' effects on the workforce.

Originality/value – No identified study focused on the impact of Industry 4.0 technologies on the purchasing process of premium automotive manufacturers.

Keywords: Industry 4.0 technologies; Internet of Things; Big Data/Business Intelligence; Purchasing Process; Premium automotive manufacturers; Transaction cost economics

1. Introduction

The fourth industrial revolution or Industry 4.0 is taking place (Lin *et al.*, 2018), pushed by customer expectations of technological developments like digitalization (Nazir and Shavarebi, 2019; Lin *et al.*, 2018; Foerstl *et al.*, 2017). Industry 4.0 implies benefits based on automation and increased amounts of accessible data (Weyer *et al.,* 2015). Real-time information sharing (Glas and Kleemann, 2016) and enhanced data processing further enables more flexible planning (Weyer *et al.,* 2015; Zhou *et al.*, 2015). Industry 4.0 consists of a number of vaguely defined and partly overlapping technologies (Lin *et al.*, 2018; Glas and Kleemann, 2016), such as Cyber-Physical Systems, Big Data/Business Intelligence, Internet of Things and Smart Factories. One content analysis by Oesterreich and Teuteberg (2016) within Industry 4.0 publications, and another broad overview provided by Pfohl *et al.* (2015), signalled the need to limit and focus certain technologies. Therefore this study focuses on two central technologies; Big Data/Business Intelligence – BD/BI (Popovic *et al.*, 2019; Wang *et al.*, 2016; Kagermann, 2015) and Internet of Things – IoT (Lin *et al.*, 2018; Osmonbekov and Johnston, 2018; Smit *et al.,* 2016).

The importance of purchasing continues to increase (Bals *et al.*, 2019: Osmonbekov and Johnston, 2018; GEP, 2018). By leveraging purchasing potentials, companies strive to achieve low cost, high quality, and low risk while realizing synergies for increasingly individualized products (Feng and Zhang, 2017; Foerstl *et al.*, 2017). Few studies examine the impact of new technologies on purchasing (Osmonbekov and Johnston, 2018; Glas and Kleemann, 2016). One exception is a recent study identifying future competency demands on purchasing professionals. Reflected by the latest development in Industry 4.0, digitalization including e.g. automation and Big Data were identified as important future competencies (Bals *et al.*, 2019). Consultancy reports further confirm the practical challenges that come with Industry 4.0. Pellengahr *et al.* (2016) showed that 37% of German companies have implemented some Industry 4.0 technologies, but only one third of them have made purchasing adjustments. GEP (2018) claims that the use of real-time data in purchasing will accelerate. How this development will impact purchasing can be explored through the purchasing process, where concrete changes on sub-process level can be seen. A focus on increased digitalization of the purchasing process for companies to stay competitive, was encouraged by Bals *et al.* (2019), Zafari and Teuteberg (2018) and Yu *et al.* (2017). Purchasing processes differ due to various industry specifics (Wynstra *et al.*, 2018; Osmonbekov and Johnston, 2018).

Studies of how e.g. IoT impacts purchasing processes generally was encouraged by Bals *et al.* (2019), and particularly in high-technology industries (Osmonbekov and Johnston, 2018) such as the automotive industry (Goyal *et al.*, 2018); with outsourcing levels of up to 80% and renowned for its pioneer and innovative role (Manello and Calabrese, 2019; Stock and Seliger, 2016; Kagermann, 2015; Zhou *et al.*, 2015). No identified study described the purchasing process of automotive manufacturers under new technologies. It would be practically relevant to make such a description in line with Lin *et al.* (2018), to support companies for successful implementation. The automotive industry is complex. A distinction can be made between high-volume and premium brands; this study focuses premium automotive manufacturers producing sophisticated and highly appointed cars (Hertenstein and Williamson, 2018), as this segment is increasing in importance and volume (Manello and Calabrese, 2019). Combining the partial knowledge in Industry 4.0, purchasing process and premium automotive manufacturing into a coherent study, formulating *RQ1: How can BD/BI and IoT practically impact the purchasing process of premium automotive manufacturers?*

To root new, exploratory research in consolidated theoretical frameworks in purchasing research was encouraged by e.g. Foerstl *et al.* (2017) and Spina *et al.* (2016). Transaction cost economics (TCE) has its focus on costs for buyer and seller to complete a transaction (Williamson, 1981). TCE is applied to evaluate the potential theoretical impact on the purchasing process, caused by BD/BI and IoT technologies. *RQ2: How can BD/BI and IoT in the purchasing process of premium automotive manufacturers theoretically impact TCE?* The purpose is to explore the possible practical impact of BD/BI and IoT on the purchasing process of premium automotive manufacturers, and to evaluate its theoretical impact with a TCE approach.

2. Literature review

For RQ1, the literature review deals in 2.1 with the focused Industry 4.0 technologies, in 2.2 with the purchasing process under these technologies and in 2.3 with automotive manufacturing characteristics. For RQ2, 2.4 contains TCE theory. 2.5 provides the research model.

2.1 Big Data/Business Intelligence and Internet of Things

Big Data refers to high-volume, high-velocity and high-variety data (Wang *et al.*, 2016), that are difficult to analyze with traditional data processing methods (Popovic *et al.*, 2019; Kang *et al.*, 2016). Through BD, new technologies extract information from various data types and create actionable knowledge (Zhou *et al.,* 2015). With BI (or Big Data Analytics), this data can be mined by smart algorithms based on e.g. probability calculations. It enables decision-making to improve visibility, flexibility and integration of e.g. purchasing processes (Popovic *et al.*, 2019; Wang *et al.,* 2016). Subsequently, identified patterns are correlated to produce new knowledge (Kagermann, 2015). Process mining and analytical platforms allow real-time control while decision-making is assisted, improving efficiency through planning and stochastic simulations (Kang *et al.*, 2016).

IoT enables things (e.g. sensors/RFID, devices, smartphones) to interact and cooperate based on mobile communication technologies, as well as updated internet communications protocols, wi-fi and bluetooth (Osmonbekov and Johnston, 2018; Hermann *et al.*, 2016; Fang *et al.,* 2016). It also enables interaction between machines and humans (Smit *et al.*, 2016). IoT is a network providing the infrastructure to integrate the physical world into computer-based systems and thereby makes things self-controlled (Kang *et al.*, 2016), and is a platform for systems integration and the interface towards the operators (Kang *et al.,* 2016). These technologies are expected to enable closer integration (Forstner and Dümmler, 2014). IoT is expected to grow rapidly, enabled by decreased sensor costs (Osmonbekov and Johnston, 2018).

2.2 The purchasing process under BD/BI and IoT

The purchasing process consists of different sub-processes (Bals *et al.*, 2019; Osmonbekov and Johnston, 2018; van Weele, 2014). van Weele's (2014) established purchasing process was selected as the base. While for van Weele (2014) the make-or-buy decision is part of the purchasing process, this study considers the make-or-buy decision to be excluded, rather being a part of sourcing. Its strategic part consists thus of three sub-processes; define specification, select supplier, and negotiation/contracting. The operative part consists of another three sub-processes, ordering, expediting and evaluation. The strategic process is typically only performed once in the case of an initial purchase. As outlined by van Weele (2014) and Osmonbekov and Johnston, 2018; future straight or modified rebuys are handled in the operative process. Purchasers face challenges in handling a mass of information in each sub-process (Schneider and Wallenburg, 2013). Figure 1 specifies the operationalization of activities in each sub-process, based upon van Weele (2014).

BD/BI can be applied to analyze purchasing processes. It facilitates strategic purchasing by evaluating supply market trends and suppliers, formulating sourcing strategies, and predicting supply disruptions (Wang *et al.,* 2016). For define specification, Lasi *et al.* (2014) foresee changed customer requirements from individualization and innovation, creating needs for additional products. These requirements, paired with technological advancements on the manufacturers' part, can further imply an expanded supplier base (Stock and Seliger, 2016). Yu *et al.* (2017) and Pfohl *et al.* (2015) described ways to automatically select suppliers, enabled by new technologies such as IoT. Fang *et al.* (2016) and Hermann *et al.* (2016) discussed how IoT can reduce uncertainty, such as uncertain capabilities to fulfill demand at suppliers, when real-time information increases transparency. IoT can also enable information sharing between suppliers and manufacturers. Osmonbekov and Johnston (2018) suggested that the purchasing process has two fundamental aspects; communication (obtaining, retrieving, analyzing and distributing information) and transaction (activities related to the fulfillment/completion of the purchase). By the adoption of IoT, both communication and transactions will become more

human-to-machine or machine-to-machine and hence change the purchaser role. New purchases and modified rebuys will still rely on human interaction to reduce uncertainty. The integration of processes, systems and information within and between organizations, by e.g. the use of information databases, enables real-time management from order placement to outbound logistics and supports collaboration (Osmonbekov and Johnston (2018; Oesterreich and Teuteberg, 2016; Smit *et al.,* 2016; Bennett and Klug, 2012). Altogether IoT will push the existing standards of purchasing (Osmonbekov and Johnston, 2018).

2.3 Automotive manufacturing characteristics

No identified study focused specifically on premium automotive manufacturing. Therefore, this section describes automotive manufacturing generally. The automotive industry is one of the most supplier-dependent and therefore purchasing-dependent industries, with OEMs as dominant and powerful actors (Caniëls *et al.,* 2013). The number of individualized variants is growing (Bennett and Klug, 2012), a car contains more than 5000 components, implying a complex tier supplier network (Caniëls *et al.*, 2013). Electronic Data Exchange (EDI) is often used for handling information flows between manufacturers and suppliers, either using traditional, costly standards or more updated web-EDI solutions (Jardini *et al.,* 2015; Bennett and Klug, 2012). Specific project-related material requirements, long contracts, cross-functional involvement, a high cost accounting focus, large supplier bases, modular product configurations and close collaborations and integration in logistics are also industry characteristics (Hertenstein and Williamson, 2018; Bennett and Klug, 2012; Pereira *et al.*, 2011; Thun and Hoenig, 2011; Schmitz and Platts, 2003).

The underlying manufacturing is sequential serial production (Bennett and Klug, 2012; Thun and Hoenig, 2011; Schmitz and Platts, 2003). The influence of Industry 4.0 on automotive manufacturing can be described as shift towards a decoupled, flexible and integrated manufacturing system (Kagermann *et al.*, 2013). Automotive manufacturing in Industry 4.0 is based on dynamic production lines controlled by new technologies (Kagermann *et al.,* 2013). Dynamic reconfiguration of workstations allows the production of individualized variant, while production planning is autonomously managed in order to prevent bottlenecks. These changes impact automotive manufacturers and their suppliers (Nazir and Shavarebi, 2019; Hertenstein and Williamson, 2018; Stock and Seliger, 2016).

2.4 Theoretical foundation – transaction cost economics

Transaction costs are costs that are needed to exchange a product between buyer and supplier (Sarkis *et al.,* 2011). Most often TCE is used in a make-or-buy situation to determine which of the alternatives that leads to lowest transaction cost (Halldorsson *et al.,* 2007; Ketchen and Hult, 2007). Transactions include three attributes; uncertainty, asset specificity and frequency (Williamson, 1981, 1985; Spina *et al.,* 2016).

Uncertainty is the inability to predict all events involving the transactions, related to the complexity of company environment (de Campos and de Mello, 2017; Williamson, 1985). Uncertainty can be understood as lack of information (Wynstra *et al*., 2018). Rapid uncertainty and degree of change is associated with high technology industries (Marshall *et al.*, 2007). *Asset specificity* is the limited value of a physical or dedicated asset in another application (Halldorsson *et al.,* 2007; Sarkis *et al.*, 2011). High asset-specific investments can lead to contracting problems, to safeguard against opportunism (Marshall *et al.,* 2007; Williamson, 1985). Unilateral investments, specific to a relation (e.g. training), are specifically related to opportunism (Wynstra *et al.*, 2018). Transaction *frequency* refers to the number of times the actors carry out transactions, classified as one-time, occasional or recurrent (Williamson, 1985). The higher the frequency the higher the transaction cost (Wynstra *et al.,* 2018).

The three attributes affect transaction costs, which can be structured by type of cost into information, negotiation and monitoring costs (Williamson, 1981; Spina *et al.*, 2016). Transactions characterized by asset specificity, uncertainty and infrequency lead to high transaction cost (Williamson, 1981, 1985). Halldorsson *et al.* (2007) analyzed reduction of a supplier base, which reduced transaction costs related to collecting information, negotiation, contract writing and monitoring penalty clauses. Bennett and Klug (2012) mentioned dedicated IT-infrastructure (EDI) between automotive partners, implying asset specificity and high switching costs. Wynstra *et al.* (2018) operationalized transaction costs very detailed as search cost (time spent on comparing and selecting supplier), tender specificity (in terms of buyer's firm situation, technical, cost and delivery terms), contract cost (time spent on drawing up and negotiating the contract), contract specificity (in terms of technical, financial, legal and overall) and ex post problems (e.g. delivery delays, price overrun, incomplete or slow product, deviations and incompatibility). Another structure is to relate transaction costs to the purchasing process. TCE distinguishes between transaction costs *ex ante to contract* or in the strategic purchasing process, including costs for searching for information, negotiating and registering contracts (Williamson, 1985; de Campos and de Mello, 2017). *Ex-post contract* or in the operative purchasing process includes costs such as monitoring of the contract in order to maximize performance (Ketchen and Hult, 2007; Halldorsson *et al.*, 2007).

2.5 Research model

This study focuses on a gradual change over a longer time period. The research model in Figure 1 is more typical, illustrating a "before-and-after" situation. It illustrates the Industry 4.0 technologies impacting the traditional purchasing process, that will lead to practical impact and a purchasing 4.0 process for premium automotive manufacturers (RQ1). With a TCE approach, the traditional and new purchasing process are compared to evaluate the theoretical impact (RQ2).
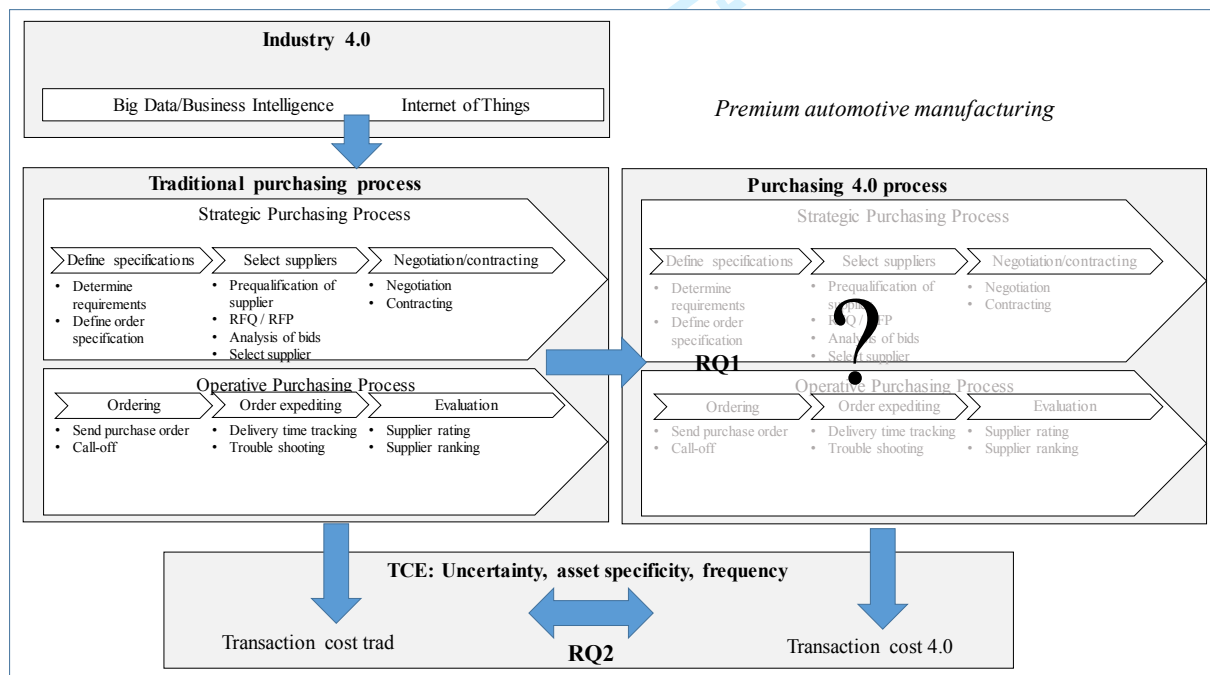
Figure 1. Research model

3. Methodology

As existing knowledge is not sufficiently rich, this study is exploratory and a case study methodology is selected. This also conforms to "how" research questions. A clear purpose as well as exploration criteria were developed prior to data collection in accordance with Yin (2014). The topic requires an in-depth approach, as well as considering respondents interacting within and between companies. In order to create representativeness in different settings within premium automotive, the study considers multiple cases. As the OEMs enabled to also study their suppliers, this possibility encouraged by Goyal *et al.* (2018) and Hertenstein and Williamson (2018) was utilized. A non-probability sampling technique was thus chosen (Saunders *et al.,* 2016). Sampling criteria were defined beforehand, restricting the population to known Industry 4.0-knowledgeable premium automotive manufacturers of different types (cars, construction equipment) for increased representativeness, and their suggested suppliers for direct material who were willing to participate in the study and for convenience located in Europe. This resulted in three cases, characterized by collaborative practices and dependency of the supplier towards the manufacturer. Nevertheless, the cases can be differentiated in the importance of the automotive industry: in case A and B the suppliers are 100% selling to the automotive industry, the sales of supplier C to the automotive industry account for 30%. Additionally, five industry experts were selected based on current publications online and within trade magazines.

Each case comprised of management and purchasing respondents among manufacturers, and sales-related respondents at suppliers (see Table I). All respondents were selected based on a mature experience in automotive purchasing and knowledge of the Industry 4.0 concept. In order to validate cross-case synthesis, experts were included. All respondents required and were granted confidentiality so no further details of the involved companies and respondents can be shared. Semi-structured interviews were conducted. The interview guide was based upon the literature review, except for TCE theory that was used for analysis. In order to ensure proper understanding, it was pre-tested on one potential respondent; this led to adjustments in wording and structure. Respondents were provided with the interview guide beforehand. The interviews were conducted in person (10) or via phone (12) and varied between 30 and 105 minutes. The sample encompassed 20 hours of interviews.

Table I. Overview of cases, organizations and respondents

Case	Organization	Respondents' position
A	German premium car manufacturer	Top Management Purchasing
		Middle Management Purchasing
		Director In-house Consulting Purchasing
		Team Leader Purchasing
		Purchaser
	Interior supplier	Top Management Sales
B	German premium car manufacturer	Top Management Purchasing
		Middle Management Purchasing
		Middle Management Purchasing
		Purchaser
	Electronics supplier	Key Account Manager
		Sales Support
C	Swedish premium construction equipment manufacturer	Top Management Purchasing
		Buyer
		Purchaser
	Metal component supplier	Demand Manager

		IT Manager Sales Interface
All	Consultancy	Director
	Consultancy	Partner & Managing Director
	Institute	Head of research group Purchasing
	Consultancy	Consultant
	Consultancy	Associate Partner

The unit of analysis (Yin, 2014) is the purchasing-sales interface between manufacturers and suppliers. Qualitative Content Analysis/QCA (Mayring, 2014) was utilized for analysis, focusing on conceptualizing the process of assigning categories to text passages, following content-analytical rules. A combination of deductive category assignment, based upon the literature review, and inductive category formation, by repetitively scanning the transcripts, was carried out. In order to create more robust findings, a cross-case synthesis was carried out (Yin, 2014). Through the early creation of uniform categories, cross-case conclusions were drawn under consideration of contrasting settings in cars and construction equipment. All evidence were considered, plausible rival interpretations were addressed and focus was set on the most significant aspects, to secure internal validity. Following Yin (2014), construct validity was created through clear concept definitions. Multiple sources of evidence (cases plus experts) were considered and a chain of evidence was provided through iterative reasoning and respondents' reviews. External validity was achieved through early development of research questions to deduct appropriate theory and create a research model, and using a replication logic through a cross-case synthesis. For reliability and in accordance with Yin (2014), the study strictly documented the procedures through QCA, case study protocols and databases. As the analysis was carried out jointly by the researchers, a formal operationalization of research steps was inevitable to create inter-coder reliability (Mayring, 2014). This approach allows for replication of the study. The literature is reliable due to the authority and reputation of sources (Saunders *et al.*, 2016). Research ethics, designed to e.g. regulate confidentiality, was ensured via a consent form.

4. RQ1 – practical impact on the purchasing process

Split up by impact on all, strategic and operative sub-processes, each section starts by presenting a Table with condensed empirical, case-by-case data on how BD/BI and IoT practically can impact the purchasing process. The themes under each sub-process are then analyzed and synthesized in a detailed, cross-case manner, adding experts' views and literature. In the last section, a possible purchasing 4.0 process is shown.

4.1 Practical impact on all sub-processes

Table II presents potential practical impact on all sub-processes in the purchasing process.

Table II. Practical impact on all sub-processes identified in the cases

Sub-process	Case A	Case B	Case C
All	IT-system collaboration platforms, standardized interfaces System support and collaboration impact purchaser role	System integration into collaboration platforms More strategic, less administrative purchaser role	Joint development of collaboration platforms, joint system interfaces More strategic, less administrative purchaser role

Collaboration platforms: One significant change is the development of collaboration platforms. Real-time, high-quality data usage through standardized, integrated interfaces is identified in all cases. A collaboration platform that integrates manufacturing with the suppliers' sales function is viewed as influential for strategic and operative purchasing interactions as transparency is improved (Oesterreich and Teuteberg, 2016; Smit *et al.*, 2016; Hermann *et al.,* 2016). The integration of interfaces at manufacturer and supplier can be achieved through IoT (Osmonbekov and Johnston, 2018; Kang *et al.*, 2016) or BI tools, which is confirmed by experts. This was found in all cases, however the level of BI usage seems being based on organizational rather than industry requirements.

Strategic purchaser role: All cases mention that the purchaser role can increasingly focus on strategic tasks. This is enabled by stronger digitalization, IT-support for data structuring, prioritizations, analysis and predictions, and automation of operative activities that reduce administrative tasks (in line with Bals *et al.*, 2019; Osmonbekov and Johnston, 2018; Wang *et al.,* 2016; Pfohl *et al.*, 2015). This implies handling practical information challenges for purchasers (Schneider and Wallenburg, 2013). For the purchaser, decision-making is improved, while reductions in uncertainty (Hermann *et al.*, 2016) facilitate faster process times. This tendency is confirmed by experts.

4.2 Practical impact on the strategic purchasing process

Table III presents potential practical impact on the strategic purchasing process.

Table III. Practical impact on the strategic purchasing sub-processes identified in the cases

Sub-process	Case A	Case B	Case C
Define specification	New individualized products Co-creation of specifications Customization information	Additional smart product scope Joint specification interface Supplier-promoted ideas	No product changes Early involvement of suppliers Understanding of suppliers' capacities
Select suppliers	Expanded supplier base (digitalized, innovative) Look for new suppliers/ innovation scouting Suggestions/pre-assessment via BI Scenario simulations of supplier markets Quotations based upon parameters Consider and quantify hidden costs IT-supported selection of suppliers via IoT and BI	Increased scope of supplier base Look for start-up suppliers Suggestions/prequalification via IoT/BI Automated information gathering Shared bidder lists Parameter-based pricing leads to complex RFQ Automated cost breakdowns Consider hidden costs Direct feedback to suppliers IT-supported selection for simple products	3D-printing suppliers Small change in supplier base Automated prequalification for non-critical components RFQ with parameter pricing Consider hidden costs Improved feedback to suppliers by BD/BI
Negotiating/ contracting	Fact-driven, electronic negotiations via BD/BI Negotiation strategies suggested Parameter/capacity contracts New compliance aspects with start-up suppliers	BI-analyzed previous negotiations, suggested strategies Automated negotiation for simple products Parameter/capacity-based contracts Shorter/flexible contract durations	Automated negotiation by IoT and BI for simple products Negotiation of parameters/ capacities implies changed contracts

		Automatic transfer of RFQ information into contracts	
Change management (added sub-process)	Technical changes integrated Improvement by BI analyses of costing patterns	BI enables automatic price changes in negotiations	Faster interaction based upon system integration and joint interfaces

4.2.1 Define specifications

Expanded product scope: Found in cases A and B, new product scope create changes for purchasing, as corroborated by Kagermann *et al.* (2013). Products will become innovative, complex and electronically enhanced, linked to software solutions. Case A, focused on interior purchasing, indicates a tendency towards higher customization, also suggested by to be valid for the automotive industry by Bennett and Klug (2012); Lasi *et al.* (2014); Feng and Zhang (2017) and Foerstl *et al.* (2017), implying massive variant complexity. This was confirmed by an industry expert but limited to certain product areas. Consequently, the purchasing portfolio for purchasers can be expanded to require broader expertise. Innovative, digitalized products come with shorter life cycles, influencing the timeframe of contracts. While these findings seem valid for cars (case A and B), customization is less common for construction equipment (case C).

Supplier-involved specifications: Based on the need for joint development of specifications and shorter product cycles, specification tasks need to be fused. Besides all required internal functions, suppliers will increasingly be involved also by promoting own ideas (case B and C), while disclosing own production capacities for the manufacturer (case C). This is handled within collaborative, IoT-based platforms. Regarding the individualization tendency primarily found in case A, the specifications can include information on customizability. This sub-process is mostly built on case findings and was not found in literature. Experts confirm a shift towards individualization and supplier suggestions. The early consideration of suppliers' capacities is a case-specific finding in case C.

4.2.2 Select suppliers

Expanded supplier base: According to cases A and B, in order to deliver innovative products, new suppliers must be scouted, explored and incorporated into the supplier base. These suppliers may not necessarily have an automotive focus, and may still be in an early business phase (e.g. start-ups). In all cases, supplier enhancements towards Industry 4.0 technologies need to be initiated by the OEM, calling for a supplier base development (in line with Stock and Seliger, 2016). These changes lead to structural and processual adjustments to consider new suppliers. A general re-shoring/near-shoring tendency can influence purchasing strategies (Stock and Seliger, 2016).

Automated prequalification: Cases A and B show that identification of new suppliers is becoming increasingly relevant, which is reducing the usability of pre-defined bidder lists. Cases A and B describe a qualification suggestion based on system information as desirable, while case C includes a potential automated supplier prequalification for non-critical components. Case A further indicates a need for scenario simulations of supplier markets. Using new technologies to automatically select suppliers was described by Yu *et al.* (2017), Wang *et al.* (2016) and Pfohl *et al.* (2015).

Parameter-based costing: All cases show a new approach to costing under Industry 4.0 technologies. The automotive industry has a high focus on cost accounting (Pereira *et al.*, 2011; Thun and Hoenig, 2011; Schmitz and Platts, 2003). Higher data transparency will enable cost allocations, going from product-centered to parameter-centered. This means that relevant

parameters, such as for a production step or material input, that in different combinations can represent all potential product variants. As a result, purchasers will be able to request for parameter quotations (RFQ), instead of request for products and components quotations. All cases see the need to expand supplier analysis through considering 'hidden costs' (resulting from quality or delivery problems). In case A, a quantification of these costs is considered. Cases B and C indicate high potential for providing direct feedback to the suppliers in the forms of benchmarks or best-practices. This can be valid for premium automotive manufacturers, according to the experts.

IT-supported selection of direct suppliers: Supplier selection in the automotive industry is mostly restricted to direct suppliers, due to the prevailing tier system (Caniëls *et al.*, 2013; Bennett and Klug, 2012). In cases A and B, system support is expected to result in nomination suggestions based on holistic data considerations. Case C considers automated selection decisions for non-critical components. This results in system-supported supplier selection for standardized, simple components. This change was also mentioned by Wang *et al.* (2016).

4.2.3 Negotiations and contracting

Fact-based electronic negotiations: In cases A and B, negotiations are expected to become fact-based, considering information on suppliers' historical negotiation behaviors. While electronic negotiations in all cases are seen as becoming more relevant with increasing advancements in BI technologies, findings from cases A and B indicate a higher importance of human interaction, especially in final negotiations, as suppliers' negotiations patterns will be accessible to purchasers. This is in line with the suggestions of Osmonbekov and Johnston (2018). The extent of analytical considerations is therefore affected by the purchasing history, context and size of the manufacturer. The degree of applicability of electronic negotiations further depends on purchasing context, such as component characteristics and markets. Shortening process times implies increasing the overlap of supplier selection and negotiations. Also as negotiations become more automated, companies may negotiate with more suppliers.

Parameter/capacity contracting: Based on the changed costing focus, contracts are expected to be parameter-centered within a certain capacity frame. Based on new products and shorter product lifecycles, contracts will have shorter timeframes. Case B presents a need for flexible contracts, allowing for the deduction of demand-driven production throughout the supply chain. Automation and system support are thus seen through the integration of the final RFQ and bidding data directly into the contract.

4.2.4 Change management

The management of technical changes of components in all cases is described to be highly critical and resource-consuming. This may be more related to the high-technology automotive industry in general than to Industry 4.0 technologies, in line with Goyal *et al.* (2018) and Hertenstein and Williamson (2018). However, encouraged by experts, this sub-process was added to the purchasing process described by van Weele (2014).

IT-enhanced management of changes: IoT-based system support, linking technical and commercial aspects between manufacturer and supplier, is expected to simplify collaborative change management in all cases. Technical and commercial changes can be conducted in collaborative platforms - a holistic and integrated system through which all required actors can collaborate (e.g. Oesterreich and Teuteberg, 2016).

Autonomous negotiations for technical changes: Previously presented changes towards parameter contracting have introduced a solution to reduce time-intensive re-negotiations for technical changes as cost parameters are set. The automation of change negotiations therefore

is seen as becoming highly autonomous in all cases, enabled by IoT technologies. According to these changes, this sub-process will be highly automated through set parameters and interlinked IT-systems. Experts judge these findings to be valid for premium automotive manufacturers.

4.3 Practical impact on the operative purchasing process

Table IV presents possible practical impact on the operative purchasing process.

Table IV. Practical impact on the operative purchasing sub-processes identified in the cases

Sub-process	Case A	Case B	Case C
Ordering	Automatic ordering Interactive planning/call-offs via IoT	Automatic ordering BI enable interactive call-offs with the supplier BI/IoT communicate and consider supplier capacities	Automated ordering process using IoT and BI, also for pre-serial production
Order follow-up (renamed sub-process)	IoT-based real-time delivery tracking Proactive trouble shooting using IoT and BD/BI with additional information	Real-time access to production/delivery status via IoT Early warning/proactive systems on e.g. weather based upon BD/BI and IoT	Affected by parameter-based pricing
Evaluation	Holistic, even targeting sub-suppliers (by BD) Automatic and shared rating	Real-time access to performance data Rating and bids feedback	No influence

4.3.1 Ordering

Automatic ordering/interactive call-offs: As found in all cases, ordering, although already being quite digitalized and automated based upon the for automotive prevailing EDI solutions (Jardini *et al.*, 2015; Bennett and Klug, 2012), is expected to become even more automatic. The initial purchase order, which activates the contract for subsequent call-offs/rebuys, can be automatically derivable from system data using IoT, without human involvement. Administrative transactions are reduced through e.g. collaborative platforms and general automation (Osmonbekov and Johnston, 2018). Call-offs are based upon production planning, which can be carried out interactively with first-tier suppliers, considering capacities and based upon IoT. This change is presented in the cases, and experts claim a general feasibility.

4.3.2 Order follow-up

van Weele's expediting sub-process is here renamed and labelled order follow-up sub-process, as Wei and Chen (2008) concluded that in the automotive industry, this sub-process besides expediting also includes quality inspection and the handling of invoices.

Real-time tracking: IoT opens up a new dimension of delivery tracking, according to cases A and B, built upon up-to-date location information of the progress of orders during production and delivery. Experts confirm this change as being industry-wide.

Proactive trouble shooting: Based on integration of suppliers and BI technologies, early warnings can reframe trouble shooting from reactive to proactive. Cases A and B even suggest using BD/BI to incorporate risks such as meteorological occurrences into trouble shooting. Beyond a pure identification of potential risks, the system is expected to combine existing data

11

to suggest problem-solving possibilities, such as a capacity shift to a different supplier (Weyer *et al.*, 2015; Zhou *et al.*, 2015). Additionally, cases A and B see the relevance of real-time trouble shooting based on IoT applications.

4.3.3 Evaluation

Holistic supplier evaluation: IoT and BD allow for holistic real-time supplier evaluation. KPIs from different functional areas can be combined, and evaluations can even be executed for sub-suppliers. This creates a broad evaluation that allows for the identification of performance issues at their roots. While the relevance of this approach is derived from cases A and B, it can be expected that also less complex supply chains like case C can benefit from this.

Rating feedback: Improved integration with suppliers can also be used to provide direct feedback to the supplier for offers and bids. Here internal information on in-house cost targets and calculations, as well as supplier information on best practices can selectively be shared to allow suppliers to improve their offers before actual negotiations. These findings are derived from cases A and B. Experts see this change as relevant for premium automotive manufacturers.

4.4 Practical impact – a possible purchasing 4.0 process

Figure 2 shows examples of how the traditional purchasing process may be practically impacted, as expected by respondents and experts. There is impact that affects all sub-processes. The strategic purchasing process has more potential to be impacted by new technologies. The purchasing 4.0 process of premium automotive manufacturers may include additional sub-processes (change management), renamed sub-processes (order follow-up) and a number of new themes under each sub-process.
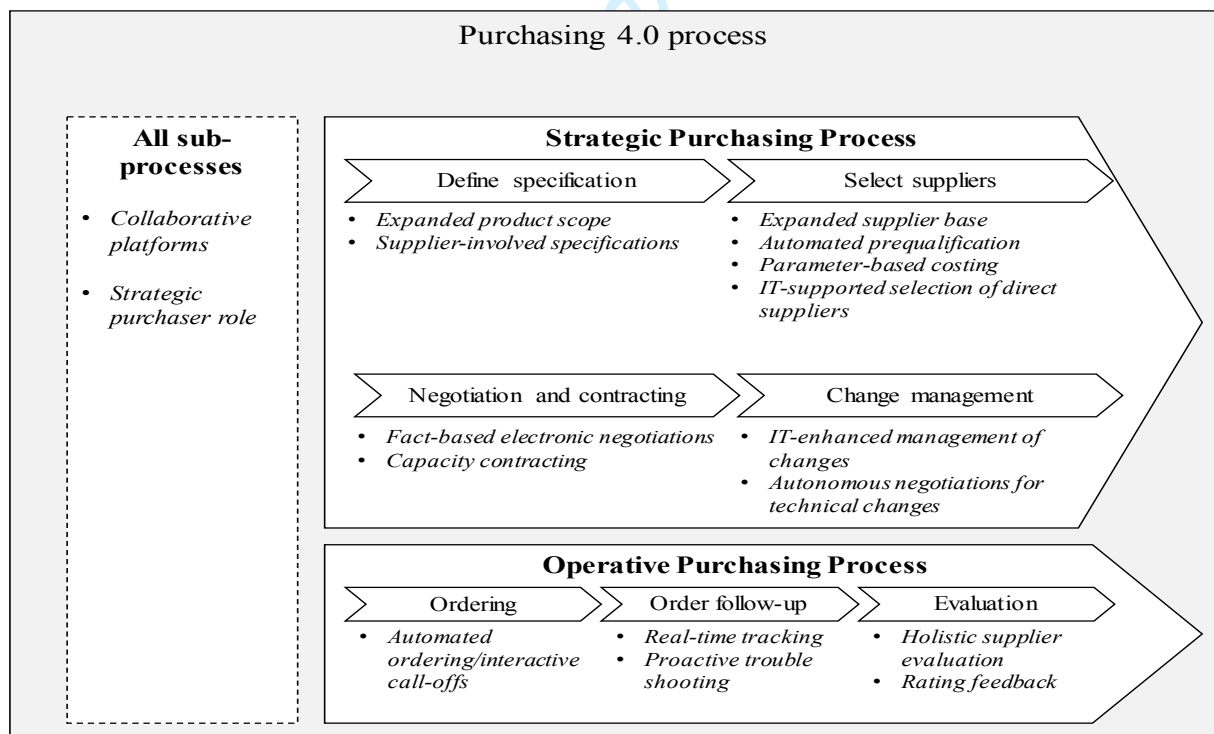
Figure 2. A possible purchasing 4.0 process model of premium automotive manufacturers

This study is solely based upon respondents from premium automotive, with mature experience in automotive purchasing and knowledge of Industry 4.0. Long experience may indicate that they do not know other industries, and they have not been asked about situations in other industries. The potential changes in e.g. "all sub-processes" are not backed up by particular automotive references, and may well occur in other industries. Other sub-processes like ordering are typically already digitalized in automotive, and changes in other industries are expected to be more significant. Change management is particularly typical for the high-technical and variant-rich premium automotive manufacturers.

To increase the representativeness for the studied industry, this study addresses both cars and construction equipment, and differences are found between them. One difference can be related to the lower volumes and variety in construction equipment. Another difference can be explained by that their respondents were comparably fewer and had lower focus on the operative purchasing process. A third difference can be that in case C, the supplier has a lower focus on premium automotive manufacturers. The sampling for multiple cases hence have captured different situations for purchasing 4.0 within the limits of premium automotive industry. Therefore, the findings remain local within the limitations, and should not be up-scaled to the whole automotive industry. The high significance of parameter-based costing and supplier-involved specifications were surprising empirical findings, not found in literature. Some expected changes are mentioned just in one case and is therefore not included in the model, such as in selecting suppliers, mentioning a requirement of a bypass of the classical quotation handling, through request for innovation proposals to allow for the potential consideration of business ideas from developing businesses such as start-ups. While this might sound like a simple adjustment, it requires modifications of compliance and related internal regulations. This would mean that purchasers request simplified costing overviews for innovation concepts under development. Another change in negotiating/contracting can be described as investment contracts with start-ups, in which a loose calculation for a yet un-finalized component is agreed upon and its development is financially supported. This is crucial in car manufacturers, allowing for shorter time-to-market innovations.

5. RQ2 – theoretical impact on TCE

Transaction cost economics dictates that the alternative with the lowest transaction cost related to three attributes - uncertainty, asset specificity and transaction frequency - should be selected (e.g. Spina *et al.,* 2016; Halldorsson *et al.*, 2007; Ketchen and Hult, 2007; Williamson, 1981).

5.1 Impact on TCE attributes

Uncertainty can be the inability to predict events around transactions (Williamson, 1981). As high-technology industries are generally associated with uncertainty (Marshall *et al.,* 2007), this is valid for premium automotive manufacturers. IoT can reduce uncertainty in the purchasing process by collaborative information databases (Osmonbekov and Johnston, 2018; Hermann *et al.,* 2016; Fang *et al.,* 2016; Oesterreich and Teuteberg, 2016; Smit *et al.,* 2016), in line with the respondents' expected collaborative platforms. Uncertainty related to lack of information (Wynstra *et al.,* 2018), should also decrease, as described in new purchaser roles. To further understand uncertainty, Osmonbekov and Johnston (2018) described communication and transactions in the purchasing process. Communication relates to e.g. obtaining, retrieving and analyzing information, which mainly can be expected to occur in the strategic purchasing process. By the adoption of IoT, new or modified rebuys could be handled with a larger share of human-to-machine communication in the strategic purchasing process, to reduce uncertainty (Osmonbekov and Johnston, 2018). Examples of changed communication found by the respondents are collaborative platforms, supplier-involved specifications and automated

prequalifications; they should all reduce uncertainty. Transactions are activities related to the fulfillment of the purchase in the operative purchasing process. Straight rebuys can be handled with a machine-to-machine approach to reduce uncertainty (in line with Osmonbekov and Johnston, 2018). Automatic ordering and interactive call-offs, found in the cases, are examples of ways of handling transactions with a machine-to-machine approach, having the potential to reduce uncertainty also in the operative purchasing process.

Asset specificity is the limited value of a dedicated asset in another application (Halldorsson *et al.*, 2007; Sarkis *et al.*, 2011). High asset-specific investments can lead to contracting problems (e.g. Marshall *et al.*, 2007). Unilateral investments, specific to relation such as a supplier, are specifically related to opportunism (Wynstra *et al.*, 2018). Traditional EDI standards used for communication in the automotive industry (Jardini *et al.*, 2015; Bennett and Klug, 2012) represent high supplier-specific investments. The new technologies, enabling e.g. collaborative platforms, represent similar, internet-based communication solutions for suppliers and hence lower supplier-specific investments. IoT sensor costs will decrease rapidly (Osmonbekov and Johnston, 2018).

Transaction *frequency* refers to the number of times the actors carry out transactions, mainly classified as one-time, occasional or recurrent (Williamson). The higher the frequency the higher the transaction cost (Wynstra *et al.*, 2018). Some examples of increased frequency related to real-time monitoring (Kang *et al.*, 2016) were found in the cases. At the same time, transactions are automated and with less human involvement.

5.2 Impact on transaction costs

Transactions characterized by uncertainty, asset specificity and frequency imply high transaction cost (Williamson, 1981, 1985). As uncertainty and asset/supplier specificity are expected to decrease, both in the strategic and operative purchasing process, also transaction cost is expected to decrease. The net impact of frequency is difficult to assess in the study.

Transaction costs can be structured by type of cost into information, negotiation and monitoring costs (e.g. Williamson, 1981; Halldorsson *et al.,* 2007; Spina *et al.*, 2016). The operationalization by Wynstra *et al.* (2018) was judged too detailed for this analysis. Transaction costs can also be related to the purchasing process, distinguishing between transaction costs ex ante and ex post to contract. *Ex ante to contract* relate to the strategic purchasing process, including costs for searching for information, and negotiating/contracting (Williamson, 1985; de Campos and de Mello, 2017). Purchasers traditionally need to handle a mass of information (Schneider and Wallenburg, 2013). Even if both product and supplier scope is expected to increase by respondents, searching for information is expected to be simplified by e.g automated prequalifications and IT-supported supplier selection. Negotiating/contracting is expected to be carried out electronically. Therefore, both these cost types are expected to decrease in the strategic purchasing process. *Ex-post to contract* relate to the operative purchasing process, and include costs such as monitoring of contract (Ketchen and Hult, 2007; Halldorsson *et al.,* 2007). Real-time tracking and holistic supplier evaluations are suggested by respondents, implying that also monitoring costs are expected to decrease.

Altogether, the theoretical impact from BI/BD and IoT in both strategic and operative purchasing process is expected to imply decreased transaction costs. In line with Williamson (1981, 1985) it should therefore be selected, or, more pragmatically, premium automotive manufacturers and their suppliers should continue their development in this direction. The general decrease of transaction costs can then be compared to the specific purchasing costs of obtaining the Purchasing 4.0 technologies. Such analysis was however not possible to take into account in this study.

6. Conclusion

Companies are encouraged to digitalize purchasing processes to stay competitive (Bals *et al.*, 2019; Zafari and Teuteberg, 2018; Yu *et al.*, 2017). Therefore, this study explored the practical impact of BD/BI and IoT on the purchasing process of premium automotive manufacturers. Collaborative platforms and strategic purchaser role were found to impact the entire process. The strategic purchasing 4.0 process contained many changes, e.g. co-creation of specifications and parameter-based negotiations, including an added sub-process (change management). Fewer changes are expected in the operative purchasing 4.0 process, e.g. interactive call-offs and proactive trouble shooting. A TCE approach enabled to root explorative research in existing frameworks. Transaction costs in both strategic and operative purchasing process are expected to decrease, by reduced uncertainty and supplier specificity, and lowered information search, negotiation and monitoring cost.

This study's main contribution to literature is the potential purchasing 4.0 process model for premium automotive manufacturers. It deepens and specifies some previous studies on Industry 4.0 in the automotive industry (Lin *et al.,* 2018; Wei and Chen, 2008) with the purchasing focus. The clearest contribution to literature is to van Weele (2014), expanded in two ways. First, the purchasing process model is influenced by Industry 4.0 technologies. Second, it is adapted to this particular industry. Outside that, this study's contribution is that it connects literature on the purchasing process with some selected Industry 4.0 technologies (e.g. Popovic *et al.,* 2019; Osmonbekov and Johnston, 2018), and automotive manufacturing (e.g. Manello and Calabrese, 2019; Hertenstein and Williamson, 2018), together into a coherent whole. The differences found among cases within the premium automotive manufacturers, imply that the findings are industry-specific, and should not be generalized into automotive until such a study is conducted.

The practical contribution and implications are inspiration; premium automotive manufacturers can develop strategies required to push purchasing standards (in line with Osmonbekov and Johnston, 2018); suppliers can deduct scenarios to allow future compliance at the purchasing-sales interface. The study of one manufacturer/supplier interface can possibly be extended to see the implications for the premium automotive supply chain, consisting of many such interfaces. Experts can draw conclusions that may merit new consulting concepts. To practically implement the expected purchasing process, challenges were identified during the interviews, such as top management commitment, access to skilled employees, supplier collaboration willingness, the need for investments, changes in IT-infrastructures and handling of data security (similar to Zafari and Teuteberg, 2018 and Glas and Kleemann, 2016). Practices differ between companies, and several respondents called for the involvement of independent associations in order to create standardization.

Societal implications were the important consideration of new technologies' effects on the workforce. Companies are advised to offer trainings that would allow less-educated employees to work within a digitalized setting. Promising solutions for supply chain transparency, as suggested by Foerstl *et al.* (2017), and the reduced need for offshoring, were offered, contributing to improved sustainability. A limitation of the study is that it reflects the respondents' world view. The fact that those responses are mirrored towards five experts' views and to literature, reduces this bias.

The study offers a number of interesting opportunities for future research. The potential purchasing process can be validated in a broader study among premium automotive manufacturers, or even in the general automotive industry. Manello and Calabrese (2019) distinguished between high-volume and premium brands; also high-volume manufacturers could be studied. Comparative studies in different industries could shed additional light of purchasing 4.0 processes. Further in-depth analyses could include larger quantitative data

collection. This would include quantifications of transaction costs and the associated purchasing costs for obtaining the new technologies. It would also be highly relevant to study how Big Data/Business Intelligence and Internet of Things affect e.g. logistical or financial performance of the system. Findings as request for innovation proposals and parameter-based costing also require additional research. Also other Industry 4.0 technologies, such as Cyber-Physical systems or Smart Factories, could be added and their impact on the purchasing process could be studied.

References

Bals, L., Schulze, H., Kelly, S. and Stek, K. (2019), "Purchasing and supply management (PSM) competencies: current and future requirements", *Journal of Purchasing and Supply Management,* Vol. 25, pp. 1-15.

Bennett, D. and Klug, F. (2012),"Logistics supplier integration in the automotive industry", International Journal of Operations & Production Management. Vol. 32 No. 11, pp. 1281-1305.

Caniëls, M.C.J., Gehrsitz, M.H. and Semeijn, J. (2013), "Participation of suppliers in greening supply chains: an empirical analysis of German automotive suppliers", *Journal of Purchasing and Supply Management*, Vol. 19, pp. 134-143.

de Campos, J.G.F. and de Mello, A.M. (2017), "Transaction costs in environmental purchasing: analysis through two case studies", *Journal of Operations and Supply Chain Management*, Vol. 10 No. 1, pp. 87-102.

Fang, C., Liu, X., Pardalos, P.M. and Pei, J. (2016), "Optimization for a three-stage production system in the Internet of Things; procurement, production and product recovery, and acquisition", *International Journal of Advanced Manufacturing Technology*, Vol. 83, pp. 689-710.

Feng, J. and Zhang, M. (2017), "Dynamic quotation of leadtime and price for a Make-To-Order system with multiple customer classes and perfect information on customer preferences", *European Journal of Operational Research*, Vol 258, pp. 334-342.

Foerstl, K., Schleper, M.C. and Henke, M. (2017), "Purchasing and supply management: from efficiency to effectiveness in an integrated supply chain", *Journal of Purchasing and Supply Management*, Vol. 23 No. 4, pp. 223-228.

Forstner, L. and Dümmler, M. (2014), "Integrierte Wertschöpfungsnetzwerke—Chancen und Potenziale durch Industrie 4.0", *Elektrotechnik and Informationstechnik*, Vol 131 No. 7, pp. 199-201.

GEP (2018), GEP outlook procurement (https://www.gep.com/white-papers/procurement-outlook-report-2018, accessed 180131).

Glas, A.H. and Kleemann, F.C. (2016), "The impact of Industry 4.0 on procurement and supply management: a conceptual and qualitative analysis", *International Journal of Business and Management Invention*, Vol. 5 No. 6, pp. 55-66.

Goyal, G., Samalia, H.V. and Verma, P. (2018), "Mediating role of process simplification in process integration and upstream supply chain flexibility", *International Journal of Productivity & Performance Management*, Vol. 67 No. 5, pp. 825-844.

Halldorsson, A., Kotzab, H., Mikkola, J.H. and Skjoett-Larsen, T. (2007), " Complementary theories to supply chain management", *Supply Chain Management: an International Journal*, Vol. 12 No. 4, pp. 284-296.

Hermann, M., Pentek, T. and Otto, B. (2016), "Design Principles for Industrie 4.0 Scenarios", *49th Hawaii International Conference on System Sciences*, pp. 3928-3937.

Hertenstein, P. and Williamson, P.J. (2018), "The role of suppliers in enabling differing innovation strategies of competing multinationals from emerging and advanced economies: German and Chinese automotive firms compared", *Technovation*, Vol. 70-71, pp. 46-58.

Jardini, B., El Kyal, M. and Amri, M. (2015), "The complexity of Electronic Data Interchange (EDI) compliance for automotive supply chain", *IEEE Conference on Industrial Engineering and Engineering Management*, pp. 361-365.

Kagermann, H. (2015), "Change through digitization—value creation in the age of Industry 4.0" In: Albach, H., Meffert, H., Pinkwart, A., Reichwald, R., eds. *Management of Permanent Change*. Wiesbaden: Springer, pp. 23-45.

Kagermann, H., Lukas, W. and Wahlster, W. (2011), "Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4", *Industriellen Revolution*, VDI Nachrichten, p. 13.

Kagermann, H., Wahlster, W. and Helbig, J. (2013), "Recommendations for implementing the strategic initiative INDUSTRIE 4.0: final report of the Industrie 4.0 working group" Frankfurt/Main: Forschungsunion and acatech.

Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., Kim, B. H. and Noh, S. D. (2016), "Smart manufacturing: past research, present findings, and future directions", *International Journal of Precision Engineering and Manufacturing-Green Technology*, Vol. 3 No. 1, pp. 111-128.

Ketchen, D.J and Hult, G. T. M. (2007), "Bridging organization theory and supply chain management: The case of best value supply chains", *Journal of Operations Management*, Vol. 25, pp. 573-580.

Knight, L., Tate, W. L., Matopoulos, A., Meehan, J. and Salmi, A. (2016), "Breaking the mold: research process innovations in purchasing and supply management", *Journal of Purchasing and Supply Management*, Vol. 22, pp. 239-243.

Lasi, H., Fettke, P., Feld, T. and Hoffmann, M. (2014), "Industry 4.0", *Business and Information Systems Engineering*, Vol. 6 No. 4, pp. 239-242.

Lin, D., Lee, C.K.M., Lau, H. and Yang, Y. (2018), "Strategic response to Industry 4.0: an empirical investigation on the Chinese automotive industry", *Industrial Management & Data Systems*, Vol. 118 No. 3, pp. 589-605.

Manello, A. and Calabrese, G. (2019), "The influence of reputation on supplier selection: an empirical study of the European automotive industry", *Journal of Purchasing and Supply Management*, Vol. 25 No. 1, pp. 69-77.

Marshall, D., McIvor, R. and Lamming, R. (2007), "Influences and outcomes of outsourcing: insights from the telecommunications industry", *Journal of Purchasing and Supply Management,* Vol. 13, pp. 245-260.

Mayring, P. (2014), *Qualitative Content Analysis: theoretical foundation, basic procedures and software solutions*. Klangenfurt: SSOAR.

Nazir, N. M. and Shavarebi, K. (2019), "A review of global automotive industry's competitive strategies", *World Journal of Science, Technology and Sustainable Development*, Vol. 16 NO. 4, pp. 170-183.

Oesterreich, T. D. and Teuteberg, F. (2016), "Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry", *Computers in Industry*, Vol. 83, pp. 121-139.

Osmonbekov, T. and Johnston, W.J. (2018), "Adoption of the internet of things technologies in business procurement: impact on organizational buying behavior", *Journal of Business & Industrial Marketing*, Vol. 33 No. 6, pp. 781-191.

Pellengahr, K., Schulte, A. T., Richard, J. and Berg, M. (2016), *Einkauf 4.0: Digitalisierung des Einkaufs*, Dortmund/Frankfurt: Fraunhofer IML and BME.

Pereira, G. M., Sellito, M. A., Borchardt, M. and Geiger, A. (2011), "Procurement cost reduction for customized non-critical items in an automotive supply chain: An action research project", *Industrial Marketing Management*, Vol. 40 No. 1, pp. 28-35.

Pfohl, H., Yahsi, B. and Kurnaz, T. (2015), "The impact of Industry 4.0 in the supply chain", *Proceedings of HICL*, Vol. 20, pp. 31-58.

Popovic, A., Puklavec, B. and Oliveira, T. (2019), "Justifying business intelligence systems adoption in SMEs", *Industrial Management & Data Systems*, Vol. 119 No. 1, pp. 210-228.

Qin, J., Liu, Y. and Grosvenor, R. (2016), "A categorical framework of manufacturing for Industry 4.0 and beyond", *Procedia CIRP*, Vol. 52, pp. 173-178.

Roblek, V., Mesko., M. and Krapez, A. (2016), "A complex view of Industry 4.0", *SAGE Open*, Vol. 6 No. 2, pp. 1-11.

Sarkis, J., Zhu, Q. and Lai, K. (2011), "An organizational theoretic review of green supply chain management literature", *International Journal of Production Economics*, Vol. 130, pp. 1-15.

Saunders, M., Lewis, P. and Thornhill, A. (2016), *Research Methods for Business Students*, Harlow: Pearson.

Schmitz, J. and Platts, K. (2003), "Roles of supplier performance measurement: indication from a study in the automotive industry", *Management Decision*, Vol. 41 No. 8, pp. 711-721.

Schneider, L. and Wallenburg, C. M. (2013), "50 years of research on organizing the purchasing function: do we need any more?", *Journal of Purchasing and Supply Management*, Vol. 19, pp. 144-164.

Smit, J., Kreutzer, S., Moeller, C. and Carlberg, M. (2016), *Industry 4.0*. Brussels: European Union.

Spina, G., Caniato, F., Luzzini, D. and Ronchi, S. (2013), " Past, present and future trends of purchasing and supply management: an extensive literature review", *Industrial Marketing Management*, Vol. 42, pp. 1202-1212.

Spina, G., Caniato, F., Luzzini, B. and Ronchi, S. (2016), "The use of grand theories in purchasing and supply management research", *Journal of Purchasing and Supply Management*, Vol. 22, pp. 18-30.

Stock, T. and Seliger, G. (2016), "Opportunities of Sustainable Manufacturing in Industry 4.0", *Procedia CIRP*, 40, 536-541.

Thun, J. and Hoenig, D. (2011), "An empirical analysis of supply chain risk management in the German automotive industry", *International Journal of Production Economics*, Vol. 131, pp. 242-249.

van Weele, A. J. (2014), *Purchasing and Supply Chain Management*. Andover: Cengage Learning.

Wang, G., Gunasekaran, A., Ngai, E.W.T. and Papadopoulos, T. (2016), "Big data analytics in logistics and supply chain management: Certain investigations for research and applications", *International Journal of Production Economics*, Vol. 176, pp. 98-110.

Wei, C. and Chen, C. (2008), "An empirical study of purchasing strategy in automotive industry", *Industrial Management & Data Systems*, Vol. 108 No. 7, pp. 973-987.

Weyer, S., Schmitt, M., Ohmer, M. and Gorecky, D. (2015), "Towards Industry 4.0—standardization as the crucial challenge for highly modular, multi-vendor production systems", *IFAC-PaperOnLine*, Vol. 48 No. 3, pp. 579-584.

Williamson, O.E. (1981), "The economics of organization: the transaction cost approach", *American Journal of Sociology*, Vol. 87 No. 3, pp. 548-577.

Williamson, O.E. (1985), *The economic institutions of capitalism*. Free Press, New York.

Wynstra, F., Rooks, G. and Snijders, C. (2018), "How is service procurement different from goods procurement? Exploring ex ante costs and ex post problems in IT procurement", *Journal of Purchasing and Supply Management*, Vol. 24, pp. 83-94.

Yin, R. K. (2014), *Case Study Research Design and Methods*. Los Angeles: SAGE.

Yu, C., Wong, T. and Zhi, L. (2017), "A hybrid multi-agent negotiation protocol supporting supplier selection for multiple products with synergy effect", *International Journal of Production Research*, Vol. 55 No. 1, pp. 18-37.

Zafari, F. and Teuteberg, F. (2018), "Der Weg zum Einkauf 4.0: Herausforderungen bei der Automatisierung und Digitalisierung im Einkauf—Eine multi-metodishe Analyse am Beispiel der Logistikbranche", *Multikonferenz Wirtschaftsinformatik*, March, Lüneburg, Germany.

Zhou, K., Liu, T. and Zhou, L. (2015), "Industry 4.0: Towards future industrial opportunities and challenges", *Zhangjiaji*, FSKD.