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Typification Of Incorrect Event Data In Supply Chain Event Management

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Abstract

Due to shorter product life cycles and the increasing internationalization of competition, companies are confronted with increasing complexity in supply chain management. Event-based systems are used to reduce this complexity and to support employees' decisions. Such event-based systems include tracking & tracing systems on the one hand and supply chain event management on the other. Tracking & tracing systems only have the functions of monitoring and reporting deviations, whereas supply chain event management systems also function as simulation, control, and measurement. The central element connecting these systems is the event. It forms the information basis for mapping and matching the process sequences in the event-based systems. The events received from the supply chain partner form the basis for all downstream steps and must, therefore, contain the correct data. Since the data quality is insufficient in numerous use cases and incorrect data in supply chain event management is not considered in the literature, this paper deals with the description and typification of incorrect event data. Based on a systematic literature review, typical sources of errors in the acquisition and transmission of event data are discussed. The results are then applied to event data so that a typification of incorrect event types is possible. The results help to significantly improve event-based systems for use in practice by preventing incorrect reactions through the detection of incorrect event data.

Keywords

CPSL; Supply Chain Event Management; Incorrect Data; Event Data; EPCIS; Typification.

1. Introduction

The supply chain management sector is becoming more dynamic and complex as a result of rising globalization. This makes the framework conditions more unstable, which raises the probability of unplanned processes [1]. This results in an expansion of the effort required for process control as well as an increase in the number of interfaces between companies and the number of processes to be controlled [2]. These conditions as well as an increase in networking lead to an ever-greater amount of data being absorbed by companies, from which the relevant data has to be extracted. The oversupply of information needs to be reduced to information that deviates and requires the attention of a decision-maker. This can be achieved through event-based systems working according to the concept of management-by-exception [3]. These systems include, for example, tracking & tracing systems and supply chain event management. The information technology basis for these systems is formed by events, which contain the data arising from a planned or unplanned event in a standardized format [4]. For the information to be used reliably in the following processes and for decisions to be made correctly, the information must first be available and the data it contains must be of high data quality [5]. If this is not the case, it can lead to serious consequences, as the following example shows: A supplier ships the product to the manufacturer, but for various reasons, the corresponding event message is not transmitted to the manufacturer. According to the event-based systems, the manufacturer starts to reschedule his production to avoid a production stop. A day later, the event is transmitted with a delay, so the manufacturer again reschedules his production. This example shows that event data that does not correspond to reality can lead to significant problems and avoidable additional costs. This can also be seen in practice. This can also be seen in practice, where the data exchange with event data does not work properly nowadays. The desired data is often not available, the interfaces are not sufficiently defined or the quality of the data is insufficient [6]. In particular, the aspect of data quality has so far been completely ignored in the description of events [7].

2. Basic Concepts Regarding Event-Based Systems

For the typification of incorrect event data, it is essential to have an overall understanding of the relevant terms. Concerning the term event, it is important to understand the definition of the term and the data structure of event standards (cf. section 2.1). To be able to comprehend the analysis of incorrect event data, the concept of supply chain event management and its difference from other event-based systems must also be considered (cf. section 2.2).

2.1 Events

The term "event" regarding event-based systems is not uniformly defined in the literature. On the one hand, events are described as occurring activities in the real world or a computer system [8]. According to Bensel et al., the term can be described as the associated data object for the occurrence of a state with essential significance for logistical processes [9]. On the other hand, Heusler et al., for example, expound that an event can only be understood as a deviation from a planned state [10]. The definitions in the literature can be sorted into the categories 'event in the sense of a status report' and 'event in the sense of a deviation' – depending on the main statement. As this paper focuses on the relevant data objects and the associated standards of events, the understanding of 'event in the sense of a status report' is being followed.

Within the scope of the exchange of events, different standards exist, which ensure that the sender and receiver use compatible formats so that the events can be read without any loss in the receiver system [11]. Through literature research, Konovalenko & Ludwig were able to identify three common standards: Tracefish, TraceCore XML, and EPCIS; the latter being the most widely used. One reason for this is that this standard is subject to fewer restrictions than the other two. Therefore, it can be used universally in various industries. In contrast, TraceCore XML was designed for data exchange in the food industry with a focus on food traceability; and Tracefish's standard is specific to the fish industry. [7] In addition to the standards mentioned above, there is also the Health Level 7 standard, which is only used in the health sector [12]. As the overview of the various event standards has shown, only the EPCIS standard is independent of the industry. Moreover, it is the most widely used standard. Thus, only the EPCIS standard will be considered in this paper.

According to the EPCIS standard (version 1.2), events always have a basic structure: each of the recorded events contains information from the four dimensions of what, when, where, and why using specific data elements [13]. The 'dimension what' specifies which objects or which object classes are involved in the event. For example, the uniquely named objects or object classes are listed in an *epcList* and usually described by an EPC in the form of a uniform resource identifier. The date and time when the EPCIS event was created (*eventTime*) and recorded in an EPCIS repository (*recordTime*) are stored in the 'dimension when'. Additionally, the time zone of the location where the event was recorded (*eventTimeZoneOffset*) is recorded. The 'dimension where' specifies the exact capture point where the EPCIS event was generated (*readPoint*). In addition, the location of the business (*businessLocation*) where the object is now located is recorded. The 'dimension why' specifies the reason why the EPCIS event was created. The business process step (*businessStep*) in which the event was generated is recorded. Furthermore, the status (*disposition*) of the object is described. In addition, the *businessTransactionList* is used to assign a business transaction to the event. The *sourceList* and *destinationList* are used to provide additional business context if an EPCIS event is part of a business transfer of ownership, jurisdiction, or custody. The entire data is stored in an XML structure with a defined syntax, the vocabulary of which is specified by the CBV. [14] The four dimensions can be used to describe the content of each event that occurs in a physical or virtual object. All events can be divided into different types of EPCIS events. The ObjectEvent is the simplest and most commonly used event. It refers to a single or several objects and is responsible for the pure observation of these. Within the scope of the AggretationEvent, the physical merging or separation of one or more objects can be recorded. This type is the second most widespread standard and, together with the ObjectEvent, covers the majority of events that occur. Another type of event is the TransformationEvent. It is used when input objects are partially or completely consumed in the creation of output objects so that some or all of the input objects have contributed to each of the output objects. A TransactionEvent occurs when one or more objects are linked to or unlinked from one or more business transactions. [15]

2.2 Supply Chain Event Management

According to Stölzle et al., supply chain event management can be defined as follows: Supply chain event management (SCEM) is a tool for controlling logistical processes that enables the timely reaction to critical exceptional events in supply chains [16]. Accordingly, SCEM, like "tracking & tracing", is one of the event-based approaches, whereby SCEM is understood as a further development of track & trace (cf. Figure 1) as it provides the data for system-controlled decision support [17].

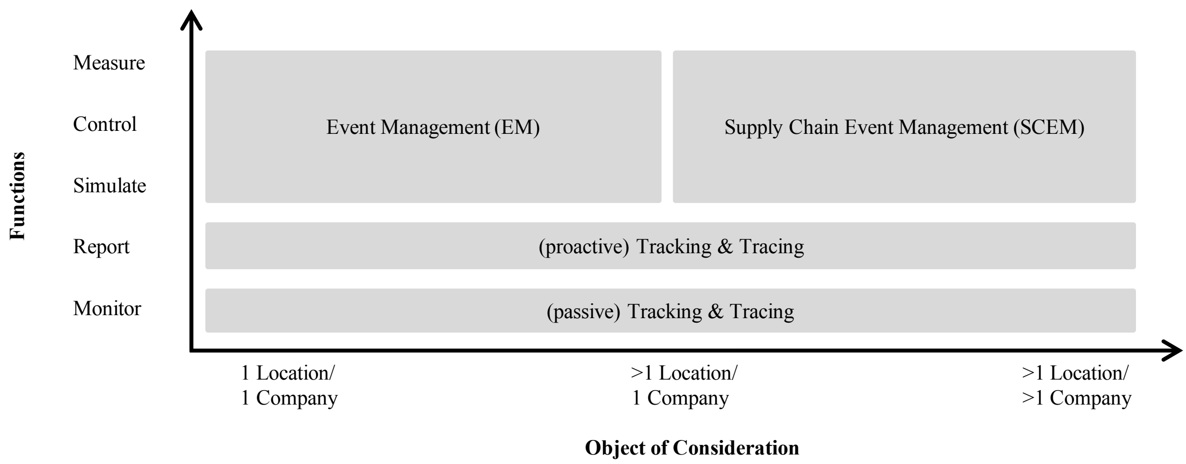

Figure 1:Classification of event-based systems (own figure)

The term SCEM system, in turn, refers to an information system or the set of information systems that enable the fulfillment of functionalities according to their function [18]. Concerning this fulfillment, the majority of the literature defines the following five core functions [10,7,18]:

- Monitor: The core function monitoring includes, on the one hand, the recording of the actual state and, on the other hand, the comparison with the target state including the defined tolerance window. Based on the comparison, an assessment of the deviation takes place afterward.
- Report: If a critical deviation from the plan is detected during monitoring, the reporting function takes over the real-time transmission of the information to the respective decision-making authority, so that it can actively intervene in the system and reduce the risk of major disruptions.

- Simulate: Following the registration of an event and notification, simulate checks and evaluates possible options for responding to the event, which serves as decision support.
- Control: The core element of controlling consists of selecting and implementing the promising alternative to correct the target-actual deviation in the best possible way.
- Measure: In measuring, the events are extracted from the individual actual runs. Based on a large number of observed runs, performance indicators are determined, which can be used either for evaluations of the supply chain processes or as input parameters for the core function monitoring.

Based on the described core functions, the SCEM can be classified in reference models, such as the supply chain planning matrix, between the areas of supply chain execution (short-term) and supply chain planning (medium-term) along the complete process chain [19]. The complete process chain explicitly means that this does not only concern supply chain processes but also all internal and external processes of order fulfillment. The reason for this classification is, on the one hand, based on the short-term reactions in the case of serious deviations and, on the other hand, on the additional possibility of abstracting actual processes, which leads to medium-term process improvements. Conceptually, the SCEM can be assigned not only in reference models but also in the following theoretical approaches: 'cybernetic control loop' and 'management by exception' [20,18].

3. Methodology

This paper addresses the following research question for the analysis of incorrect event data.: How do incorrect event data occur in supply chain event management and how can they be typified or described?

To answer this research question, a systematic literature review has been conducted. Due to the scientific recognition and the professional proximity, it is oriented towards the procedures mentioned by Webster & Watson and Levy & Ellis [21,22]. The factors used to define the study area can be summarised as follows:

- Inclusion criteria: language (German and English), availability (full text), document type (journal articles, monographs, collected works), period (2011-2021)
- Databases: ScienceDirect, IEEE Xplore, Google Scholar, RWTH Aachen University Library Catalogue
- Search terms: 17 search terms for data acquisition, 12 search terms for data transmission, 12 search terms for concrete forms of incorrect data/search terms are based on Boolean combinations from different keywords (study area ("supply chain", "event management", "EPCIS", etc.), data ("transaction data", "feedback data", "event data", etc.), errors ("deficient", "inaccurate", "inconsistency", etc.), data acquisition ("data acquisition", "data collection", "production data acquisition", etc.), data transmission ("data sharing", "ETL", "data exchange", etc.), incorrect occurrences ("types", "characteristics", "error detection", etc.))
- Search strategy: first search run (abstract review, full text review) / second search run (forward-backward search) / third search run (forward-backward search)

Regarding the research question, the search is split into three aspects. First, the modes of operation and sources of error in data acquisition and transmission are considered to find causes for the emergence of incorrect event data. Then, the concrete forms of incorrect data are being searched for. In the first search run on the topic of data collection, 31 relevant sources were found. In the second run, an additional 29 contributions were found, and in the third run, another 14 were discovered. In the search in the subject area of data transmission, a total of 18 relevant sources were found in the first run. In the second run, a further eight sources were found. The third run added two contributions. The search for manifestations of erroneous event data resulted in four new sources in the first run, eight sources in the second run, and no sources in the third run. In this way, a total of 114 contributions were found that are related to the research topic of this paper.

4. Research Results & Typification

As a result of the systematic literature research, typical sources of error in data acquisition and data transmission could be identified. In addition, approaches were considered that describe concrete forms of occurrence of incorrect event data.

4.1 Sources of Data Acquisition Errors

In practice, a wide range of data acquisition methods is used. To limit the identification of data acquisition error sources in this paper to those most relevant to practice, the following basic assumption was made: Data acquisition methods that are very often used in practice produce more data acquisition errors in absolute terms than those that are used less frequently. Based on this assumption, the sources collected in the literature review were also analyzed concerning the question of how frequently a data acquisition method was mentioned.

The six data acquisition technologies that are cited the most in the 114 sources surveyed are the following: RFID (62 sources, representing about 54%), 1D code (29%), manual data acquisition (25%), semi-automated operational data acquisition (18%), 2D code (10%), and RTLS (9%). Under the assumption made earlier, it can now be assumed that RFID technology causes the most data capture errors in practice, followed by 1D code (e.g. barcodes), manual data acquisition, etc.

Examples of specific errors in data acquisition can be easily described using the barcode or manual data acquisition. Typical sources of errors in barcode scanning are deterioration of the readability or damage to the code during transport due to scratches, dirt, or moisture [23]. In addition, the reader may be defective or incorrectly aligned during the reading process [24]. These sources of error can result in an event not being captured during acquisition (missing data acquisition) or not being passed to downstream systems in real-time (delayed data acquisition). The manual form of data acquisition is to be classified as particularly error-prone due to the high dependence on the human work factor. Thus, the correctness of data acquisition depends on the attention and ability of the person responsible [25]. This means, for example, that a lack of attention can lead to numerical errors during data entry. This in turn leads to incorrect data acquisition. Furthermore, it is possible that an object is captured although it should not be captured (unnecessary data acquisition) or is already captured (duplicate data acquisition).

Even when considering all of the different technologies, all of the data acquisition results related to event data can be grouped into six general categories:

- Correct Data Acquisition: Exactly the data that should be captured has been captured and is now correctly available.
- Missing Data Acquisition: The data that should have been captured was not captured and is therefore not present.
- Unnecessary Data Acquisition: Data that should not have been captured was captured anyway and is now unintentionally present.
- Duplicate Data Acquisition: Data was captured multiple times and is now redundant.
- Incorrect Data Acquisition: Data has been collected but is incorrect, inconsistent, or incomplete.
- Delayed Data Acquisition: Data was captured correctly, but is not available in real-time.

4.2 Sources of Data Transmission Errors

Data transmission can be divided into the steps of data integration and data exchange, whereby data integration is of higher importance in the context of this paper [26]. First of all, it should be noted that no relevant sources of error in connection with data exchange in the EPCIS standard could be identified during the literature research. One reason for this may be the high degree of standardization and automation of the standard and the associated lower probability of errors occurring.

Data integration can be divided into the substeps extraction, transformation, and loading (ETL) [27]. Failures in the ETL process can manifest themselves, on the one hand, in the fact that data that has already been fed in incorrectly is not recognized and corrected as intended and, on the other hand, in the fact that further errors are caused in the course of the process [28]. The causes for this can be found both in the development phase and in the operational phase of the ETL process and, similar to data acquisition, are based on both technical and human error [28]. Specific sources of failure in the development phase of the process include inadequate requirements definition [27], lack of testing of the process [29,30], and lack of continuous maintenance and adaptation of the process to changing user requirements [31]. Due to the lack of testing with real data, it is not possible, for example, to determine whether incorrect or redundant data is detected and cleaned up (incorrect data transmission). During the operational phase, errors may occur in the first two phases of the ETL process due to incorrect and/or inappropriate extraction and transformation rules [31–33]. For example, an incorrect assignment of data fields (schema mapping) can result in new incorrect data records (error-producing data transmission). In addition, technical sources of error, such as network errors or problems with the data carriers, can occur in the phase of loading the data into the repository [32]. In addition to creating new errors, this can also lead to delays so that the data is not provided in real-time (delayed data transmission)

When considering the sources of error in data transmission, it turned out that in general they can be divided into four possible categories, which are presented below:

- Optimal Data Transmission: Error-prone and redundant data is detected and cleaned up.
- Incorrect Data Transmission: Error-prone and redundant data is detected but not cleaned or not detected and not cleaned.
- Error-producing Data Transmission: Error-prone and redundant data is only produced in the course of data transmission.
- Delayed Data Transmission: Data is not provided in real-time due to delays in the process.

4.3 Specific Forms of Incorrect Data

Based on the typical sources of errors in data acquisition and transmission, it is now possible to concatenate manifestations of incorrect event data. For the categorization of the forms of occurrence of operational feedback data, there are some isolated approaches in the literature. These approaches subdivide the forms of occurrence based on data acquisition errors [34], data quality characteristics [35], data sources [29], or data attributes [36].

The occurrences of incorrect data found in the literature can be abstracted and summarized. It can be seen that errors in event data in the context of the SCEM can affect several data components: identification number (e.g., tag ID, item number), time information (e.g. date, time of entry), location information (e.g. reader ID, capture location), total data record. The type of error can vary between the six characteristics missing, wrong, redundant, inconsistent, unnecessary, and outdated. For example, incorrect event data can consist of missing identification numbers, redundant time information, or outdated location information.

4.4 Typification

Regarding the typification based on the forms of occurrence of incorrect event data, the causes of the emergence of incorrect event data and their occurrences have to be put into context and abstracted. Based on this, the occurrence of incorrect event data can be typified. For this purpose, the error sources of data acquisition and transmission are assigned to the occurrences of incorrect data (cf. Figure 2).

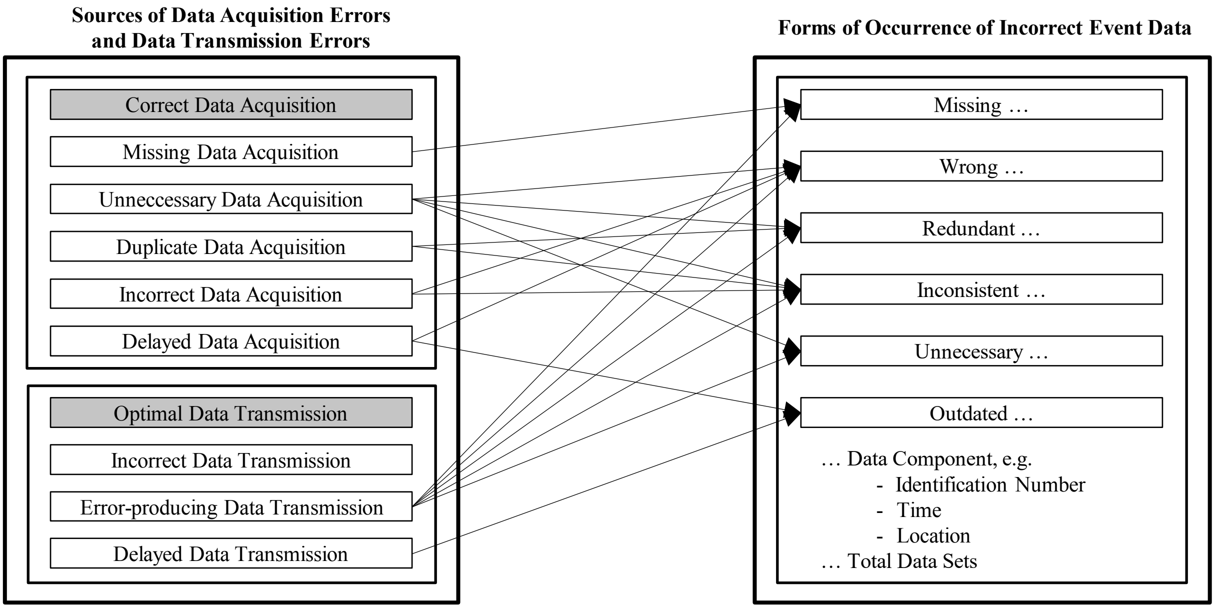

Figure 2: Framework for contextualizing and describing incorrect event data in SCEM (own figure)

The categories defined in chapters 4.1 and 4.2 regarding data acquisition and transmission are shown on the left side of the figure. Arrow connections are used to assign these to their possible occurrences in the context of incorrect event data (cf. chapter 4.3). For example, missing data acquisition can refer either to individual contents of a data set that are not recorded or to the entire data set. Specifically, it can therefore be associated with missing data components or missing overall data sets. If incorrect data is either not recognized and thereupon not cleaned or recognized and nevertheless not cleaned, then the incorrect data transmission would be present. It does not establish occurrences of incorrect event data, but it is also unable to correct such occurrences.

Using this framework, the incorrect event data can be typed and contextualized. Since the data components mentioned in chapter 4.3 form comparable categories as the dimensions of the EPCIS standard [15], specific incorrect event data can be derived. For this purpose, the four event dimensions are considered separately. This is briefly explained for each dimension using a specific example:

The ‘dimension what’ contains information about the physical and digital objects involved in an event [13]. A parallel can be drawn between the identification keys of the EPC and the data component of the identification number. When placed in the framework for contextualizing and describing incorrect event data in SCEM, the EPC identification key would, thus, be associated with the same occurrences and causes as the identification number. Therefore, an example of an incorrect occurrence of an EPCIS event could be a record that contains an incorrect SGTIN number (cf. Table 1).

Table 1: Example of an incorrect occurrence form of the ‘dimension what’

Dimension	Data Element	Incorrect Event Data	Correct Event Data
What	epcList	GTIN 106141411234569	GTIN 106141411234569
		Serial 12345	Serial 12346

The ‘dimension when’ of EPCIS events includes the three elements of *eventTime, eventTimeZoneOffset,* and *recordTime* [14]. The contents of the dimension can be compared to the when data component in Figure 2. Based on a transfer of the findings to the ‘dimension when’, the occurrence of an outdated specification of the *eventTime* in the EPCIS standard could be mentioned (cf. Table 2). This could occur, for example, if an event is not recorded until sometime after its actual occurrence due to a time-delayed data collection.

Table 2: Example of an incorrect occurrence form of the 'dimension when'

Dimension	Data Element	Incorrect Event Data	Correct Event Data
When	Event Time	Sep 23, 2012, at 10:12 am UTC	Sep 23, 2012, at 09:59 am UTC

The *readPoint* and *businessLocation* of an object are recorded in the EPCIS standard based on the 'dimension where'. A possible occurrence of an incorrect EPCIS event could be, for example, an inconsistent specification of the Read Point if it contradicts the time zone specified in the When dimension. Table 3 shows a *readPoint* in Germany and at the same time an *eventTimeZoneOffset* that does not correspond to the German time zone.

Table 3: Example of an incorrect occurrence form of the 'dimension where'

Dimension	Data Element	Incorrect Event Data	Correct Event Data
Where	ReadPoint	50° 46' 31.244" N 6° 5' 1.992" E	28° 0′ 44″ N, 28° 58′ 34″ E
When	*eventTime ZoneOffset*	+03:00 (UTC)	

The 'dimension why' can contain information about the *businessStep* and the *disposition* as well as a *businessTransactionList*, a *sourceList,* and a *destinationList*. For example, the occurrence of a record could be derived with a misstatement of *disposition* that indicates an object is stolen but is in transit between two trading partners (Table 9).

Table 4: Example of an incorrect occurrence form of the 'dimension what'

Dimension	Data Element	Incorrect Event Data	Correct Event Data
Why	disposition	stolen	in_transit

5. **Conclusion & Outlook**

The concept of SCEM promises companies optimized, faster decision-making, enabled with the help of proactive notifications of relevant events within SC. In practice, this should be seen as an opportunity, especially against the backdrop of increasing customer demands and uncertain market conditions, to exploit the potential of SCEM and improve its competitive position in the long term. Companies are dependent on a solid database that provides the relevant data on time and with sufficient data quality.

This paper creates added value for the conceptual consideration of supply chain event management as well as its use in practice through the scientific consideration of incorrect event data. For the further development of event-based systems, it is indispensable to transfer the results concerning the potential sources of errors into the corresponding occurrences for event data. Through systematic consideration, the foundation for a generally valid typification of incorrect event data based on their form of occurrences has been laid. In the further, for example, automatic filtering of incorrect event data can be developed, which is before the actual core functions simulate, control and measure. This could exclude the automatic incorrect reaction based on incorrect event data (cf. example in the introduction).

When considering this field of research, there is a need for further research. For example, further consideration of possible causes of the emergence of incorrect event data could include other stages of the life cycle of the data, in addition to the steps of data acquisition and transmission.

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Biography

Jokim Janßen (*1993) works as a project manager and scientific assistant at the Institute for Industrial Management (FIR) at the RWTH Aachen since 2019. Before that, he gained experience in supply chain management at Miele & Cie. KG and developed a strong background in event-based systems. In his current work as the group leader in supply chain management, he is managing projects in the context of digitalized supply chain management in research, consortia, and consulting projects.

Prof. Dr.-Ing. Dipl.-Wirt.-Ing. Günther Schuh (*1958) is the director of the Institute for Industrial Management (FIR) at RWTH Aachen University, holds the Chair for Production Systems at the WZL, and is a member of the board of directors of the Fraunhofer Institute for Production Technology IPT in Aachen. Professor Schuh is a member of several supervisory boards and boards of directors.

Prof. Dr.-Ing. Volker Stich (*1954) has been head of the Institute for Industrial Management (FIR) at the RWTH Aachen University since 1997. Prof. Dr.-Ing. Volker Stich worked for 10 years for the St. Gobain-Automotive Group and lead the management of European plant logistics. In addition, he was responsible for the worldwide coordination of future vehicle development projects.