Conceptual considerations for real-time supply chain efficiency monitoring

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Abstract

A recent simulation study proved that the efficiency of supply chains is highly volatile because of a number of different factors. Therefore, we elaborated a model to evaluate supply chain efficiency. In our contribution, we will show the results of a case study and present considerations for real-time efficiency monitoring.

Key words: supply chain, efficiency, real time monitoring

Introduction

Strictly speaking, the term "logistics" describes either the movement of goods and items or the flow of information. Thus, logistics involves the spatial movement of goods, items, or information over time. More precisely, logistics is an integrated system of interdependent primary and subordinate processes that bridge internal and cross-company interfaces. Thus, logistics supports entrepreneurial actions and services, such as production processes, in which input factors are transformed into a specified output. However, logistics itself also requires a certain input factors to generate output in terms of logistics services.

With this in mind, the overall objective of logistics is high efficiency. Logistics efficiency is indicated by the ratio between logistics costs that are dependent on the deployed resources and logistics performance that represents the logistics service level. Thus, efficiency indicators combine cost and performance targets. High logistics efficiency results from an optimum input-output ratio of the logistics processes, which is maintained over a certain time if the deployed logistics resources are successively reduced while the logistics service level is gradually increased.

Logistics performance is indicated by the availability of goods and materials, lead time, delivery time, reliability, and flexibility. Logistics performance, however, does not occur coincidentally, but is the result of forecasts and planned logistics targets with respect to costs, quantity, quality, and time. These targets determine the rating of logistics efficiency indicators. Thus, logistics efficiency represents the degree of short-term target achievement in logistics. Presently, due to globally competing supply chains, the simultaneous achievement of several logistics targets is required to obtain high logistics efficiency. Reduced efficiency is often due to various process losses (Winkler 2011); sometimes, an alternative process might be superior to the existing process to reach the planned logistics targets. The extent of the efficiency reduction depends on the variance between the planned and actual values of the examined logistics process. When logistics efficiency is reduced because of failures or misconduct, the necessary process adjustments must be planned and implemented.

Heretofore, logistics efficiency has been analyzed predominantly within a single company. Lean Management, Business Process Re-engineering, and Benchmarking are examples of managerial approaches used to identify and purposefully mitigate or avoid operational inefficiencies (Stewart 1995). The result is an improved input-output ratio of logistics processes per unit of time. In entrepreneurial practice, it has become increasingly important to expand the internal efforts of efficiency improvement to an intercompany level. These endeavors are well known as Supply Chain Management. In this concept, the objective is coordinated planning, managing, and control of logistics processes from suppliers to producers and retailers along the entire supply chain to achieve an efficient flow of goods and information (Winkler and Kaluza 2006). Traditional improvement projects that aim to increase the efficiency of logistics processes along the supply chain, however, are doomed to failure because no appropriate evaluation of the improvement potential exists. This deficit must be resolved by using sophisticated and comprehensive metrics as well as system dynamics models that facilitate the identification and elimination of the sources of process loss.

This paper presents a practical approach to improving logistics efficiency along the entire supply chain. In this context, logistics is perceived as the accumulation of many primary and subordinate processes associated with various business functions (Engblom et al. 2012). Each logistics-related activity or service is the result of a combination of such specific processes. Therefore, we briefly clarify the concept of efficiency in logistics processes. Then, the current gaps in the efficiency evaluation of logistics processes along the supply chain will be described. This is followed by a detailed introduction to the developed Supply Chain Improvement System (SCIS), in which the requirements identified by the representatives of industrial enterprises during the course of an empirical study and the consequent functionalities of the SCIS are presented. Finally, the elaborated efficiency improvement system at the supply chain level is described in detail.

Basics of a Supply Chain Improvement System (SCIS)

Structure of a SCIS

The main difference between traditional process improvement at the enterprise level and intercompany efficiency improvement with the help of the SCIS is the method and extent of the efficiency evaluation. For intercompany efficiency improvement, it is necessary to evaluate the efficiency of all of the logistics processes along the entire supply chain. Thus, the major task is efficiency evaluation of the different primary and subordinate processes in the fields of production logistics, transport, handling, and warehousing; i.e., from the raw-material supplier to the end customer. For reasons of overview and interpretation, it is recommended that appropriate efficiency indicators are developed to represent the results of the initial process evaluation. Additionally, calculating value-added time with respect to its share of the total lead time increases the informative value of the elaborated efficiency indicators. However, the calculation of efficiency indicators requires specific tools and methods for data collection and processing. The SCIS offers a wide range of functionalities that serve this purpose.

The conceptual structure of the SCIS in Figure 1 is characterized by an architecture with three different application levels, which can be applied independently. Level 1 is the simplest way to conduct a supply chain improvement project. After the primary supply chain processes — transport, handling, warehousing, and production — are modeled, it is necessary to collect the relevant process data for the supply chain analysis. Consequently, the relevant efficiency indicators must be calculated in the described manner, and the calculation results must be analyzed. Applying level 2 of the SCIS requires a much more detailed model of the relevant supply chain. This model is developed using simulation software. The simulation model of the relevant supply chain is provided with the required process data to calculate the efficiency indicators. The specific advantage of level 2 is the opportunity to conduct simulation studies. In contrast to levels 1 and 2, level 3 of the SCIS must not be regarded as a project. It is much more along the lines of a true IT system that supports decision makers in improving supply chain efficiency. Therefore, a detailed model of the supply chain must be developed, and all relevant IT systems that produce and collect required process data in real time must be integrated (Winkler et al. 2013).

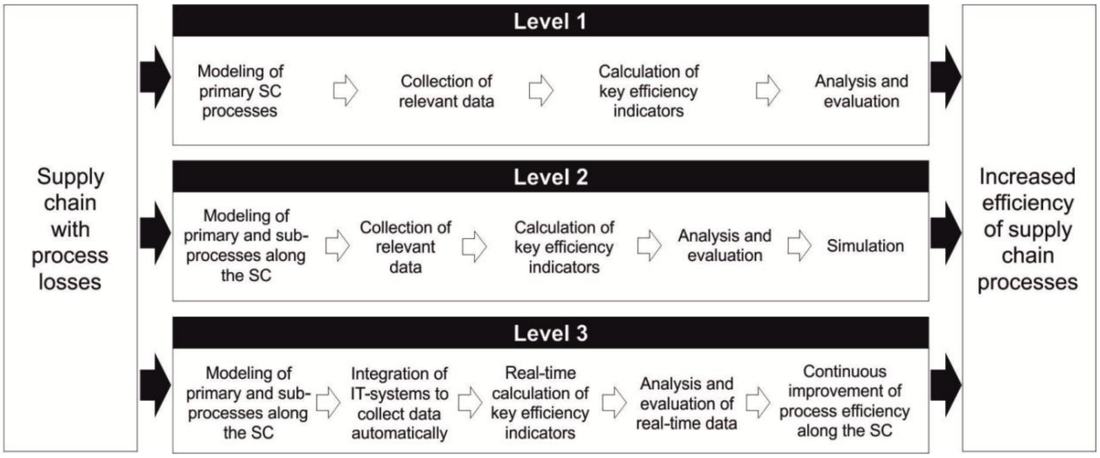

Figure 1. The three levels of the SCIS

However, in some cases, a combination of the described SCIS levels is convenient. In such cases, it is necessary to apply the three levels sequentially. Thus, it is possible to check the general efficiency status of a specific supply chain by applying the level 1 of the SCIS. If applying level 1 shows efficiency losses, using level 2 enables the detailed identification of the losses, and, with simulations, various measures can be analyzed to effectively reduce the detected losses. To remain efficient after applying the SCIS on levels 1 and 2, level 3 is implemented, which enables the consequent and sustainable efficiency improvement of the investigated supply chain or supply chain area.

Using metrics for supply chain efficiency evaluation

For the SCIS, the adaptation of internal efficiency metrics or indicators to the supply chain level is important. Depending on the individual requirements, key indicators are available in the scientific literature, as well as in entrepreneurial practice, for the evaluation of the efficiency of logistics processes. The traditional concept of Overall Equipment Efficiency (OEE) is considered to be one of these key indicators and is an example of how to evaluate the efficiency of production. The OEE calculation includes the operational availability, as well as the level of performance and quality (Muchiri and Pintelon 2008; Braglia et al. 2009). The efficiency evaluation of transport processes is conducted similarly. However, we recommend two ways to proceed: (1) The evaluation of Productive Vehicle Utilization, which represents capacity utilization and (2) the evaluation of Overall Transport Efficiency, which considers the operation of the means of transport. The Productive Vehicle Utilization is determined by the maximum freight hold volume, which is compared to the current use of capacity. The operating efficiency of a means of transport, in turn, is determined by the transport time with special regard to the respective transport conditions. Additionally, the total time that a means of transport is available for value-added processes is compared to its actual operating time (Delivand et al. 2011). The efficiency of the handling processes is also represented by two specific efficiency indicators, i.e., Handling Efficiency and Handling Equipment Efficiency. The basis for calculating Handling Efficiency is the total working time of the employees that are available for the handling processes. Subsequently, this value is reduced by any time losses that occur. Conversely, Handling Equipment Efficiency indicates any losses that are generated by deployed handling equipment. For storage efficiency, three indicators that consider different processes are used to guarantee the objective evaluation of storage processes. Inventories, warehouse operations, and the amount of storage space influence the efficiency evaluation of warehousing processes. The indicator, Productive Warehousing, provides information on the efficiency of the warehouse processes because the total time that is available for warehousing is reduced by various process losses. The Productive Stock, in turn, is the ratio between the actual stock at hand and stock that is economically purposeful. Thus, this calculation indicates overstocking. Productive Storage Utilization represents the ratio between the actual capacity utilization and the storage capacity that is economically purposeful, which indicates the excess storage space. In addition to the previously described efficiency indicators, the calculation of Average Supply Chain Efficiency serves to provide information about the input-output ratio of the entire supply chain. For this purpose, the value-added time along the supply chain is accumulated and compared to the potential productive time along the supply chain. Here, the potential productive time is determined by summing the value-added and non-value-added times along the examined supply chain.

A brief case study for demonstrating typical efficiency losses in supply chains

The investigated company in this case operates in two different countries on three production sites. For the case study, we have collaborated with one of these production sites. During the implementation of the SCIS on level 2 to validate the practical applicability of the concept, the project launch was determined by selecting a manageable supply chain area. Therefore, the supply chain area for a specific product of the cooperating company’s product portfolio was defined. The product consists of four components, but to reduce complexity for the purposes of the project, only the shipment of two of them will be considered. The first component is sequentially manufactured on two different production sites in Croatia. Meanwhile, the second component is produced in Serbia. Both components are shipped to a handling terminal in Slovenia, where they are commissioned and transported together by truck to the manufacturer in Austria. In Austria, the components are assembled into the final product. Subsequently, the product is transported by truck to the customers, who are primarily located in Germany. The executed supply chain improvement project, with the application of the SCIS on level 2, addresses the transport processes between the following entities: the two suppliers in Croatia, between Croatia and both Serbia and Slovenia, between Slovenia and Austria, and between Austria and the customers in Germany. In addition to the transport processes, the production processes of the Austrian manufacturer, as well as the handling processes are part of the project. Moreover, the warehouses for the manufacturer's inbound and outbound shipments are considered. Figure 2 shows the selected supply chain area.

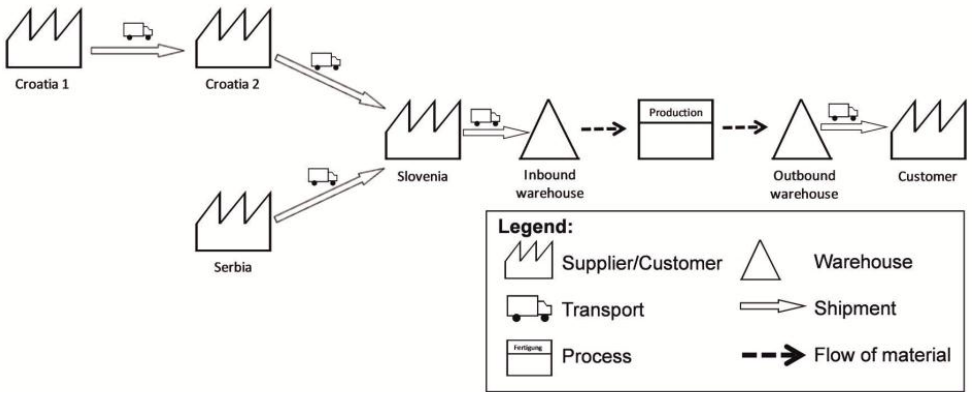

Figure 2. The supply chain area analyzed applying the SCIS on level 2

Subsequent to the selection of the relevant supply chain area, a detailed simulation model was developed. In accordance with the top-down principle, the authors started by modeling the supply chain area with its primary elements. The model was refined by developing several sub-models for specific supply chain entities or processes. The final model contains all of the mentioned and described entities of the supply chain area including all of the relevant primary supply chain processes. The simulation model was developed with the support of specific simulation software. Figure 3 shows the elaborated simulation model on the supply chain level.

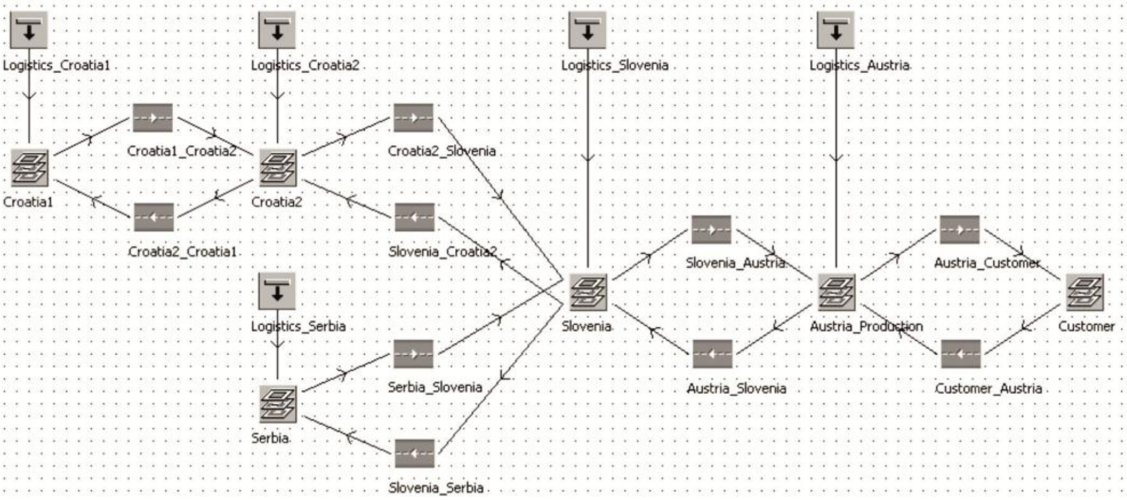

Figure 3. The simulation model of the selected supply chain area

Following the development of the simulation model, the efficiency indicators for the objective evaluation of the primary supply chain processes and the entire supply chain were implemented. For this purpose, it was necessary to connect data from the real supply chain with the integrated formulas in the simulation model. Based on that data, the required indicators were computable by using the simulation tool. After the indicators were implemented, a simulation run was started to show the development of the efficiency indicators over a period of thirty days. This chapter will not focus on the results of each efficiency indicator, but the results of the SCE will be explained (Kuss and Winkler 2014). However, after simulating the supply chain processes over thirty days, the average SCE was evaluated at 3.78 percent, which seemed to be very low. Thus, the indicator was analyzed in detail by revising the development of the SCE over the thirty days simulation period, which is presented graphically in Figure 4.

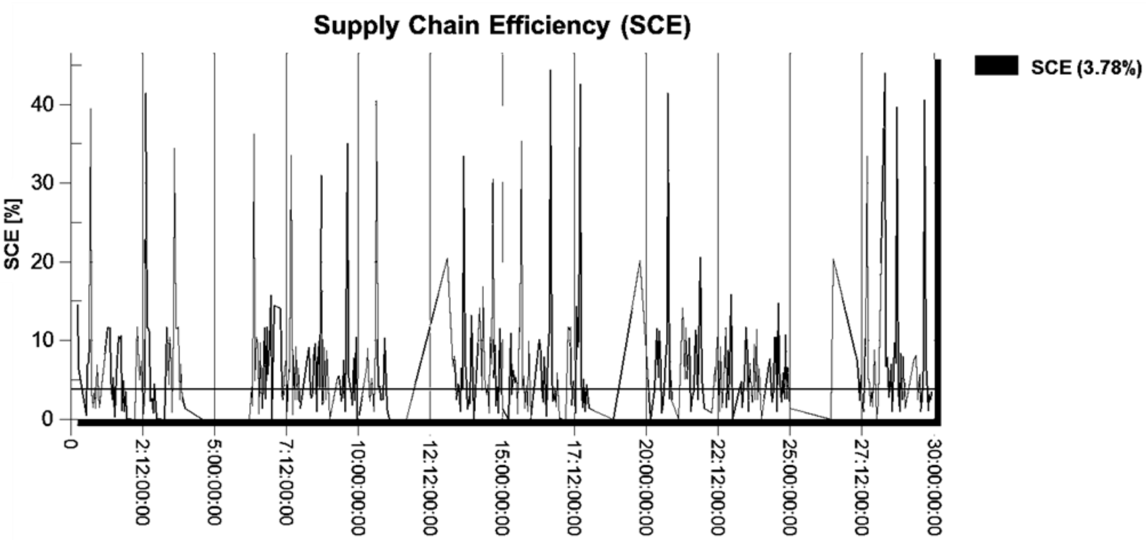

Figure 4. The development of the SCE during a simulation period of thirty days

Developing a real time supply chain efficiency monitoring

The level 3 of the SCIS enables continuous efficiency improvement with the support of various IT systems. Therefore, a detailed model of the relevant supply chain is a prerequisite. This model must be developed in a specific SCIS IT system that further integrates all other relevant IT systems along the selected supply chain area. Examples of such IT systems are enterprise resource planning, manufacturing execution, transport data, and radio frequency identification systems. These systems provide most of the data required to calculate the efficiency indicators in real time. The real-time calculation results are displayed by a management cockpit and can be analyzed by decision makers, who are thereby able to elaborate specific measures to improve the efficiency of the investigated supply chain. To integrate all relevant companies along a supply chain, including integrating their IT landscapes, the SCIS operates as a cloud solution. Thus, all companies that are part of a supply chain are connected with one another via the SCIS cloud, which collects relevant process data from these companies and processes the data using a vast data base and an adequate data base management system. The task of the database management system is to process the captured data into the required efficiency indicators. Additionally, the calculated indicators are displayed by the SCIS management cockpit. Specific decision makers, such as supply chain managers, are provided with the graphical representation of the efficiency indicators in real time. Thus, the measures necessary to increase process efficiency can be planned and realized promptly.

Now, to correctly implement level 3 of the SCIS and to calculate the relevant efficiency indicators, technologies are required for data acquisition, processing, and storage. Within the four primary supply chain process categories — transport, handling, warehousing, and production — various technologies and systems are required to capture all necessary data to calculate the relevant indicators. At the system level, production data are provided by manufacturing execution, production planning and scheduling, enterprise resource planning, and advanced planning and scheduling systems (Winkler et al. 2013). Additionally, IT systems provide relevant warehouse data including, warehouse management, merchandise management, and enterprise resource planning systems. The mentioned systems typically also provide most of the required data for evaluating the efficiency of the handling and transport processes. To acquire data that are not provided by the mentioned IT systems, it is necessary to apply specific data acquisition technologies at the process level. Depending on the supply chain process category, such technologies include, e.g., radio frequency identification, the global positioning system, various sensors (temperature, optical, etc.), bar code systems, mobile data-capturing concepts, human machine interfaces, and supervisory control and data acquisition technologies (Cutting-Decelle et al. 2012). However, to implement level 3 of the SCIS, it is necessary to integrate all of the required data acquisition technologies and systems from all partners along the relevant supply chain area. Figure 5 shows the systematic connection between systems and technologies for collecting the relevant data to calculate the efficiency indicators within the four primary supply chain process categories along supply chains.

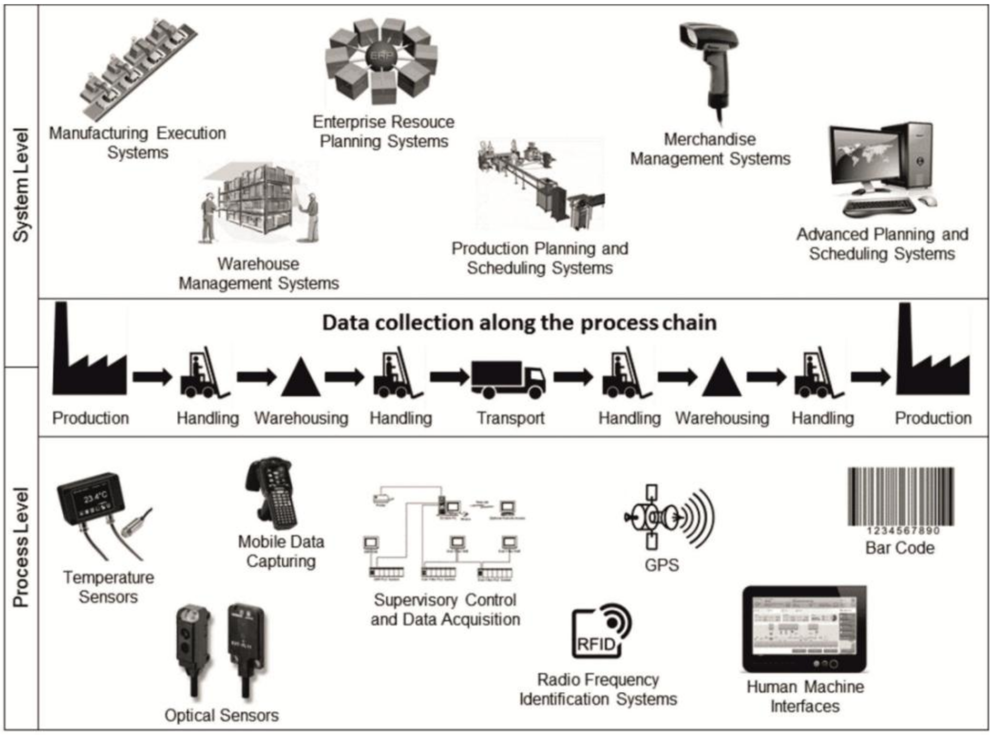

Figure 5. Systems and technologies to collect relevant process data along a supply chain

Integrating all of the abovementioned IT systems and applying specific data acquisition technologies, the SCIS acts in the form of a cloud. Moreover, the internet-based SCIS cloud contains a database and specific business intelligence concepts. However, the comprehensive integration of the SCIS on level 3 also requires specific technologies and concepts for standardized data exchange and data transfer. Some of the most relevant technologies for developing the SCIS concept on level 3 and their roles in supply chain improvement efforts are described below.

The data transfer challenge for the SCIS is the variety of IT systems along supply chains. Typically, a supply chain is constituted by a specific number of companies from various industry sectors that apply data management software according to their specific needs; generally, each company has individual IT solutions (Nurmilaakso 2008). Because of the large variety of companies with different IT landscapes, there is a need for standardized technology to transfer relevant data to the SCIS cloud. Web services, extensible markup language (XML), and electronic data interchange (EDI) are technologies and concepts that support standardized data exchange (Nurmilaakso 2008).

Considering the concept of the SCIS on level 3, the application of web services is an appropriate way to manage the challenge of different IT systems that have to be integrated within the SCIS. Web services are software systems that enable data exchange or that call up the activities of remote systems; thus, the use of web services allows for connecting programs across distant points worldwide via the internet (Daigneau 2012). Various internet-based applications can be connected by web services, enabling program-to-program communication. Using web services, various applications at different locations can be integrated into one large IT system. Moreover, applying web services provides the required measures for integrating different systems (Daigneau 2012). It is the task of SCIS-related web services to collect relevant data from the different IT systems of all relevant supply chain partners and to transform them into a consistent and standardized data format.

The application of web services requires the use of different technologies based on XML to enable data transformation and transmission out of and into various programs and databases. Using XML, web services can be mapped to applications including programs, objects, and databases or to any comprehensive business function (Newcomer 2002). For example, the web service description language (WSDL) that is used to describe web services, including their functionality, is based on XML as well; for example, WSDL uses XML grammar to specify a public interface including all data information for all XML messages (Cerami 2002; Daigneau 2012).

Furthermore, XML is the standard used for data transfer between companies along the relevant supply chain and the SCIS. Web services collect the required data from the supply chain partners' IT systems and transform them into XML files that are transmitted to the SCIS cloud. However, before the data are transmitted to the SCIS database, a web service transfers the information into the required data format for calculating an efficiency indicator. Subsequently, the calculation results are transferred to the companies and managers along the supply chain and vice versa, again using web services and XML technology. Figure 6 shows the operating mode of the SCIS on level 3 regarding the use of specific data transfer technologies.

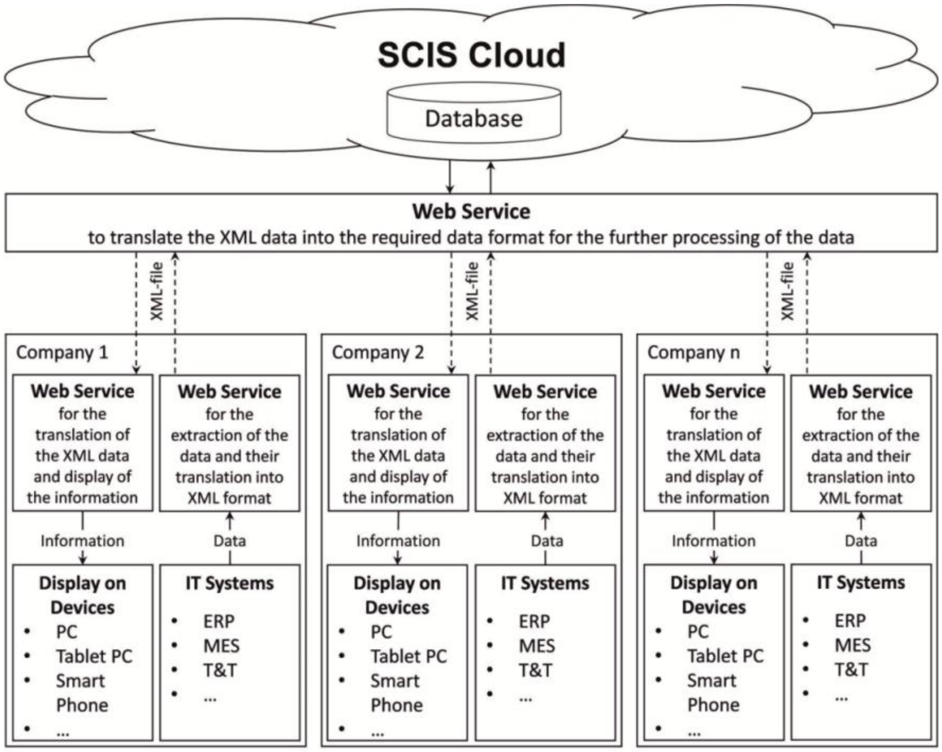

Figure 6. The operation mode of the SCIS on level three regarding data transfer

Although the theoretical concept development of level 3 of the SCIS has already been advanced, no case study has been conducted yet because implementing the SCIS at the third level is quite complex and extensive. Additionally, the elaborated theoretical concept must be extended by a comprehensive technological concept. Therefore, the support of an IT service provider is required to implement the SCIS on level 3 in entrepreneurial practice. The main challenge for the IT company will be integrating all companies along a supply chain and managing the resulting interfaces between these companies and the SCIS cloud.

However, the authors intend to proceed with developing the SCIS on level 3, and a level 3 efficiency improvement project in entrepreneurial practice is planned for execution in the coming years.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

In the context of Supply Chain Management, an increasing integration of the entire process chain and its goal-oriented design and improvement are currently challenging entrepreneurial practice; thus, it is a major area of research for the scientific community. In this paper, we have shown that objective evaluation is required to efficiently design and purposefully improve logistics processes along the supply chain.

Future research work considering the SCIS concept will focus on the further development of level 3. In addition to working out the concept’s technological operating mode, it will be necessary to improve the usability of the system itself. Thus, various alternatives to provide decision makers along the supply chain with relevant efficiency data will be developed and tested. Furthermore, a case study to show the practical applicability of the SCIS on level 3 will be performed. Therefore, it will be necessary to collaborate with an IT service provider who is able to develop and manage the resulting interfaces between the SCIS and the companies along the supply chain. In addition to managing IT interfaces along the supply chain and addressing the required data acquisition and data transfer technologies, one key aspect of further research in this context will be the graphical representation of the efficiency data generated by the SCIS. Thus, it will be necessary to develop a user interface that provides decision makers with the required information from anywhere along the supply chain in the form of actionable knowledge anywhere and anytime.

Moreover, future research activities to improve the SCIS concept include conducting simulation studies to define the appropriate measures for sustainably improving supply chain efficiency. Toward this end, an adaptive assistance system based on simulations will be elaborated.

An additional future task will be to extend the original SCIS approach by providing financial data. The financial information will support managers and other employees with entrepreneurial responsibility in making well-founded decisions to improve the entire supply chain or selected supply chain areas.

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