Towards an Approach to Identify the Optimal Instant of Time for Information Capturing in Supply Chains

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Abstract. Supply chains are becoming increasingly complex and with this development the challenges towards information management increase. The importance of capturing the right, most relevant information in order to avoid having too much information to handle is commonly accepted in industry and academia. But the question not yet sufficiently discussed by industry and academia is: What is the optimal instant of time to capture the relevant information along the process chain? With this paper the authors look into this issue by first analyzing two practical cases, from a transport and a manufacturing perspective. Afterwards, the elements of information captured are shortly elaborated and finally, constraints on the determination of the optimal instant of time for information capturing are elaborated in order to build a foundation for further research. This paper is a first step towards a methodological approach taking on these issues. A short conclusion and outlook summarizes the paper.

Keywords: information management, synchronization, SCM, manufacturing, transport processes, product state

1 Introduction

In today's ever more complex world, the exchange of information within supply chains is gaining importance e.g. for transparency reasons. Achieving higher transparency, meaning provision of information about future schedules or past events to stakeholders involved, allows process improvements in order to reduce total costs or providing better service levels and a more synchronized supply chain. Finally, the improvement of the processes should increase their efficiency.

Paradigms like the Internet of Things [1] or Cyber Physical Systems [2] highlight the increasing relevance of performing information exchange. Both paradigms are focusing on information creation and information exchange among physical and virtual objects. By using the captured information, decisions could be supported and/or made by computers or humans on how to execute various processes within the supply chain. Those processes can again be executed by either machines and/or humans.

Information management is understood as "the application of management principles to the acquisition, organization, control, dissemination and use of information

adfa, p. 1, 2011.

relevant to the effective operation of organizations of all kinds" [3]. Much of the research regarding information management is done in the field of improvement activities within the communication technology, or showing the impact available information has on a supply chain [4; 5; 6]. Identifying relevant information needed for improving specific processes is challenging, but already widely discussed in research and industry [7; 8]. However, experts in the field are aware of this problem. Furthermore, for today's supply chains, the relevant information and the right addressees are mostly known and the stakeholders are supported by various available supporting methods (e.g., Supply Chain Event Management [9]). The related challenge, analyzing the optimal instant of time to capture this relevant information, did not attract that much attention by researchers to this point. The optimal instant of time for information captured within this paper is understood as the point in time along a supply chain process where certain relevant information can be captured in the most efficient way, with regard to cost, technical limitations etc. The authors are aware that the use of the term *optimal* is not a perfect description but in absence of a better, equally brief term decided to use the term optimal throughout this publication. That being said, it is nevertheless essential to look further into this issue in the future, in order to establish an efficient information management and be prepared for growing information needs, e.g. real time-provision of process information. One possible reason why this issue is not yet elaborated on as of today might be that it is either possible to establish the instant of time through common sense or it is not considered relevant when the capturing does take place exactly.

This paper is structured as follows: In order to establish a solid foundation for future research in this area, available and common procedures currently used in practice for identification of the right instant of time for capturing relevant information in supply chains are presented in section two. To take the whole supply chain and the different requirements into account, that section is divided into two sub sections, thus covering manufacturing and transport processes. In section three, the different elements of relevant information captured in supply chains are identified and elaborated on. This is followed by an analysis executed in section four with the goal of categorizing the possible flexibility of information capturing regarding the instant of time. Moreover, restrictions towards the influence of the instant of time towards relevant information are identified. Additionally, a methodology from another domain, possibly related to the identification of the optimal instant of time for capturing information within a supply chain, is briefly introduced. Finally, section five concludes the paper and gives an outlook on future research within this topic.

2 Instant of time determination for information capturing in supply chains

This section focuses on how the optimal instant of time for capturing information is currently determined from a practical (industrial) point of view.

For ease of understanding, the information analyzing the capture of the whole supply chain, is split up into two basic parts, which in the understanding of the authors', best represent the major requirements. These two parts are the production planning and inventory control process, in the following *manufacturing*, and the distribution and logistics process, in the following *transport* [10]. This breakdown is also in accordance with the SCOR model, aggregating *Source* and *Deliver* to transport and *Make* to manufacturing. Therefore, the first sub section looks at industrial manufacturing processes and the second one at transport processes. Finally, the results of both basic processes regarding the information capturing are consolidated.

The overall principles of information management (e.g., [11; 12; 13]) of ensuring the right information is available at the best possible moment (in terms of time, granularity, location and quality) is applicable for all areas of the supply chain. However, the principle does not clearly state when the relevant information should be captured to fulfill these requirements. The approach to capture all measurable information at all times possible is found to be causing more problems than doing good by increasing transparency and productivity (e.g., [7]).

2.1 Instant of time determination for information capturing in manufacturing

Information management in manufacturing focuses mostly on how available information should be managed (e.g., [14; 15]) or what existing IM system should be selected to reach the set goals (e.g., [16; 17]).

However, in industrial practice of a manufacturing SME, a more hands-on approach can be found. For this section, the processes of a Tier1 automotive supplier were analyzed. The company produces engine parts subject to high stress during usage with high quality requirements and very little failure tolerance. The processes are automated in most cases, as is the information capturing.

In manufacturing, there is some information which must be known for the following processes to proceed. For example, after machining, the exact geometry (dimensions) has to be available to set the parameters for the following process of milling. Therefore, the instant of time to capture the relevant information (geometry) was determined or at least limited by the previous process (influencing the geometry) and following process requirements.

After milling, the balance is tested and the information captured is deemed ok or not ok. The specific parameters of the individual product are measured but not stored or communicated to another instance. The not ok parts are then separated to be measured again in a machining center where countermeasures are, if possible, directly carried out. These parts then go through a final quality inspection by hand. The instant in time for this information capturing (quality ok / not-ok) was not set time wise but handled flexibly.

Based on this example it was found, that for some information capturing activities, the instant of time is pre-determined by the processes, more specifically the requirements of the following process. However, the information in this case is measured after machining. In an additional process step, it could possibly be derived within the process of machining or directly before milling. So there is at least a small window of flexibility. On other occasions, however, it is handled without a set instant of time.

Overall, it was found, that no systematic approach to determine the optimal instant of time was applied in this use case.

2.2 Instant of time determination for information capturing in transport

There are already a lot of studies available that look at the costs and the processes for implementing an information management system for transport processes (e.g. [18]). The benefits of information capturing within transport processes are also explained in a lot of publications (e.g. [19; 20]).

However, to the authors' knowledge, in accordance with the findings in manufacturing, until today there has been no approach found in science and industry for the determination of the optimal instant of time for information capturing within transport processes. In the following, a use case, based on a current research project for transport processes is presented to highlight the current practices. The German research project RFID-based Automotive Network (RAN) (http://www.autoran.de/), focused on improving the automotive supply chains by increasing transparency based on an efficient exchange of information. Therefore, it was necessary to identify the relevant information needed within the supply chain. In this context, one work package has had the task to model all relevant processes within the automotive industry in a generally accepted (by automotive professionals & researchers) manner.

First of all, currently implemented processes were analyzed by modeling the processes using the methodology of Event-driven Process Chain (EDPC). Secondly, these processes were analyzed and generally accepted processes (standard *processes*) were modeled by using the EDPC method again. In total, twelve so-called standard processes were identified: two examples are loading and external transport. The main result of the conducted work was that the modeled processes describe what information is needed within the different standard processes and what information is generated from that. Furthermore, the sequence of the information capturing is described when necessary. Sometimes the sequence was not considered necessary, in which case parallel paths were modeled. By defining processes start and end, borders can be defined in between the necessary information needs to be generated.

In order to draw a conclusion, the instants of time for information capturing in transport processes were not defined precisely within the standard processes, because in most cases there was no generally applicable optimal instant of time for all companies involved within the automotive supply chain. The design of the processes and the determination of the instants of time did not follow a structured approach; it was rather driven by practical experience of the people and experts involved.

As was highlighted in the sections above, there is no structured and methodological approach available today to determine the optimal instant of time to capture relevant information within supply chains.

The question remains: why is that the case? Is there simply no need to determine the optimal instant of time today as it is determined by surrounding processes or requirements by following processes/addresses needing the information?

In order to answer those questions raised above, in the following the elements of captured information in supply chains will be examined, followed by a theoretical discussion on categorization of possibilities to capture relevant information in supply chains. Furthermore, influencing or limiting factors on the determination of the optimal instant of time are briefly presented.

3 Elements of captured information in supply chains

To be of value, the captured information within the supply chain needs to contain certain elements. Based on the goals of logistics management (Seven-Rights-Definition of Logistics) expresses by Plowman [21], the right goods have to be of the right quantity and quality, in the right location at the right instant of time, and for the right customer for the right costs. Looking at the information captured within the supply chain the element quantity can be derived from the element identity (aggregation of individual products). The element costs and customer cannot be captured on the shop floor or the transport process during the material flow; however, it can later be annotated to the individual product. Based on a supply chain point of view the relevant information elements to be captured are presented in Fig.1.

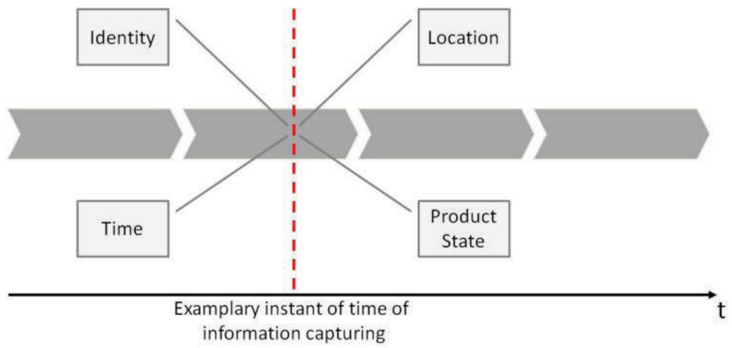

Fig. 1. Elements of information captured

Identity
It is always necessary to link the captured information to a specific object. Therefore, the object has to be identified precisely and uniquely. The identification can take place automatically by scanning a barcode or a RFID transponder or by entering the information manually into an IT system etc.

Time
A time stamp integrated into every event captured is necessary for having unique information. Moreover, the time stamp is necessary to have a precise history of every object being tracked within the supply chain.

Location
Knowing about the location of an object is also very important when generating an event. E.g. information of the current process can be derived from location/time.

Product State
Last but not least, the product state which incorporates various characteristics of a product e.g., quality, dimensions etc. of an object is considered relevant information [22]. Based on the product state's characteristics, the following process steps and their parameters within supply chains can be planned. An example for a state characteristic is the diameter after machining, but also residual stress allocation within a steel disc.

4 Thoughts on constrains towards the optimal instant of time for information capturing

In the following, limitations and pre-set conditions to determine an instant of time for information capturing are presented and, if possible, categorized. This is followed by a short elaboration on external conditions/factors influencing the instant of time for information capturing. In the final sub-section, existing approaches from other domains are presented which could be beneficial when working towards an approach supporting the identification of the optimal instant of time for data capturing in supply chains.

4.1 Categorization of the instant of time for information capturing

The first limitation that can be derived from the use cases in section two is that requirements and needs of following processes can be a limiting factor towards the determination of optimal instant of time in a supply chain.

Based on those findings three possible scenarios were identified (see Fig. 2.).

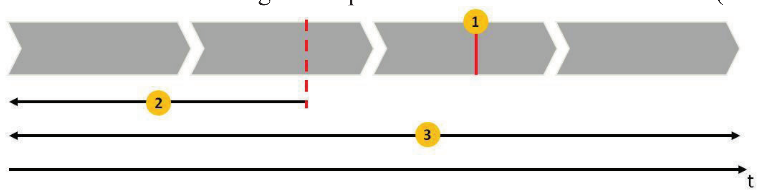

Fig. 2. Categories of Instant of Time capturing

The first category ***"fixed"*** ((1) in Fig. 2.) describes a case where the capturing of the relevant information has a pre-set instant of time as the relevant information must be captured at a certain instant of time during the process. An example can be a truck leaving the compound. This information can only be captured at that specific instant of time. In manufacturing, this is comparable with the measurement of the temperature at an instant of time during the heat treatment process.

The second category is, when certain flexibility in the determination of the instant of time exists (***"flexible with borders"*** (2) in Fig. 2.). In this case the relevant information needs to be captured in a certain area of the process at a certain instant of time, but the execution of the information capturing within the processes is not clearly specified. However, this limitation mostly consists of the instant of time when the considered relevant information (product state) changes before the addressee needs it. An example from manufacturing (section 2.1) would be the described scenario where the geometry must be known before the milling process starts, but the precise instant of time for capturing it is not clearly defined (earliest the moment the geometry changed the last time). Within transport processes an example highlighting this category is when an object is unloaded at a warehouse. The information could be captured, right at that very moment, when the forklift unloads the object from the trailer, but it could also be captured when driving through the gate of the warehouse or when the forklift removes the object.

The third and last category describes the case that the instant of time is absolutely flexible regarding the supply chain processes (***"total flexibility"*** (3) in Fig. 2.). This case is a pure theoretical one. When information is relevant within the supply chain, some addressee can only use the information at a certain moment. This addressee is then the limiting factor and this category would fall under category (2). The only theoretical application of this category the authors could think of is the following: an addressee needing to access certain information about the supply chain, but only after the processes are fulfilled and the product is with the customer. This could be within a Product Lifecycle Management (PLM) context or e.g., a governmental agency requiring information for taxation. However, this case will be excluded from further elaboration within this paper.

Another set of categories, influencing the instant of time is how and how often the information capturing takes place within the supply chain. When imaging continuous capturing of information the question for the optimal instant of time becomes obsolete as there is just one long instant of time. If the information capturing is randomized, setting a fixed instant of time would most likely defy the purpose. Categorization on how and how often relevant information can be captured is defined below:

One time

The relevant information has to be captured once within the process chain. An example is "gate out" if a truck leaves the compound.

Multiple times

If information has to be captured multiple times throughout a process chain it has to be differentiated between *"regular"*, where information has to be captured at pre-set times e.g., temperature measurements during transport of perishable goods. As the temperature of objects is very inertial, it is necessary to measure the temperature in specific intervals. A second possible characteristic of multiple time information capturing is *"random"*. This can be human or computer triggered events to control the quality of products.

Continuously

Continuous information capturing in a supply chain can be necessary for high value products like diamonds or weapons e.g., through a continuous capturing of the location at all times for security reasons.

A possible instant of time which does not fit directly into these categories is if the instant of time of information capturing is triggered by changing status or state. This could be a Kanban system, where the information is captured once the box is empty. Another example from transport processes could be a truck running late due to traffic congestions and the actual position of the truck does not match the position of where it should be at a specific instant of time (out of synch). An example from manufacturing would be a continuous check of the dimensions and no information is captured (no event) if it is within the tolerance. As soon as the tolerance is reached, the information is captured.

4.2 Influencing factors for the instant of time of information capturing

There are a few overarching and predetermined influencing factors for the determination of the optimal instant of time for information capturing in supply chains. Technical restrictions enforce information capturing at a certain instant of time during the process. Other influencing factors can be economic reasons, often strongly connected to technical reasons, limiting the possibilities of information capturing. Information capturing can also be limited by the confidentiality of information during the process. Those factors cannot be influenced but must be taken into account.

Classic limiting factors with a definite instant of time determination are documentation of the transfer of perils and, connected to this, laws or governmental regulations determining when certain information has to be captured in certain industries.

4.3 Existing approaches for identification of the instant of time for information capturing

In this section, an approach with partly similar requirements from another domain will be introduced briefly. However, it has to be understood that this approach does not directly address the issues raised before but rather provides a starting point or lever for the development of an approach with the goal of determining the optimal instant of time for information capturing in supply chains.

Quality Gates are utilized primarily in the product and software development process, [23]. The development of complex products over a time horizon of several years comes with large coordination and synchronization challenges. Therefore, a guideline and a reference process have to be developed to guide the project team through the process. This reference process allows measuring progress and maturity of the project (or the product). Through Quality Gates, the reference process is divided into synchronized process phases [24].

The basic idea of the Quality Gate approach is to determine these process phases and ensure that all defined goals are reached before moving on to the next phase [25]. Thus, the gates are *decision points* where information is captured within a process, which is the basis for a decision concerning further actions [26]. Therefore, the approach to determine the optimal instant of time to install Quality Gates within a process could provide valuable information for the problem at hand.

5 Conclusion & Outlook

The question of how to determine the optimal instant of time to capture the relevant information along supply chain processes is not answered yet. In this paper the authors took a look into this issue by analyzing two practical cases, from a transport and a manufacturing perspective. Afterwards, the elements of information captured were shortly elaborated. Finally, constraints on the determination of the optimal instant of time for information capturing as well as an approach from the domain of software development, Quality Gates, was briefly discussed towards possible overlaps.

In conclusion, it is to be said that the issue is important and deserves more attention from industry and academia. In a next step, the Quality Gate and related approaches will be analyzed further to derive mechanisms which can be applied to develop a generalized approach to determining the optimal instant of time for data capturing in supply chains. Right now, the authors are involved in a study at a major German car manufacturer analyzing this issue. At the same time, similar processes are analyzed at the manufacturing SME in order to ensure that the to-be-developed approach represents the different requirements. In the future, the to-be-developed approach will be evaluated in industrial scenarios and integrated in existing quality frameworks.

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