New possibilities of using monitoring technology to improve supply chain security

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Abstract

Modern supply chains are complex, which makes them vulnerable to security incidents. The objective of this paper is to evaluate supply chain tracking and monitoring concepts and to identify new ideas and business opportunities for security services in logistic multi-stakeholder networks. By adding tracking equipment, the security of supply chains can be improved through real time monitoring. Security benefits include the collection of concrete knowledge of security incidents, possibilities to react in real time and to minimise consequences. Developments in sensor and communication technologies allow new supply chain monitoring concepts, and hence new business opportunities. The paper describes the experiences gained in several European and Finnish national projects regarding monitoring technology and the improvement of supply chain security. A critical analysis of the benefits and limitations of implementation of tracking technology is also been described.

Keywords: Security; supply chain; tracking and monitoring technology; innovation; value.

Résumé

Les chaînes logistiques modernes sont complexes, ce qui les rend vulnérables aux incidents de sécurité. L’objectif de cette étude est d’évaluer des concepts nouveaux de suivi et de surveillance des chaînes logistiques et d’identifier de nouvelles idées et opportunités d’affaires pour les services de sécurité dans des réseaux multi-acteurs logistiques. En attachant équipement de suivi aux moyens de transport ou aux produits, la sécurité des chaînes logistiques peut être améliorée grâce à une surveillance en temps réel. Des avantages pour la sécurité comprennent la collecte de connaissances concrètes des incidents de sécurité, les possibilités de réagir en temps réel et de minimiser les conséquences. L’évolution des technologies de capteurs et de la communication rendent possible des nouveaux concepts de contrôle de la chaîne logistique, et donc de nouvelles opportunités commerciales. Le document décrit l’expérience acquise dans plusieurs projets européens et nationaux finlandais concernant la technologie de surveillance et l’amélioration de la sécurité de la chaîne logistique. Une analyse critique des avantages et des limites de la mise en œuvre de la technologie de suivi est également décrite.

Mots-clé: Sécurité; chaîne d'approvisionnement; le suivi et la surveillance technologie; l’innovation; la valeur.

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1. Introduction

Modern supply chains have a large number of transport phases and actors involved, which makes them vulnerable to various disturbances. Unsurprisingly, therefore, the significance of security in supply chains has increased considerably during the last decade. In addition to that, the developments in sensor, location and communication technologies allow new supply chain monitoring concepts, and hence new business opportunities. Although the basic tracking technology is mature, the selection of the optimal technological solution, business case development, implementation of the technology, and the exploitation of real-time tracking data are challenging tasks. The principal concept of the monitoring of consignments with intelligent devices is that they send information and alerts in real time to the predefined alarm handling location, which can be the company’s own alarm handling centre or an outsourced commercial alarm handling control centre, already used for other security services. Supply chain monitoring systems have the ability to track critical events and send alerts whenever security disruptive events occur. The online delivery of the information across supply chain partners to provides increased visibility (Hendricks et al., 2010).

Globalization has extended supply chains and made them more vulnerable to a wide range of disruptive events. As disruptive events can have significant business impacts, it is important to recognize that events vary greatly in terms of likelihood and severity (e.g. Hopp et al., 2010; Essig et al. (Eds.), 2013). The exact nature of supply chain disruptions will probably not be fully understood at first and may only become fully understood over time. Each node of the supply chain involves a set of risks and management processes. In a risk treatment program, each action’s value in terms of reducing the likelihood and impact of the risk is defined. Likelihood is used to refer to the chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically. Impact is used to refer to the evaluated consequence of a particular outcome. (ISO 28002)

New innovations related to tracking and monitoring solutions can include either technology based devices or service concepts or combinations of those, i.e. product-service systems. In order to develop new innovations, a company must have a comprehensive combination of both technological opportunities and customer needs. The selection of optimal technological solutions can be balanced according to financial opportunities and the future customer needs.

The actual benefits and additional value have to be identified and justified for the customers. Again, the benefits can be shared for core solutions and value-added services, and on the other hand to measurable and non-measurable elements of value. By adding tracking equipment, shipments can be monitored in real time, which offers possibilities to improve the security of supply chains. The use of real-time tracking technologies can provide beside security management benefits also logistics efficiency enhancement through optimisation of logistic processes. Security benefits include the collection of concrete knowledge of security incidents, possibilities to react in real time and to minimise consequences. In particular, it is a challenge for technology providers to understand, describe and demonstrate the value of new technological security solutions to the customer. In order to understand the value, technology providers need to understand, assess and demonstrate the effects that security has on the customer organizations’ core businesses and value perceptions.

The objective of this paper is to evaluate supply chain tracking and monitoring concept and their development and to identify new ideas and business innovations for security services in logistic multi-stakeholder networks. The paper also considers the value and the value creation of the security monitoring solutions in the supply value chains. The focus is on technology based products, and additional service innovations for supporting the monitoring processes of supply chains The structure of the paper is as follows: first, the theoretical underpinnings of the supply chain security and the value perception of new innovations will be discussed, after which broader challenge and restraints of the usage of the monitoring technology for management of security will be exposed. The results of the research are then offered, before a final section in which the implications of the research for the security monitoring are considered.
2. Methodology

The paper presents the development of new approaches for the security management for supply chains in multimodal networks based on the usage of the modern monitoring technology and presents the results of evaluation results in real supply chain cases. Within the research, a key issue was the use of monitoring technology and services taking into account the different variations in supply chains. The results are mainly based on

- The development in the Finnish national Logproof project (2011-2013), where new ideas and business opportunities for developing new product-service systems for managing disturbances and to minimize the risks related to disturbance management were identified, developed and tested.
- The development in the Finnish national SCIE project, where the use of battery-driven monitoring units was demonstrated in multimodal transport between Finland and Europe (Scholliers et al., 2011).
- Evaluation in the SMART-CM (Smart Container Management) project, where container security devices (CSD) consisting of location sensors, cellular and/or satellite communications and door sensors were effectively used for monitoring over 100 containers between Europe and Asia (Aifadopoulou, 2012).

In the projects, together with the supply chain stakeholders, different monitoring concepts, consisting of location sensors, cellular transmissions, photographs and the integrity, were successfully developed and tested in truck transport in Finland and between Finland and Russia and, in addition to that in two global multimodal supply chains a hinge-mounted container security device was tested for monitoring global container shipments.

The evaluation of the case shipments was based on the general business case evaluation, performance and acceptance indicators, and monitoring data evaluations. The evaluation information was retrieved from workshops and feedback from various stakeholders of different types of the supply chains, technical evaluation and monitoring data analysis.

3. New innovations related to tracking and monitoring technology

Gould et al. (2010) found three core benefits of the supply chain security in their literature review on supply chain security (SCS). The core benefits were improving supply chain security, making supply chain processes more efficient, and improving supply chain resilience. Supply chain security can be improved by making it less vulnerable with help of organizational or technical solutions. Supply chain processes can be made more efficient by fixing guidelines drawn from risk management and total quality management for implementing structural changes to business processes along supply chains. Supply chain resilience can be improved by implementing security measures to improve the ability of the supply chain to detect and react to security incidents. Investments in appropriate technology or measures can lead to reducing the chances of supply chain disruptions.

As the result of a Logproof project study (Hannola et al., 2013), nearly a hundred novel ideas related to supply chain disturbance management were identified. These ideas included both technological solutions and additional services to support and to improve supply chain security. Most of the identified ideas (35%) were related to the monitoring of supply chains, including monitoring of transportations, products and drivers. Some of the identified ideas for the monitoring of supply chains are presented in Table 1. The other identified ideas concentrated on services for deviations management, training, tools for reporting and analyzing of disturbances, cost benefit optimization of disturbances, and technologies for transportation equipment.
Table 1. Monitoring and tracking services and technologies for supply chains (Hannola et al., 2013)

<table>
<thead>
<tr>
<th>Ideas for monitoring of supply chains</th>
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<tr>
<td>Intelligence with a product: a product is continuously aware of its location and condition, and it reports by itself through “Internet of things”</td>
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<tr>
<td>Identification and individualization to all goods at a product level</td>
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<tr>
<td>System for monitoring identified and individualized products and transportation units</td>
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<tr>
<td>Common platform, where all the parties of a supply chain receive real-time information about the condition of the supply chain</td>
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<tr>
<td>Follow-up system for package-specific electronic seals</td>
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<td>Location technology, which consumes extreme little amount of energy, as a standard in the metal containers</td>
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<tr>
<td>RFID-identification built during the manufacture of a container or trailer</td>
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<tr>
<td>Container internal camera surveillance</td>
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<tr>
<td>Control of all relevant deviations in supply chain, 24/7 monitoring, reaction and follow-up</td>
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<tr>
<td>Monitoring of returnable transportation units and customer invoicing based on this data</td>
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<tr>
<td>Combination of video surveillance data and an identity of a container</td>
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<tr>
<td>Optimizing tool for supply chain management based on the tracking data of the shipments</td>
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<td>Identification and real-time tracking of pallets</td>
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It is clear that the selection of optimal services and technological solutions for further development should be balanced according to financial benefits and the customer priorities of needs. Therefore, the ideas in Table 1 were prioritized according to their impact for disturbance management and feasibility during the next five years. The ideas with high impact and low feasibility were described as the innovations of the future. These ideas included, the idea about integrating intelligence with a product, which is continuously aware of its location and condition and reports by itself through “Internet of things”, and the idea about a common platform, where all the parties of a supply chain will receive real-time information about the condition of the supply chain. (Hannola et al., 2013)

4. The value of new technological security solutions

The introduction of new innovations and security solutions is often not enough in the field of security business (Murtonen, 2013). According to Kähkönen et al. (2012), value creation is a combination of actions with three different perspectives: ability to respond to the competition and environmental changes, exploitation of relational capabilities and ability to understand and respond to customer needs and demands. When implementing new technological solutions in supply chains, the actual benefits and additional value of the solution for customers have to be identified and justified. In many cases the value of the new security related technology is not apparent to the customer. It is important to identify the target customers and the customer’s needs, which the new solution will fulfil. To make this value visible to the customer, the solution provider needs to identify the product or service offering attributes: what the offering will be and in what customers may use the product or service related to the new technology. New technology is usually valued by customers according to technology’s ability to create new solutions and the possibilities or ability to decrease the costs by finding a solution to a customer’s problem. For new technology there is no specific value, different customers may value different attributes (latent as well as visible) of the technology (Chesbrough et al., 2002).

The identification of the total value of a security solution can be tough, but it can be simplified to be a trade-off between customer benefits and sacrifices. Sacrifices usually consist of total monetary and exchange value, while benefits can significantly vary by customer (Zeithaml, 1998). As well as in other business areas, in safety and security business there are elements of value that can be addressed and measured easily, but also elements that are difficult or even impossible to measure at least in quantitative terms (Ulaga et al., 2001). According to Lapierre (2000) and Hannola et al. (2012), the benefits can also be sub-divided into core solutions and additional services, or to hard (measurable) and soft (non-measurable) elements of value, as depicted in Table 2.
Haelterman (2011) suggests that the monetary cost of introducing a certain security measure should be carefully measured and balanced against the cost of alternative solutions. The costs and resources used to risk management measures must be in a right proportion to the achievable benefits (Salmijärvi, 2013). Measures that may initially be thought of as being less expensive than alternative options may actually prove to be the contrary. Firstly, when planning of new security measures certain preconditions of the availability, feasibility, required knowledge and expertise, user awareness, and commitment, and co-operation need to be in place. Additionally, the cost components related to the introduction of certain security measures need to be identified. Besides the monetary costs, the fixed and variable costs must be covered, there are costs related to managing of staff, customers and other stakeholders. Possible new risks or unintended consequences, such as displacement of the crime must be deliberated. The consideration of actual and potential costs and benefits assists also to prioritize and evaluate potential investments on monitoring and tracking technology and services.

Supply chain security management is sometimes linked with the quality management by allocating the resources into preventive and reactive activities (Hintsa et al., 2010). The total costs of managing supply chain security can be divided to mandatory, reactive and proactive costs as presented in the supply chain security cost graph (Fig. 1). Proactive costs consist of up-front investments on security products, services, and implementing and maintaining security programs. Reactive costs, however, are the price for accepting certain security risks. They also include e.g. the value of lost security benefits, costs of security incidents, and costs of non-compliance. Reactive costs tend to decrease when companies invest on proactive security. Additionally, mandatory costs represent security investments required for keeping organisation’s business operations running. Based on Fig. 1, by understanding the three cost groups, the optimal monitoring solution can be found, and the total costs can be minimized.

Fig. 1 Supply chain security cost graph shows the costs optimisation of supply chain security management (Adapted from Hintsa et al., 2010)
Coordination and incentive mechanisms for joint new technology investments bring potential to improve supply chain efficiency and security (Lee et al., 2011). In order for considering a security investment attractive, a security concern has to dominate the efficiency concerns for a supply chain stakeholder. If security concerns are not strong enough, supply chain stakeholders need a further incentive to invest up to the level that maximizes the supply chain-wide profit. Lee et al. (2011) also remarked that the pioneering or leading adopters of the new technology face the risk resulting from the uncertainty of other stakeholders’ investment behaviour.

In addition to technological innovations, handling of exceptions is a critical factor in supply chain security management. Exception management involves the identification and the efficient reaction on exceptions (e.g. search of misplaced products, attempt to recover stolen products). Exception management consists of the process of keeping track of the activities of business processes, the process of checking the cause of exceptions occurred, and the process of deciding the solution and applying the solution for the exception (Xu et al 2011). An efficient exception handling resolution is critical, since effective response measures allow normalizing the situation or at least mitigating the damages without unnecessary delays, and limiting the overall impacts.

5. Results - the consignment monitoring concept

Real-time information on the supply chain security incidents enables early detection and information on stakeholder decision structures shortens response time of security events (Gould et al., 2010). Through the use of real-time monitoring, the latency to respond to the incident can be decreased. Besides the security benefits the use of monitoring equipment create possibilities for improving the efficiency, e.g. through more accurate estimates of the time of delivery, and a more accurate inventory of transport resources (Permala et al., 2011). In addition, monitoring can be required because of the nature of transported goods, for example, monitoring of optimal temperature is a prerequisite for cold chain management (Raab et al., 2011). In these cases, different sensors are applied in order to collect information about the environmental and conditions (e.g. temperature, humidity, shocks) during logistics operations. Only efficient monitoring ensures the quality, safety, and economic viability of the supply chain.

Supply chains which are covered by a single vehicle can be monitored using monitoring units fixed in the vehicle. Multimodal consignments pose challenges both to the monitoring technology and devices used as well as to the collection of information from partners. Through tracing the location and conditions of the consignments during transport, and by communication with a background system, the complete supply chain can be monitored from origin to destination in real-time. Fig. 2 shows the concept developed for the real time consignment security monitoring. The concept is divided into two phases: the planning phase and the execution phase, both of which consist of three phases: activation, transport execution, and the receipt phase. The planning phase comprises the base for the successful and financially profitable monitoring concept. During the planning, the risk analysis is the basis for the requirements and the contracts. The planning phase includes also supply chain modelling, reaction plans prearrangements and if needed, personnel training. Modelling of the supply chain involves predefinition of the normal situations and allowed deviations. The modelling of the supply chain is the baseline for the monitoring device setting definition, e.g. by setting alarm levels for available transportation routes including geofencing areas and sensor data, frequency retrieval and transmission of data.

In the execution phase the monitoring of consignments and possible reaction measures are carried out according to the predefined plan. The challenge of the monitoring is to find a cost efficient way for the monitoring which includes reactions when needed but not when the shipment is transported within the pre-agreed time or location limits. The interpretation of the monitoring data is of great importance and varies between fields of operation and supply chain. The existence accurate route schedule information is one of the key back ground information for successful monitoring. The training of relevant personnel is in most cases needed for the attachment of the device, the interpretation of the monitoring information and reaction measures, receiving the shipment, removing the device and device return logistics. Especially the guidelines development for the personnel, who handle and interpret the alerts and reactions, is a critical aspect.
The concept was tested in different shipments within Finland and internationally. Tests included shipments of metal reels from Finland to Italy using both short sea shipping, rail transport and road transport (Scholliers, 2011), and shipping of metal products from Finland to Sweden, Poland, Germany and Estonia. In the Logproof project different concepts were tested for transports of furniture in Finland and in shipments from Finland to Russia, including testing of trailers intrusion detection, and of shipments of machinery in a maritime container. During the shipping, the information was monitored and analysed in real time by the research team and the exceptions were discussed with the stakeholders involved. The security monitoring concept planning and development must also include except situation handling concepts which can include carrier and authority contacting procedures and recovery arrangements.

6. Discussion

6.1. Monitoring of consignments

Both the monitoring and battery technologies have developed during the last years and nowadays a wide range of devices are available on the market for different supply chain security monitoring purposes. Different types of products, consignments, supply chains, and stakeholders involved pose different requirements for the technology and monitoring solutions, both related to the nature of the shipment (e.g. size, supply chain duration, critical parameters for transport such as temperature, humidity and shock), to the main risks to be addressed and to the possibility of performing mitigations actions in real-time. Other aspects affecting the solutions include e.g. the installation possibilities of the device, receiving partner acceptance and returns logistics. Therefore, finding solutions, which fit the realiser’s, the supply chain and the consignment needs and enhances business, security or other benefits is a challenging task. The monitoring technology choice depends on the needs and can be chosen to monitor different environmental quantities, relevant for the supply chain, and including environmental conditions (temperature, pressure, moisture, acceleration), integrity (light, package or lock condition, intrusion detection), and location (satellite, GSM). The intelligent devices notice the deviations according to the predetermined settings, and actions are executed dependent on the received signals, the transport phase and predefined action plans. The settings for the monitoring devices and alert ranges need to be determined based on
experience and expectations. The frequencies of sensor data and location collection and of data transmission have to be selected based case specific based on the selected monitoring concept and security risks.

Efficient detection of exceptions requires not only monitoring technologies, but also a proper understanding of the exceptions and the actions needed to manage them. Generally, for the correct identification and diagnosis of exceptions, the information from monitoring equipment has to be fused with other available data, such as the shipment plan, environmental data and information from other sensors, e.g. CCTVs and imaging systems in terminal areas. Also, the driver of the vehicle is generally the best to react and to provide information on the exception. Hence, the need for effective reaction is that the contact data of the driver is permanently available to the service centre or to the responsible monitoring partner.

In practice, from the security monitoring point of view the changes between different transport phases were in general the most critical. This is because the consignment is normally at rest, there are more stakeholders involved and the responsible supply chain partner is not self-evident. More research is needed on the identification of the actual supply chain phase and the responsible stakeholder and of different kinds of exceptional situations. To constitute a general understanding of the situation at hand at the other side of the globe requires fusion of multiple supply chain related data, including the tracking and different sensor data and possibly also other data sources (e.g. meteorological information, AIS-information, railway traffic tracking information, road traffic information) in order to support the responsible monitoring partner and to improve the level of service.

6.2. Benefits

The tests showed that the benefits can be attained from increased visibility and the ability to track and control the deliveries more efficiently. The business benefits of the using of innovative monitoring technology lay also in the decrease the bureaucracy and documentation for the security management. In addition, the impacts on supply chain quality indicators such as service level quality were found important. Monitoring of shipments facilitates increased automation, reduces costs and lead times, and the possibilities to react on deviations. The monitoring increased cooperation between supply partners and increased commitment. Finally the practical execution phase and small details in the execution of the monitoring define how successful the business case will be.

6.3. Obstacles – restraints

Major challenges in the implementation of the security monitoring technology include the assurance of collaboration between parties involved, especially between the consignor the consignee or if necessary, the authorities. The partners in the supply chain do not always have close relationship, which makes the development of measures more difficult. Difficulties increase if the operating cultures differ, the monitoring is planned only for a part of the transportation chain, customs declarations are needed or the attitude towards security monitoring of the authorities is unknown. In order to assure the benefits of the monitoring concept, procedures involving third party employees must be optimised. These procedures include the installation and activation of the devices by the consignor and the return logistics procedures by the consignee.

When using monitoring technology to improve supply chain security different boundary circumstances must be carefully considered. The overall execution of the monitoring is much easier if the implementing partner has the control over the supply chain. As in these cases the monitoring is mostly done with fixed equipment in the transport equipment.

The definition of the normal conditions and accepted deviations posed challenges, in other words the discrimination of allowed deviations from exceptional situations was awkward. The transport phase is determined from the transport plan, sensors and location values. Accurate advance information on the transport plan was however be difficult to obtain, because the supply chains were long or there were many subcontractors involved in the transport execution.

The duration of the device batteries is often critical concern when monitoring supply chains. The battery life time depends on the measurement, transmission frequency and conditions. The need for monitoring is often the largest for the final leg of the supply chain, which posed high requirements especially for supply chains with a maritime leg. On the other hand the transmission density of the device affects to high extent to the battery life.
On solution is to make the updating and communication frequencies of the device variable, in order to optimise the battery life, by making data transmission denser in critical areas (e.g. handling or road transport) than in safe areas (e.g. maritime transport).

Currently there is almost no standardization of monitoring devices, and hence they mostly comply with software from the device manufacturer. Some devices are more open technology orientated, and allow communicating with third party software. On the other hand, other technology providers are very careful with the proprietary features of the devices (e.g. for power management or for access to specific sensors). Hence, the selection of the background system or service provider is of great importance.

7. Conclusions

Monitoring technology offers possibilities to increase the efficiency and especially security of supply chains. Tests in different national and international supply chains have proven that the technology has developed rapidly in the last years and solutions are available for implementation. However the technology investments for consignment monitoring are still rare and the investments need often thorough reasoning both internally and to the customer.

Understanding of the value of supply chain monitoring is of great importance. The value of well implemented monitoring supports the business benefits and, enhances security, e.g. direct benefits including the real-time knowledge of the status of the consignment and the possibility to react if needed. Additionally, the data gained provides customers increased knowledge on the supply chains, and allows identifying possible development needs and bottlenecks. The monitoring concepts also allow advanced situational awareness, and improved resilience in case of unexpected disturbances.

An innovation of advanced security solution requires development based on co-operation with technology providers and supply chain partners. Even though it is a necessity, this kind of shared development process is still somewhat immature in supply chain field. In the process, the development or the selection of the background system and the service provider is of great importance.

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References


