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# TYPOLOGY OF CONFIGURABLE RFID TRACKING IN FASHION LOGISTICS

## Abstract

### *Purpose*

The aim of this paper is to propose a typology of RFID-based tracking solutions designs to fit differing supply chains. The typology is presented as principles of form and function contributing towards a design theory of configurable RFID tracking for fashion logistics.

### *Design/methodology/approach*

The typology is developed based on case study of a logistics service provider (LSP) interested in designing a tracking solution for different customers in fashion logistics. In addition to the LSP, four fashion retailers were involved in the study. The case study was carried out using a review of existing RFID tracking implementations in the fashion industry, analysis of a RFID tracking pilot conducted by the case company and interviews with representatives of the retailers.

### *Findings*

By varying three design parameters (place of tagging, place of tracking start, and place of tracking end) a tracking solution can be configured to fit the requirements and constraints of different fashion supply chains. In the fashion logistics context under investigation, such parameterization addresses retailer requirements, brings concrete and quantifiable benefits to both LSP and its customers, and enables incremental adoption of RFID tracking.

### *Research limitations/implications*

Even though the typology is developed in the specific setting of a case company developing RFID tracking solutions for fashion logistics, the design parameters identified in the study can be used when considering configurable tracking solutions also in other domains and settings. However, further research is needed to evaluate the proposed typology in those settings.

### *Practical implications*

The proposed typology enables fashion companies to consider which configuration of RFID tracking best fits the requirements and constraints imposed by their particular supply chain. For fashion companies, who find adoption of RFID tracking difficult despite the obvious benefits, the proposed typology enables incremental implementation of supply chain-wide tracking.

### *Originality/value*

The developed typology, describing how RFID-based tracking solutions can be adjusted to fit the needs of fashion companies with differing supply chains and requirements is novel. The typology is generalizable to most fashion logistics settings and probably to numerous other logistics domains.

*Keywords:* RFID, supply chain management, retail trade

*Paper type:* Research paper

# 1 INTRODUCTION

In fashion retailing, the biggest challenges in supply chain management are related to the low predictability of demand. The season is short and products should be in shops right after the season changes. But at the same time the industry suffers from long lead times, typically up to six months, when sourcing from off-shore production. This forces fashion retailers to fix their supply plans based only on vague forecasts. Consequently, some models and sizes are produced in excess while others run out far too soon, resulting in lost sales during each season and forced markdowns at the end of each season, as well as stock-outs and high inventory carrying costs. (Christopher *et al.*, 2004; Fisher and Raman, 1996)

To deal with the situation, fashion companies have developed different approaches to enhance responsiveness (Fisher, 1997). A responsive company is able to adjust its output rapidly within the available range of four external flexibility types: product, mix, volume and delivery, in response to an external stimulus (Reichhart and Holweg, 2007). In addition to forecasting, a common requirement for responsive solutions to work is that sales and inventory movements are accurately recorded and shared in the supply chain. In order to be responsive, the information between supply chain members has to move fast and that information must be correct. To obtain this information, tracking systems are needed (Holmström *et al*., 2010). In fashion retailing, item-level tracking is the only way to achieve the benefits of tracking, and the most cost-efficient way to introduce this tracking is to adopt RFID (radio frequency identification) (Moon and Ngai, 2008).

Many fashion companies have not introduced RFID tracking, even though the benefits have already been well known for a decade (Ngai and Gunasekaran, 2009). The fashion retailers that have been particularly successful in benefiting from RFID tracking operate highly integrated supply chains with suppliers, distribution centers and retail shops under the direct control of the retailer (Hadfield, 2007). A likely reason for non-adoption among fashion retailers in general, is that introducing RFID tracking on a supply chain-wide scale is more challenging when sourcing from a wide variety of suppliers, or relying on logistics service providers and franchisees in distribution and sales. The aim of this paper is to propose a typology for configurable RFID-based tracking solutions. The typology addresses the needs of different actors in efforts to increase both efficiency and responsiveness of fashion supply chains.

To develop the typology we first review RFID tracking solutions currently in use in the fashion industry analyzing both functionality and form. A range of alternative designs of RFID tracking were developed and evaluated in collaboration with a LSP (Logistics Service Provider) company who was conducting a RFID tracking pilot and four fashion retailers interested in adopting RFID tracking. The proposed typology was developed based on the alternative designs and the evaluation of the designs by the LSP and fashion retailer representatives. The typology describes how a tracking solution can be configured by varying three design parameters (place of tagging, place of tracking start, and place of tracking end) and helps managers consider the justification for alternative RFID tracking configurations.

# 2 LITERATURE REVIEW

One purpose of supply chain management is to control different functions of the supply chain in order to enable timely and reliable delivery of products from manufacturer to end customer (Mentzer *et al*., 2001). When inter-organizational processes operate in an environment prone to failure and disturbance, the delivery process rarely functions as scheduled. Therefore several procedures and tools have been developed to answer this supply chain management problem and improve responsiveness. Otto (2003) writes about a management concept – known also as a name for software solution and components – Supply Chain Event Management (SCEM), which attempts to identify, as early as possible, the resulting deviations between the plan and its implementation across the multiplicity of processes and actors in the supply chain, and to activate corrective actions according to predefined rules. However, in order to get the exception data as

early as possible and to be able to execute corrective actions, an effective tracking system is required also for SCEM to work (Otto, 2003).

Tracking systems, in general, send a message to the tracking database when a tracked item arrives at a predefined checkpoint in the distribution network. Typically, some automatic identification technology (like barcodes or RFID) is used for registering the passing of a checkpoint. Tracking systems are needed, on the one hand, for linking the information systems and the physical reality in the supply network and, on the other hand, for introducing paperless and more accurate information systems. (Holmström *et al*., 2010; Kärkkäinen *et al.*, 2004; Stefansson and Tilanus, 2001).

At the moment, the barcode is the most common technology used in tracking, even though the use of technically advanced but more expensive RFID is increasing. There are three essential parts in an RFID tracking system: the tag (or "transponder"), the reader device, and the back-end computer system. If RFID technology is used for tracking, no line of sight is needed in reading the tagged items. Dirt and wear are neither a problem when RFID tracking is used. Another substantive benefit of RFID compared to the most common barcodes in use in retailing is that all RF identifiers are unique. Because of these characteristics of the technology, RFID tracking offers particular benefits in logistics management in every echelon of the supply chain that are not possible to reach by using barcodes or similar technology. Therefore, RFID-based tracking systems are being used in several industries from manufacturing to recycling and waste management. (Attaran, 2007; Främling *et al.* 2007; McFarlane and Sheffi, 2003; Mehrjerdi, 2011; Ngai *et al*. 2008; Sheffi, 2004; Wyld, 2006)

The common view found in the literature is that RFID tracking should cover the whole supply chain and be an integral part of inter-organizational operations (Wyld, 2006; Zhou, 2009; Fosso Wamba and Chatfield, 2009). However, the literature does not elaborate on the introduction of RFID tracking in different types of supply chains. The literature highlights constraints affecting the design of RFID tracking solutions, such as the cost of attaching RFID tags (Bottani and Rizzi, 2008; Brown and Russel, 2007; Gaukler *et al*., 2007). Manufacturing is identified as the lowest cost echelon for attaching tags (Whang, 2010). However, as the literature points out, the retail level is in the best position to benefit from RFID technology and therefore the majority of the existing RFID tracking systems cover only the downstream stages of the supply chain: the distribution center (DC) and a few stores (Vijayaraman and Osyk, 2006; Soon and Gutiérrez, 2008). Some authors even regard supply chain-wide multi-company RFID tracking solutions to be almost impossible to implement in practice, and therefore argue that research should focus on the benefits of intra-company or simple inter-company applications (e.g. Spekman and Sweeney, 2006).

Even though the literature acknowledges a more limited extent of tracking coverage than integrated supply chain-wide RFID tracking, the authors of these articles do not challenge the objective of supply chain-wide tracking. Based on a review of literature a typology of alternative RFID tracking solution designs, and their benefits and weaknesses appears to be lacking. There is a need to synthesize empirical research indicating that in many supply chain contexts more limited solution designs may be more straightforward to implement while still offering many of the same benefits as an integral supply chain-wide system would provide (Fosso Wamba and Chatfield, 2009; Visich et al. 2009).

The fashion and apparel industry has been active in piloting RFID tracking, and numerous companies in the industry already have successful solutions. The RFID Journal refers to the report of IDTechEx, where it is estimated that in 2008 the apparel industry purchased approximately 200 million RFID tags. The cost of those millions of tags is about 38 % of the value that the whole retail sector spends on RFID. (RFID Journal, 2008) Recent literature about RFID implementations in the fashion and apparel retailing sector barely discusses any other recognition level than item, because the most common applications such as automatic checking and verification of the content of incoming shipments, and stock-taking require tracking of individual clothing items (Moon and

Ngai, 2008; Azevedo and Ferreira, 2009; Balocco *et al.*, 2011). However, when shifting focus from the retail to the supply chain as a whole, it is not self-evident that tracking is beneficial on item-level, rather than pallet or container level.

| Name of the company | Where the RFID tags are attached? | Where tracking starts? | Where tracking ends? | Function of RFID tracking | Supply chain parties involved | Scale | Takn in production use |
|---|---|---|---|---|---|---|---|
| Lemmi Fashion (Germany) | Manufacturing phase | In transit from vendor to DC | when the shipments leave DC | Improvements in DC operations: better visibility to warehouse, improved shipping accuracy, pinpointing problems in operations | DC, negotiations with retailer companys (in 2006) | All Lemmi's products are RFID tagged | 2005 |
| M&S (UK) | Manufacturing phase | manufacturing phase or DC | point of sale | Improve inventory-taking and accuracy, faster and more accurate replenishment | factories, DC, stores | 150 factories, 20 countries, 120 stores and 13 clothing departments, 100 million RFID tags annually | 2006 |
| Mi-Tu (Hong Kong) | inventory of the stores | when a customer picks item | point of sale | Improve purchasing experience by using intelligent fitting rooms, decreasing shoplifting, combining fitting room data with sales data | Mi-Tu stores | All garments in two fashion stores in Hong Kong | 2007 |
| Tomorrow's Mother (USA, Canada) | Manufacturing phase | DC, incoming | point of sale | Improve inventory accuracy of the company's departments in stores, increasing the efficiency of replenishment shipments | DC of Tomorrow's Mother, stores that sell company's garments | Maternity departments in 384 stores across USA and Canada | 2007 |
| Charles Voegele Group (Slovenia) | Manufacturing phase | Manufacturing phase | point of sale | Improve inventory-taking and accuracy, improve store design based on tracking consumers purchasing habits, decrase errors in logistics | Manufacturer, freight station in China, European DC, stores | 8 manufacutrers in China, 4 stores in Slovenia (2009), system enlargement on-going | 2008 |
| American Apparel (US) | Manufacturing phase | DC, outgoing | point of sale | Improved inventory accuracy, decreasing theft, resulting decrease in loss sales | American apparel is vertically integrated company from manufacturing to DC and stores | RFID in 100 stores in the end of 2011, plan to equip all its 280 stores by the end of 2012 | 2008 |
| Throttleman (Portugal) | Manufacturing phase | Manufacturing phase | DC | Improve inventory accuracy in DC, fasten the time the products spent in SC | Manufacturer in India, DC in Portugal | In 2008, Throttleman tagged 60 % of its items, about 370 000 articles. Plans of enlarging the system to cover 100 stores of Throttleman | 2008 |
| Gerry Weber (Germany) | when the products are leaving from the manufacturer | manufacturing phase | point of sale (own retailing), DC (other retailers) | Prevent lost sales due to poor invetory accuracy and errors in shipments, transmitting manufacturer information, improving retail store processes and security. | Manufacturers, DCs, own stores, negotiations with franchising stores | All 26 million items were tagged in 2011 | 2009 |
| Staff Jeans (Greece) | Manufacturing phase | Manufacturing phase | point of sale | Improving receiving and inventory accuracy in DC, improving retail store security and purchasing performance of consumer | vertically integrated company from manufacturing to DC and stores | 0.8 million RFID tagged items in 2010 | 2010 |
| Van Vuuren Mode (Holland) | DC, excluding Gerry Weber's clothes (already tagged) | DC | point of sale or point of return | Delelop on-line shopping and reverse logistics | stores and DC | 500 000 items annually, 26 departments stores and webshops | 2011 |

*Table 1. Overview of ten existing RFID tracking solutions in fashion and apparel.*

Table 1 presents an overview of ten RFID tracking solutions in use in the fashion and apparel industries. The tracking solutions are selected to reflect different types of supply chains and options available in designing the RFID tracking solution. The information reflects the situation based on the latest available public sources.

The biggest existing item-level RFID tracking solution in the apparel and fashion industry is that of Mark & Spencer (M&S). M&S started a large-scale roll-out after a successful trial of the use of RFID tracking in selected stores in 2006 (Hadfield, 2007). Later the RFID tracking solution was scaled up to cover 150 factories, 120 stores and 13 clothing departments in 20 countries. M&S annually purchases approximately 100-150 million RFID tags for its suppliers so that they can tag the clothes that are going to be delivered to M&S. (RFID Journal, 2008; Roberti, 2010). M&S is an example of a company which has its own fashion brands, which are primarily sold in its own stores.

In Table 1, other similar companies that sell their own brands primarily in their own stores are Charles Voegele Group, American Apparel and Staff Jeans (Charicleia, 2010; Gaudin, 2008; Gentry, 2008; Hardgrave, 2009; Swedberg, 2009; Swedberg, 2012; Wessel, 2010).

Another large-scale RFID user is German Gerry Weber, a retailer that tagged all 26 million items sold in 2011 (Roberti, 2011). Gerry Weber has built its RFID tracking system based on intended benefits in its own stores, even though a significant share of the products end up with franchising companies or other retailers, which do not use the RFID tags for tracking (Roberti, 2011). Tomorrow's Mother leases maternity departments in 384 stores and uses its RFID tracking solution to control these departments on premises managed by other retailer companies (Swedberg, 2007c; Violino, 2008).

The retailers Van Vuuren Mode in the Netherlands and Mi-Tu in Hong Kong only sell fashion items produced by other companies. In Van Vuuren Mode, RFID tags are attached in the company's own DC and tags in Mi-Tu are attached in the retail stores (GS1 Hong Kong, 2007; Swedberg, 2007b; Säilä, 2011). Lemmi Fashion and Throttleman are not retailers, but fashion suppliers who do not have their own retail stores. Therefore their RFID tracking systems concentrate on obtaining benefits from improved operations in the distribution echelon (Azevedo and Ferreira, 2009; IT Reseller Magazine, 2008; Speer, 2006; Swedberg, 2007a).

The function of the reviewed fashion industry solutions covers the main benefits achievable through RFID tracking as identified by McFarlane and Sheffi (2003). Almost all of the solutions presented aim to decrease errors in handling operations and shipments, which improves inventory accuracy in stores and DCs. The improved accuracy reduces the likelihood of out-of-stock situations decreasing the cost of lost sales. Another stated aim of many of the reviewed solutions is improved handling efficiency in DCs and in receiving shipments in stores. This functionality is important as it offers both savings in labor costs and reduces delivery times. Some of the retailers that have implemented RFID tracking in retail stores also expect to decrease shrinkage caused by theft, and to improve the purchasing experience of consumers by offering better information about available products.

As seen from Table 1, in most of the RFID tracking solutions the RFID tags are attached in the manufacturing echelon of the product. This is the choice for attaching RFID tags especially when all the products are meant for a single retail company. However, even when the tag is attached in the manufacturing echelon, not all the companies reviewed started tracking in that echelon. Some companies attach RFID tags in their DCs, and one retailer even postponed tagging to the store. In eight out of ten RFID tracking solutions reviewed in Table 1, tracking ends at the point of sale. The two companies that do not track products in retail stores have supply chain partners that handle retailing. RFID tracking is only implemented in the DC, but the intention is to later negotiate with retailer companies to extend tracking to the retail echelon.

Developing typologies is a possible approach to synthesizing design knowledge on the different options over where to attach tags, when to start tracking, and when to stop tracking in different supply chain contexts. Comparing implementation costs with the possible benefits of tracking in different supply chain echelons makes trade-offs explicit. When tagging is done in the manufacturing echelon, there are more possibilities to benefits, but at the same time, in many supply chain contexts there is excess tagging of products that will be distributed through channels where RFID tracking is not yet in use. For this type of comparison, supply chain management literature has introduced the theoretical concepts of postponement and speculation (Yang et al., 2004, Boone et al., 2007). In the RFID tracking context, speculative tagging in the manufacturing echelon would mean that RFID tags are attached before knowing the share of products that will be distributed through channels using RFID tracking. Postponed tagging means that RFID tags are attached in the later echelons of the supply chain when it is known that all the tags will be used for tracking purposes.

In summary, RFID tracking can accelerate, simplify and improve the existing processes, for example in the case of warehouse management, and is thereby useful in shortening the excessively long lead times of the fashion industry. Tracking also helps in collecting accurate data on shop inventory and customers' shopping and buying behaviors, thus enabling more accurate forecasts and less stock-out (Visich *et al*. 2009; Sarac *et al*. 2010). However, for retailer companies in general, building tracking systems is not easy because they usually lack knowledge about the technology and its possibilities (Visich *et al*. 2009), and developing an actual business case might be difficult for many retailers constrained by a diverse supplier base and network of logistics service providers and retail channels (Curtin *et al.,* 2007). Therefore a typology for configurable RFID tracking, focusing on the business benefits and challenges of different alternatives, would likely decrease fashion companies' barriers to adopting RFID. However, this kind of typology is still missing in the research literature, which may be explained by most solutions, with the exception of the open system of Wal-Mart's (Roberti, 2010), being designed solely for the focal company's own needs. A typology would help to more flexibly show how solutions could also be adopted by partners in other supply chain echelons or even competing supply chain members, thereby driving down development and implementation costs for all.

# 3 METHODOLOGY

The primary method used in this paper is case study (Yin, 1994). In case study research, researchers are able to develop relevant and testable theories by collecting and analyzing qualitative data (e.g. Benbasat et al., 1987; Roth, 2007). The case company is a Logistics Service Provider (LSP) interested in designing a tracking solution supporting their customers in fashion logistics. The LSP also sees services that support supply chain responsiveness as a potential competitive advantage in the future. Working with the case company was interesting because it has been actively piloting the use of RFID and other tracking technologies in its operations, for example for tracking roll cages and vehicle positioning. It also already was piloting RFID tracking with a customer in the fashion industry. In the pilot, the customer company was attaching RFID tags to all clothing items that the LSP has been handling in a DC for the customer. Furthermore, the LSP offered access to more retailers interested in implementing RFID tracking.

This way the case study provided an interesting context for developing a typology for configurable RFID tracking in the fashion supply chain. The case LSP had experimented with RFID tracking and saw an opportunity for introducing it in the fashion industry. At the outset of the study the LSP had the outline of an idea of a solution, but was unsure how the different design alternatives would fit the needs of different retailers.

The development of the typology contributes towards design science theory. In general, a design science theory describes a means to an end (Holmström *et al.*, 2009), by articulating: (1) Purpose and scope, (2) Constructs, (3) Principles of form and function, (4) Artifact mutability, (5) Testable propositions, (6) Justificatory knowledge, (7) Principles of implementation, and (8) Expository instantiation (Gregor and Jones, 2007). A typology addresses one of these design theory elements, namely the principles of form and function. The proposed typology combines function as described by value equations (Anderson *et al.*, 2007) and form as described by design parameters of a configurable RFID based tracking solution.

The typology was developed in four phases based on a literature review, analysis of the case company's piloting of RFID tracking, and interviews with representatives from the case company and the four retail companies.

In the first phase of the case study, the researchers reviewed the literature to find existing RFID tracking solutions from the fashion industry. The findings were contextualized based on interviews and workshops with personnel from the case LSP. Three alternative forms of a solution were identified for RFID based tracking in fashion logistics in the case company context.

In the second phase of the case study, the researchers revisited RFID literature and looked for existing RFID tracking solutions quantifying possible benefits that RFID tracking could bring to the operations of the case LSP and to its fashion retail customers. Personnel involved in the tracking pilot were interviewed to gain insight into the potential benefits of RFID tracking for both the LSP and its retail customers. Based on this literature review and interviews the likely benefits of RFID tracking were identified and magnitude estimated. The estimates were formed together with the case LSP personnel.

In the third phase of the case study, the needs of four fashion retailers were mapped against the three design alternatives and likely benefits identified in the preceding phases. Retailers were involved in improving the understanding of the proposed form and function of RFID tracking in specific supply chain settings. Two CEO's, one CIO and one development manager were interviewed. The semi-structured interviews consisted of questions about previous RFID experience, the stages and challenges of the supply chain, differing information systems and the structure of the retail network. One interview took an hour on average, and a voice recorder was used to improve the reliability of the interviews. The interview guide is presented in Appendix A.

Limiting the number of retail companies to four, was deemed sufficient as Eisenhardt (1989) suggests that a range of 4-10 examples "usually works well" in inductive case study research. The four retailers were selected based on the LSPs acknowledgment of good supply chain competence. The four fashion retailers are integrated vertically, meaning that they are responsible for the apparel design, and sell at least half of their products in their own retail stores. Compared to the companies reviewed in Table 1, the selected retailers are considerably smaller and have limited resources to initiate a RFID tracking solution on their own.

Finally, when the first propositions of a typology describing form and function of configurable RFID tracking solution had been formulated, workshops held on the premises of the two most active retailer companies were organized. Based on the case study findings and literature reviews the propositions synthesized by the typology were discussed together with the representatives of the hosting retailer company and personnel from the case LSP. Based on these workshops, the solution typology was validated and refined in the supply chain setting of the retailer.

Different phases of the research and how they are applied in the case of this paper is summarized in Table 2. These phases mainly proceeded linearly, even though some activities of two different phases overlap.

| Phase of the research | Description |
|---|---|
| 1. Identifying alternative forms of the case company's RFID tracking solution | Systematically searching for alternative forms by analyzing existing RFID tracking solutions in the fashion industry and a pilot conducted by the case company. Three realizable alternatives were identified though collaboration between case company personnel and researchers. |
| 2. Recognizing and describing the most important benefits to LSP and fashion industry customers | By combining the literature review of existing tracking solutions in the fashion industry with interviews of LSP personnel involved in the pilot, the likely benefits in the case setting were identified. |
| 3. Evaluate alternatives of RFID tracking in specific supply chain settings | Customer interviews. Summarizing the benefits and identifying the most suitable form of RFID tracking solution for specific fashion industry customers. |
| 4. Typology development | Proposed typology refined in two workshops together with representatives of the hosting retailer company and personnel from the case LSP |

*Table 2. Phases of research and their use in the case study.*

In summary, seven persons from the case LSP were involved in the case study in 12 interviews and four workshops. In addition, the researchers interviewed representatives from four fashion companies, and spent two days observing daily routines in different fashion stores. Two workshops were arranged on the premises of the most active customer companies after developing a preliminary version of the typology for configurable RFID tracking in fashion logistics.

# 4 RESULTS

## *4.1 Typology*

The alternative forms of RFID tracking solutions are based on the analysis of existing tracking implementations presented in the literature review section (see Table 1). Based on the review factors that effect of the form of the tracking solution are:

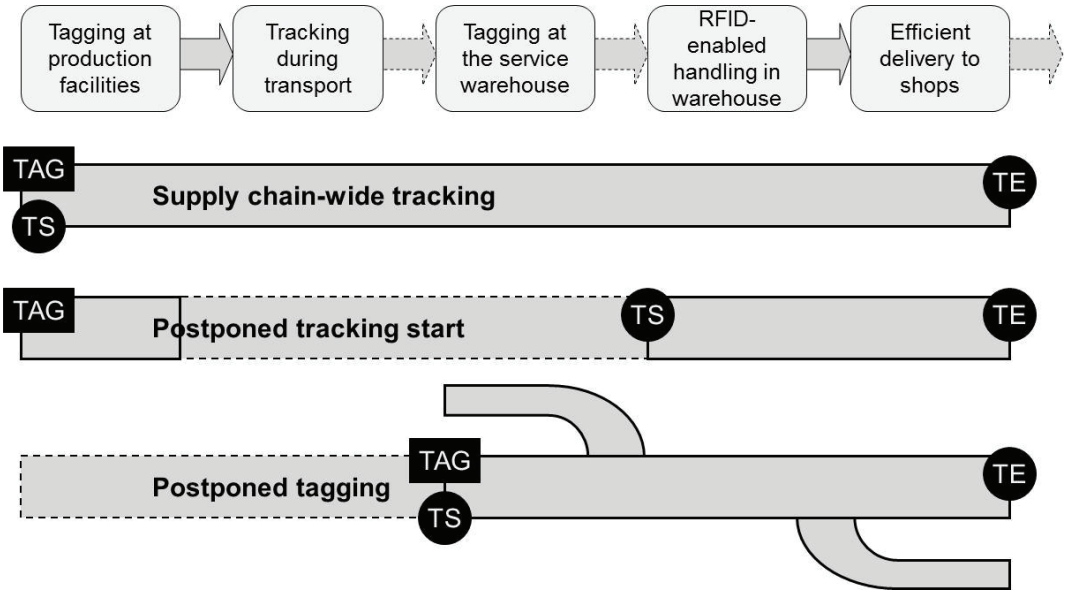
- **The structure of the supply chain**. Many of the RFID tracking implementations, where the RFID tags are attached in the manufacturing echelon of the supply chain and used in the retailer stores, are in the vertically integrated supply chains such as American Apparel and Staff Jeans or in the supply chains, where the retailer has a dominating role and its own fashion brands such as M&S. Therefore, vertical integration or the dominating role of the company seems to simplify the implementation and enlargement of the tracking system.
- **The initiator's position in the supply chain**. Mi-Tu and Van Vuuren Mode are rather small retailer companies and therefore they tag their products in the warehouse or DC unless for some reason the products already have RFID tags. Throttleman and Lemmi Fashion instead are fashion suppliers and therefore their tracking ends, when the products leave their DC.
- **The focus of tracking**. Especially in M&S's, American Apparel's and Tomorrow's Mother's current RFID tracking applications the purpose is to improve the accuracy and speed of replenishment of the retail store and improve the stores' performance, not to improve the management of the whole supply chain. Therefore in their RFID implementation, tracking mainly starts when products leave from DC, even if RFID tags are mainly attached further upstream.

The outcome from existing tracking implementations is that RFID tags are attached in the manufacturing echelon whenever possible, because the cost of attaching is the cheapest there. In some supply chains, where the RFID tracking initiator does not have its own brand or manufacturing, attachment of RFID tags is postponed to the place, where the focal company obtains the products. However, even if the companies attach RFID tags speculatively, tracking start is often postponed to the later echelons of the supply chain – typically for the DC.

Therefore, two design parameters (place of tagging and place of tracking start) can be identified. By adjusting these two parameters, their impact can be seen in the costs of tagging and equipment, in the amount and volume of achievable benefits and in the suitability of the solution for different customers and configurations. The place where tracking is stopped is a third design parameter. In the case of fashion logistics tracking stop is usually in the retail shop, as limited or no benefits can be achieved in after-sales. Most benefits are achieved in the shop in the receipt of goods and in stock-taking.

The typology for configurable tracking is illustrated in Figure 2. Basically, there are three alternative places for tagging: the manufacturing phase, some of the DCs or the retail store. However, tracking instead has more variety, as it can cover almost every actor of the supply chain, if the products already have RFID tags. Alternative configurations can be described by using the defined three design parameters in different combinations. In the case setting three alternatives were deemed practically relevant. The settings of the design parameters for each of these configurations are marked with abbreviations TAG (place of tagging), TS (place of tracking start) and TE (place of tracking end).

*Figure 1. Typology of configurable RFID tracking.*




"Supply chain-wide tracking" is potentially the most beneficial, as well as the most resource intensive configuration. It provides the greatest benefits as tracking is started in the manufacturing echelon, but it is also quite demanding to implement. In this option, all the events related to the product between the manufacturer and the retail shop can be linked to the RFID tag and it is possible to determine the complete cost of the product from manufacturer to the retail store.

"Postponed tracking start" is a less demanding option as tags are attached in the manufacturing echelon where it is the cheapest, but tracking between manufacturing site and the warehouse of the LSP is not introduced. This way most of the benefits in the supply chain-wide configuration can be achieved but the costs for tracking are lower. Even if some events in the supply chain remain inexact, this tracking option still offers enough information to define the total cost of the product with sufficient accuracy, because, among other possible factors, all the transportation modes during stages of incomplete tracking can still be known.

"Postponed tagging" is a configuration where RFID tags are attached to products just before they enter the operations of an actor capable of benefiting from RFID tracking. The most common place to attach RFID tags in this configuration is a retailer or LSP operated DC. This option provides flexibility when flows of goods are complex. It enables tagging products that are sourced from any manufacturer, and tagging only those products that are sold in certain shops. As such, however, this type of postponement is not especially cost-efficient for retailers. Even if this option is the easiest to implement, the information about product manufacturing cannot be obtained and neither can the item-level costs of products reaching the end-consumer be reliably defined.

The benefits and weaknesses of the alternative configurations are summarized in Table 3.

| | "Supply chain-wide tracking" | "Postponed tracking start" | "Postponed tagging" |
|---|---|---|---|
| Description | RFID tags are attached in the manufacturing echelon of the product, and RFID tags are exploited throughout all the supply chain | RFID tags are attached in the manufacturing echelon of the product, but tracking between manufacturing site and the warehouse of the LSP is incomplete. | RFID tags are attached in the LSP's warehouse and tracking starts in that echelon |
| Benefits | + Manufacturing echelon is the cheapest place of tagging<br>+ Covers the entire supply chain<br>+ Possible to obtain information about manufacturing conditions<br>+ All the supply chain members could get the benefits of RFID tracking | + Manufacturing echelon is the cheapest place of tagging<br>+ Covers the most essential parts of the supply chain<br>+ Possible to obtain information about manufacturing conditions<br>+ Most of the supply chain members could get the benefits of RFID tracking | + All the RFID tags that are attached will be exploited in the supply chain processes<br>+ Less outside partners (e.g. manufacturers) to negotiate about practical issues and responsibilities |
| Weaknesses | – Expensive to arrange tracking between manufacturing site and LSP's warehouse<br>– Some of the RFID tags will probably be wasted, because the tagged product may end up in a supply chain which is not using RFID tracking | – Tracking between manufacturing site and the warehouse of the LSP is incomplete<br>– Some of the RFID tags will probably be wasted, because the tagged product may end up in a supply chain which is not using RFID tracking | – Tracking before LSP's warehouse is not possible.<br>– Not possible to collect item information about manufacturing and upstream supply chain activities<br>– Attaching RFID tags is more expensive in the LSP's warehouse than in the manufacturing echelon |

*Table 3. Comparison of benefits and weaknesses of the three configurations deemed practically relevant by the case company.*

## *4.2 Evaluation of alternative configurations in case context*

Based on the interviews of representatives from the case LSP and four fashion retailers, this section highlights the specific needs and challenges for configuring the tracking solution in the case context.

The comparison of the different tracking system configurations presented in Figure 1 and Table 3 was used when selecting the appropriate form of tracking for the fashion customers of the LSP. Even if "Postponed tagging" would be the easiest to introduce, there are several reasons why this alternative is not the most suitable in this case context. Firstly, tagging in the facilities of the LSP is considerably more expensive than at the manufacturing site. Secondly, the LSP's possibilities to exploit the tag in its operations are limited if the LSP itself tags the products. Over ten percent savings in warehouse operations in the pilot case required that the tags could also be exploited in the shipments receiving process. Thirdly, information about the manufacturing conditions and the possibility of calculating item-specific supply chain cost of individual pieces of clothing is lost if the products are tagged as late as in the facilities of the LSP. The benefits of the other two options "Supply chain-wide tracking" and "Postponed tracking start" are rather similar. However, supply

chain-wide tracking is more expensive and difficult to realize, because the case LSP has only little influence over other LSPs that are handling the products between Asian manufacturers and major European ports. Also the benefits of tracking products when they are somewhere between Asia and Europe brings little, if any, added value for the customers of the LSP. Defining the supply chain cost of the individual product does not require exact information about the shipping, because knowing the type of transportation used provides the needed information with the required accuracy to calculate the cost, in the "Postponed tracking start" scenario as well. Therefore "Postponed tracking start" was the preferred option for the case LSP.

If tracking starts right in the production facilities there are more opportunities for exploiting the information on the tags. In current barcode-based systems, different sizes, colours and models may have their own barcode number, but different items that have the same attributes cannot be distinguished. But is that enough? The same type of garment can be manufactured in different places. So for example, in the situation where the trousers and jacket of the same suit are made in different factories using a different roll of cloth, are they interchangeable? One benefit of RFID technology in tracking is that all RF identifiers are unique, and therefore all pieces of garments can be handled individually. The technology can be used to track, record, and trace all the phases of the product during its life-cycle after an RFID tag is attached. In addition to contributing to quality maintenance, this kind of item-level information enables finding the cost-efficient alternatives to serve the product. Therefore the combination of early placement of an RFID tag and the possibility to track a single product at the item-level would enable the case LSP to respond to the several kinds of needs of the potential fashion company customers.

At least in the near future, considering consumer ambivalence, it is anticipated that it will be necessary to integrate RFID tags into the hangtags typically used on garments. Therefore, attaching the RFID tags at production facilities requires co-operation with the hangtag supplier that the customer is using. If the tags are already attached at the production facilities, tracking can also be started there with suitable equipment. Data on which products are sent from the production facilities, and further tracking data during the transport, are provided either through a portal hosted by the LSP or, if desired, directly into customer systems. All data can be handled in a centralized manner in the current systems of the LSP. RFID tags are utilized in the processes of the service warehouse and one option is to attach the tags only after the products are received at the warehouse. Finally, shop receiving and stock-taking can be performed with portable RFID-readers.

# 5 CONCLUSION

The paper presents a typology for configurable RFID tracking solutions to fulfill the requirements of fashion companies with differing supply chains. Examining the typology of the fashion industry systems presented in the literature (see Table 1) the typology of form and function can readily be found in existing implementations. However, synthesizing the alternative configurations as a typology enables fashion companies to seek process improvements, while taking into account possible constraints to supply chain-wide implementation in their particular supply chain context.

The principles of the form of typology derive from the literature and the concepts of postponement and speculation. The requirements behind the formulation are based on the context of the case LSP and its fashion customer companies. Configurability is essential because supply chain-wide RFID tracking systems are not widely used by many supply chain parties of the case LSP. Configurability allows customers of the LSP to start RFID implementation by seeking benefits in retail operations from tagging products in the DC. Later the cost of tagging can be reduced incrementally by engaging suppliers to tag in the manufacturing echelon. Configurability of tracking start and stop is also valuable, as in many situations tracking between the manufacturer and LSP's warehouse does not bring considerable added value, but in some cases may be important in acting against counterfeiting of luxury brands. Furthermore, item-level tracking from manufacturing to retail maybe turned on temporarily in process improvement projects to identify non-value adding and wasteful practices in the supply chain.

A limitation of the current study is that the proposed typology does not address the challenges of implementation. Companies which have fundamental problems in logistics operations e.g. as a result of poor logistics management or underdeveloped processes, will hardly gain any benefit from using the proposed tracking solution before they have settled these problems. In addition, RFID can neither solve all the problems related to scheduling, because RFID tags will not move shipments quicker from one place to another, nor avoid occasional problems in transportations. Instead, tracking information can be used to accelerate handling processes, e.g. in ports and DC's, by increasing automation. Tracking information also enables identification of the deviations between a plan and its implementation, which is required for SCEM to work. At the very least tracking offers statistical information about durations and their variations for different processes. This application enables comparison of different alternatives of shipping the material flows, which may eventually help in scheduling and achieving better supply chain management

In terms of further research, a relevant issue in the fashion industry, where the proposed typology was developed is problem of piracy. Tracking an RFID tag attached in the manufacturing echelon through the supply chain can prove the genuineness of the product and prevent fake clothing items from becoming mixed with authentic products. However, developing these kinds of innovative solutions requires the co-operation of the LSP, the retailer, and the manufacturer, possibly requiring the extension of the typology with further design parameters.

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# APPENDIX A: INTERVIEW GUIDE

***Background***

1. What is your company's attitude towards RFID technology and tracking? Have you any implementation plans?

2. What are the challenges your company face related to logistics and supply chain management as a whole?

Are there any problems related to e.g. following issues:

a) Out of shelves in retail stores
b) Excess products and selling them in huge sales in the end of the season
c) Big inventories, slow turnover
d) Lack of information about what is coming from factories and where they are at the moment
e) Lack of information about the products in the retail store
f) Faulty deliveries

3. Is there any link in the supply chain, which causes problems frequently?

4. What phase(s) of the logistics processes you would like to get more information?

5. Where do you believe to get the biggest benefits at the moment and in the future if introducing RFID tracking?

***About supply chain***

6. How long before the season you make the orders? What are the information/forecasts behind the orders?

7. Where and how many factories or agreed suppliers your company has? Are there differences in the sizes of the orders from these suppliers? What are the most important factories?

8. One possible place for RFID tag is inside or on the hangtags. What kinds of actors provide you these hangtags and where they are operating mainly?

9. What are the routes from factories to the country of destination / service warehouse? Do you use always the same actors in the sea freight? Tell more about the actors related to transports as a whole?

10. Are there possibilities to improve restocking practices of the retail stores? Are the supplementary orders sent automatically?

11. What kind of information systems are used in your supply chain? Do these systems support item-level information?

12. How often the stock-taking is made in the retail stores? How much effort it takes at the moment?

***Other***

13. As a whole, it seems that it is rather easy for clothing manufacturers to equip their own retail stores with couple of RFID readers and other useful hardware. To improve the profitability of the investments for tags and tagging systems, it might be necessary to be able to use RFID tags also in other retail stores. Related to that issue:

How important role your own retail stores have in your whole selling network? What kind of role your company has related to the decision making in the retail stores that sell your products?

14. Which part(s) of the supply chain you believe you are able to arrange tracking yourself and where do you need outside help? Have you any wishes considering the role of the LSP?