Research paper

Wireless product identification: enabler for handling efficiency, customisation and information sharing

Mikko Kärkkäinen and Jan Holmström

The authors

Mikko Kärkkäinen is a Researcher and **Jan Holmström** is a Senior Research Fellow, both at the Department of Industrial Engineering and Management, Helsinki University of Technology, Helsinki, Finland.

Keywords

Wireless technology, Product information, Supply chain management, E-commerce, Materials handling, Customization

Abstract

More sophisticated customer demand chains and electronic business pose new challenges to supply chain management. Delivery sizes decrease as a result of more deliveries directly to the point of use. Customers are demanding products and deliveries customised to their specific needs. Also, the information concerning small, customised deliveries has to be shared in volatile supply networks. This article analyses the opportunities of wireless product identification technology in transforming supply chain management. A new concept of item level supply chain management and enabling steps to achieve the benefits are proposed. Innovative companies already use wireless product identification with great benefits in specific functional areas, e.g. manufacturing and warehousing. However, the biggest potential is in supply chain wide solutions, i.e. item level supply chain management.

Electronic access

The research register for this journal is available at
http://www.emeraldinsight.com/researchregisters

The current issue and full text archive of this journal is available at
http://www.emeraldinsight.com/1359-8546.htm

Supply Chain Management: An International Journal
Volume 7 · Number 4 · 2002 · pp. 242–252
 · ISSN 1359-8546
DOI 10.1108/13598540210438971

Introduction

The need to present more valuable service for the customers and, at the same time, to cut the cost of the delivery process is the most difficult problem in supply chain management (Christopher, 1992). Companies adopting new supply chain management solutions that increase value added to the customers at a lower cost, will quickly be able to improve their competitive advantage. Today, wireless product identification – i.e. the ability to identify a product or a part automatically without physical handling – is becoming the basis for exactly such new solutions in supply chain management.

The aim of this paper is to indicate the reasons for using wireless product identification in supply chain management, and present current supply chain applications using wireless product identification.

The first section of the paper brings forth the challenges of supply chain management that are making the use of wireless product identification interesting for companies. The second section introduces the concept of item level supply chain management and the technology; namely, radio frequency identification (RFID) that enables it. In the third part, some current applications of wireless item identification are presented, and in the final section the benefits of building supply chain level applications are outlined.

Why wireless supply chain solutions?

Before moving on to discussing what this new technology is, and what are the new supply chain solutions, let us look at the challenges companies are facing today. For example, consider the need for increasing logistics service levels in the automotive industry. The challenge quickly becomes formidable when there is a need to customise both the delivery service and the product (Fuller *et al.*, 1993; Småros *et al.*, 2000). The requirements on supply chain management are very high when someone orders a car configured to his or her exact needs that then is to be delivered to the specific location chosen by the customer. The seller has to manage the car individually through production and distribution until the final delivery address is reached without delay and increase in costs. Furthermore, if the car has specific custom-made parts in the product configuration, the challenge is even bigger as

Supply Chain Management: An International Journal
Volume 7 · Number 4 · 2002 · 242–252

also component supply has to be managed on the individual item level.

When designing supply chain management solutions, the first major challenge to overcome is fast and efficient handling of differentiated material flows. In our automotive example, product customisation led to a vastly greater number of delivery addresses as customers determined the point of final delivery. Increased number of delivery addresses has in many industries led to more differentiated material flows throughout the supply chain (Rickhardson, 2000). E-commerce, be that B2B or B2C, further increases the number of delivery addresses, because the delivery is often made to the point of use of the consumer. In addition, e-commerce customers also frequently demand faster deliveries with less or no delivery charges (Jedd, 2000). The result is that all sellers have to move to shorter delivery lead times in response to the shorter delivery lead times of their competitors. Combined with the need to reduce inventory levels for greater cost efficiency, the first major challenge is thus to improve the differentiation and velocity in materials handling.

The second challenge of supply chain management that is relevant from an identification point of view is efficient customisation, i.e. the ability to effectively produce and deliver products that meet customer's individual needs. To do this, a company has to know what to do with each individual product, and operate efficiently on small batches of products or deliveries (Suomi, 1992). In the automotive example, efficient customisation was demanded at single item level, both in production and delivery of the vehicle.

The third major challenge related to product identification is to control production and logistics accurately and flexibly across multi-company networks. The problem derives from the difficulty of sharing delivery-specific information between companies. When deliveries are moved across organisational boundaries, there are severe problems in matching the received information to the physical delivery, and in synchronising material and information flows. These problems are most severe in situations where many small deliveries are processed as, for example, in car factories receiving just-in-time deliveries (Johnston and Yap, 1998).

Furthermore, the problems of information sharing increase, when logistic operations are outsourced. Arranging effective means to share information with supply chain partners is one of the biggest problems in the outsourcing of logistic operations. Whether the solution for information sharing is EDI, or a B2B hub, it always takes both time and effort to integrate information technology (IT) systems and to eliminate manual processing steps (Christianson, 2000; Turek, 1999), and still there is the problem of linking the information to the right delivery. However, outsourcing is important in supply chain operations because it increases flexibility and scalability (Gormley and Cameron, 1998). Also, third-party logistics providers can often increase the operational efficiency of the supply chain (House and Stank, 2001). For example it is rarely feasible for the companies to have a global infrastructure of their own for end customer delivery.

Both the customisation and handling problems as well as information sharing problem can be solved with wireless product identification and item level supply chain management. In item level supply chain management, products are handled and customised in batches of one across organisational boundaries in multi-company networks. Item level supply chain management is explained in more detail in the next section.

Product identification is the basis for item level supply chain management

Item level identification is the basis for item level supply chain management. Item level supply chain management is possible if every product (or part) has an identity of its own; the product can be recognised and information about it can be read or updated effortlessly in the whole supply chain. In item level supply chain management the product's information is available (and updateable) anywhere where the product is, whether it is the assembly line or the home of the end consumer. The issue is how to do this efficiently.

The most efficient applications for item level supply chain management can be built with wireless product identification. To achieve greater velocity in distribution, distribution centres have to be extremely effective in handling and sorting shipments. British Airways (Nelms, 1999) and Lynx Express (*Frontline Solutions*, 2000) have successfully used wireless identification

technology to achieve significantly faster and more accurate sorting and distribution.

The challenge of being able to produce customised products efficiently, even at item level customisation, is easier to solve when products can be identified on single product level. For example, QSC-Audio Products has built a smart convoyerised assembly system using RFID technology. This system enables the company to build to order with mass production efficiency. RFID tags are used to identify the products on the assembly line, and the configuration of a particular product to be assembled is attached to its identity (Feare, 2000).

The problems in the sharing of operational information linked to small, customised deliveries across company boundaries are solved if all the necessary information about handling a product is attached to the product and attainable in an effortless (automatically readable) way. For example, EDI messages can be stored on identifiers attached to deliveries (Johnston and Yap, 1998). Besides solving the problems of linking material and information flows together, the communication of operational information with the deliveries themselves decreases the need to integrate information systems in order to build effective processes between companies. The possibility to use identifiers to carry operational information in systems readable form enables supply chain partners to automate processes without systems integration. Therefore, it is possible also to use short-time partnerships more effectively.

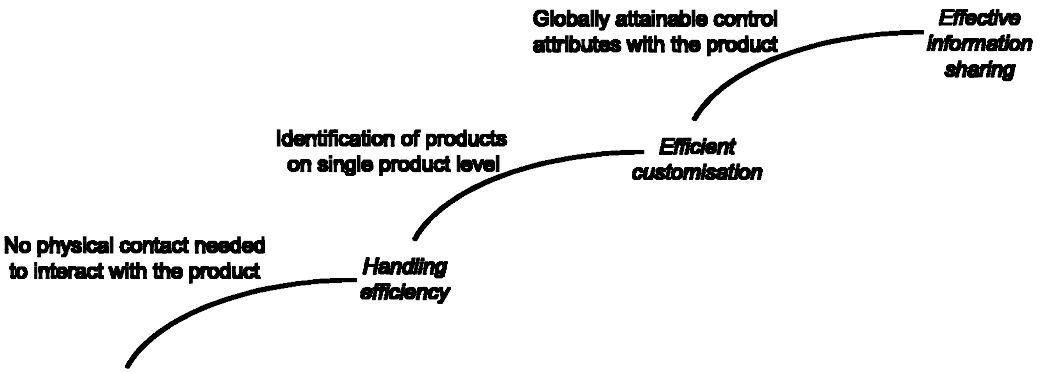
As the examples indicate, item level supply chain management is a solution to the handling, customisation, and the information-sharing challenges in supply chain management. The enabling steps to item level supply chain management are illustrated in Figure 1. Handling efficiency is the basis on which item level supply chain management is built on. It can be achieved, when products are identified without a need to physically handle them. Automatic identification in single item level enables efficient customisation. In efficient customisation, products or deliveries are efficiently processed and handled in small batches. Effective information sharing enables efficient handling and customisation even in dynamic inter-company networks. The key to effective information sharing is attaching the control attributes to the product, so that they are globally available.

Greater handling efficiency can be achieved if the need to handle the product in order to identify it is eliminated. To be able to interact with the product without physical contact, wireless product identification technologies can be applied. Most commonly used wireless identification technology is based on RFID tags. It can fulfil the requirements of item level supply chain management with acceptable costs. Products can be identified effortlessly, because RFID tags do not require line of sight in order to be read, they can be read through non-metallic materials and about 60 tags can be read simultaneously (Jones, 1999; Boxall, 2000; Lindström, 2000). The tags are also resistant to temperature and other environmental factors and can be read and written at least 300,000 times (DeJong, 1998). The read/write capability of RFID tags also enables changing the product information during processing (i.e. re-routing and price-changes). Other technologies that could be used are Bluetooth chips for expensive equipment and global positioning systems (GPS) for very large items such as containers.

To be able to practice efficient customisation, products have to be identified at single product level. Then it is possible to individually control items in all parts of the supply chain, e.g. in manufacturing and distribution, which provides the ability to offer customised products and services for the customers (Töyrylä, 1999). Using the RFID technology, the identity of the product is stored in the tag. Common RFID tags provide from 256 bits to several kilobytes of read/write memory (Gould, 2000; Philips Semiconductors, 2000; Omron, 2000), which would be more than enough to give each individual product an identity of its own.

Effective information sharing can be achieved if supply chain execution data, e.g. how the product is to be handled and where it is to be delivered, is communicated with the product in a machine-readable way. Then, the synchronisation of the information and the physical objects can be assured (Johnston and Yap, 1998). Also, paper-based processes can be eliminated without the need to integrate IT systems. This enables efficient processes also in short-term relationships. When using RFID technology, the control attributes of the item can be stored in the tag's

Figure 1 The enabling steps of item level supply chain management



memory or it can contain a reference to a network address where the information about the product is stored, so the control attributes are attainable everywhere where the product is (Ashton, 2000; Stebbins, 2000). When using the network address the product's information is also attainable at all times after once seeing the product.

What is the cost of wireless product identification technologies? Today, RFID tags are reaching a feasible cost level for an increasing number of supply chain applications. The cost per tag is between $0,25 and $1,00 depending on production volumes (Gould, 2000). The price of a reader is estimated to be approximately $1,000 (Småros, 2000).

Current supply chain applications utilising wireless product identification

Innovative companies have been able to improve their service levels and reduce costs by modifying their business processes using wireless identification technologies. The important point to notice is that the benefits are real, that wireless supply chain management solutions have already achieved noteworthy benefits in all the major stages of the supply chain, i.e. in sourcing, manufacturing, warehousing, distribution, retailing, and aftersales.

The benefits achieved by companies using RFID in their processes in different supply chain stages are summed up in Figure 2. The examples are selected to illustrate existing applications in different supply chain phases: sourcing, production, distribution, retail, and aftersales services. In sourcing and manufacturing Toyota (*Modern Materials Handling*, 1998), Ford (Maloyney, 2000) and QSC Audio Products have been able to improve performance using RFID tags. British Airways, Unilever (Burnell, 2000a), and LynxExpress have been able to streamline distribution with wireless product identification. Supertag (Hawkes, 1994; Chamberlain, 1997), Buko Ltd and Dow Chemical Co. Ltd (Chamberlain, 1997) have developed solutions to speed up retail processes. And Northern Electric Services (Jones, H., 1999) has made its asset management more effective using RFID technologies.

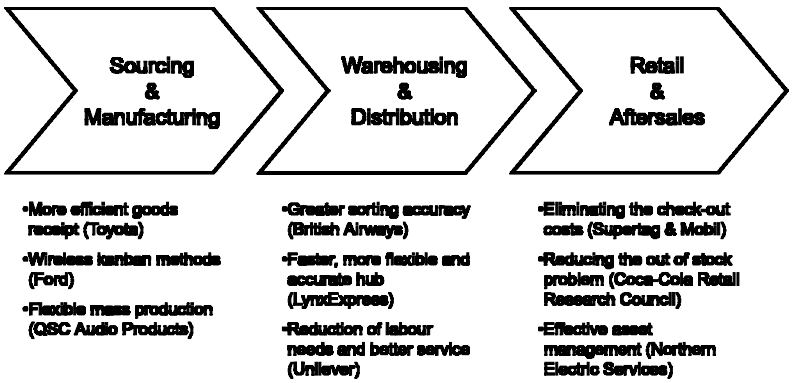
Next, we shall explore in more detail how wireless product identification has been used as the basis for new, more efficient and responsive solutions in different stages of the supply chain. Of course, the benefits achieved in the applications are not solely attributable to the use of wireless product identification. However, it plays a major role in all of the examples.

Sourcing and manufacturing

Toyota, Ford and QSC Audio Products have been able to streamline sourcing and manufacturing using RFID. Toyota has cut production delays through more efficient parts receipts, and Ford has modified its parts replenishment system between storage areas and the assembly line by developing a new wireless *kanban* method. QSC has been able to combine the benefits of mass production and make-to-order with its smart convoyerised assembly system.

In the Toyota solution parts replenishments has been made more effective by using RFID technology to make an automatic goods receipt as soon as the shipment arrives to the factory yard. The company has been able to reduce the number of costly production disruptions, and re-scheduling as incoming shipments are automatically registered in the yard management and production scheduling

Figure 2 Supply chain benefits achieved with wireless product identification



systems. Immediately upon arrival an incoming truck can be directed to the unloading dock for the material that is required on shortest notice. That is, the unloading docks are determined based on the parts requirements situation on the assembly line (*Modern Materials Handling*, 1998).

Ford has developed a new wireless *kanban* method with WhereNet, a technology provider company. The new method has made it possible to move away from a solution where parts had to be buffered on the assembly line to cover the requirements for a whole shift to a solution where it is possible to pull parts to the assembly line in real time according to actual requirements. The system brings parts to the line as needed, tracks materials in the facility, and improves labour efficiency and flexibility. The estimated savings compared to a more traditional, wired solution is $500,000 (Maloyney, 2000). The solution differs from schedule synchronisation by its robustness to the disruptions in the production process. As the production line is continuously replenished by actual consumption, then, for example, variations in lead-times do not cause complications in replenishments.

Ford is now trying to leverage its understanding of the possibilities of RFID technology and has developed a joint venture with WhereNet to market the wireless *kanban* replenishment method (Burnell, 2000b).

Our third example company, QSC Audio Products, has been able to cut manufacturing lead-time, increase throughput and move from a build-to-stock operative model to build-to-order model where the economic batch size is one unit. The company uses RFID technology to track and direct work-in-process (WIP) through the facility, which enables it to optimise the flow of WIP and redirect products during assembly if needed (Feare, 2000).

Now, let us consider the applications in the light of the enabling steps model presented in Figure 1. The fact that no physical contact is needed to interact with the products in flux – the supply chain is managed over the air, wirelessly – yields benefits in all three cases. The companies solved the issue of efficient handling of differentiated flows by creating new solutions for obtaining information from passing material flows. Toyota used RFID technology to automate goods receipt, and link this to its production scheduling system. Now Toyota knows what parts have arrived as soon as the shipment enters the plant's yard. Ford uses wireless product identification for more effective parts inventory management. When parts can be accurately located both in inventory and on the assembly line they can be more quickly replenished.

QSC went one step further. The company also solved the customisation problem by utilising the product's ability to carry its own identity. By using wireless product identification technology it has been able to attach the necessary information to the material flow itself. The assembly system receives the information about what needs to be done with a particular product directly from the product itself. The assembly system then can use the information provided by the product to control assembly work and route the product through the plant.

Warehousing and distribution

Automatic identification technologies, mostly bar codes, have long been employed in improving warehousing and distribution operations. However, the use of bar codes involves manual handling, which creates friction in the material flow. Either the

Supply Chain Management: An International Journal
Volume 7 · Number 4 · 2002 · 242–252

packages with bar codes or the reading devices are handled manually in order to read the codes (Moore, 1999; Bylinsky, 2000). Dirt and bending also reduce the read rates significantly, if they are handled in several occasions (Olliver, 1995).

A product identity that could be read over the air, yields large benefits as materials flow more reliably and expeditiously. For example, British Airways, LynxExpress, and Unilever have all been able to make their distribution processes more effective using wireless product identification. WhereNet even sees the possibility to stop allocating warehouse space in part by using wireless product identification (Johnson, 2000).

British Airways practically eliminated errors in baggage sorting with a RFID-based baggage sorting system. It is estimated that airlines could achieve savings of $6 to $12 billion with cost of $600 million to $1,2 billion, world-wide. The assumption on which the savings are based is that all airlines would move to RFID-based baggage checking. There is also a read/write memory in the tags, so bags can be redirected effectively, if passengers change their flight plans (Nelms, 1999).

LynxExpress has been able to build what the company calls a "super-hub" using RIFD technology. The "super-hub" is 70 percent faster than a conventional hub, significantly more flexible, and virtually error free. All the shipments are equipped with RFID tags, and identified automatically as they enter the hub. They are also scanned when they enter the loading dock, and the system sends an alarm if the shipments include parcels that are on a wrong routing.

LynxExpress's RFID-based system cost £40,000 more than a bar code-based system, but the pay-back time for the additional investment was only two months, thanks to the benefits of greater efficiency (*Frontline Solutions*, 2000). Unilever achieved similar benefits in a warehouse in Italy as it reduced labour needs by two-thirds and improved order fulfilment time by 20 percent (Burnell, 2000a).

Wireless product identification has the potential to radically change warehousing, because products can be stored almost anywhere, moved as needed and found in a moment's notice. WhereNet estimates that the possibility to change the way in which warehouse space is allocated can save between 10 to 20 percent of warehouse space (Johnson, 2000).

The benefits of wireless product identification in warehousing and distribution come mostly from reduced handling, using systems in which the transactions made to the products are automatically recorded. This results in a more effective and more friction-free flow, where the handling of the product and information collection is the one and the same activity. In distribution, the ability to give the item a unique identity also makes it possible to develop new and more efficient solutions to re-direct and sort shipments on the move.

Retail and aftersales

In retailing, wireless product identification enables automatic goods receipt, faster inventory counts from shelves and major reductions in checkout costs. For aftersales, wireless product identification technologies also make new customer service models possible. Especially in the business-to-business situation, new solutions based on wireless product identification can create notable aftersales benefits to the customer.

In a typical supermarket out-of-stock situations cause a 3 percent loss of revenue through lost sales. According to a study conducted by Andersen Consulting, 53 percent of out-of-stock situations are based on inefficiencies in the store ordering process. Another 8 percent of out-of-stock situations happen while the necessary supplies are in backdoor inventory but have not been shelved (*Supermarket Business*, 1996).

A solution to the problem is to take the task of ordering away from the store, i.e. replenish by consumption. A goods receipt system that automatically and accurately adds incoming material to inventory book-keeping combined with point of sales (POS) demand information, enables new, possibly order-less, replenishment solutions between distribution centres and supermarkets. This would reduce out-of-stock situations greatly. For an automatic goods receipt the identification of products would not have to be item level, transport package or pallet level identification would already be sufficient.

There are problems with POS-based replenishment systems. The errors in stock readings accumulate and the supplier never knows how much there is actually in the stock until an inventory count of the shelves is

Supply Chain Management: An International Journal
Volume 7 · Number 4 · 2002 · 242–252

performed. In order to develop a robust vendor managed inventory (VMI) solution, the supplier would have to know the inventory of the customer. If products could be identified automatically at item level, inventory counts (counts from shelves) could be done quickly when needed, and used instead of orders. The inventory count could be done, for example, with readers that are built into the shelves. This would even enable the supplier to perform the inventory count independently of the retailer. Another effective way of performing the shelf counts would be with hand-held readers (Milner, 1999; Bushnell, 2000).

Today, checkout costs are approximately 3 percent of retail revenue in supermarkets in Finland (Kämäräinen, 2000), and the level of costs is quite similar in other industrialised countries (Hennessy, 2000). To reduce these costs the companies Supertag, Buko, and Dow Chemicals have developed technologies with which grocery shopping can be checked out without the need for checkout personnel (Hawkes, 1994; Chamberlain, 1997). This way it would be possible to eliminate the labour-intensive and time-consuming activity of bar code scanning at the checkout. If supermarkets utilised electronic payment methods such as those piloted, for example, by Mobil in the USA, customers could check themselves out and the whole of checkout work could be eliminated (*Chain Store Age*, 1999a; Reid, 2000).

In e-grocery retailing, wireless product identification opens up new possible value offerings to customers, in addition to easier order assembly and more reliable deliveries. If products can be identified without handling in the customer's home, the supplier could manage customer's food supplies without orders from the customer. In other words, VMI could be implemented with the end consumer of groceries (Småros and Holmström, 2000). Companies, such as Matsushita and Electrolux, are already developing refrigerators that provide data-capture possibilities to implement VMI to the end consumer (Butler, 1999).

The development of new aftersales services using wireless product identification can yield substantial new benefits to the customer. Wireless product identification can e.g. improve asset management and assist maintenance technicians.

Virgin Islands' Government and Northern Electric Services Ltd have achieved cost savings and enhanced efficiency in management of their electronic assets (Security, 1999b; Jones, H., 1999). Assets that are managed are tagged with RFID tags. Information about original manufacturing lot, performed inspections, and maintenance operations, as well as all special information related to their usage, are also programmed to the tag. Tags are read and written by field workers using hand-held readers (Jones, H., 1999). Gartner Group estimated in its study that sound asset management would yield savings of 11 to 26 percent of IT budgets (Jacobs, 2000).

How could RFID technology be used as the basis for new aftersales solutions? For example, after the product is sold, all that is needed to build a portable maintenance database is to attach an RFID tag that then is updated with each service transaction. When the customer delivers the product for a repair, the tag is read and the information of the customer's identity, previously conducted repairs, what preventive maintenance needs to be done, and whom to bill, is achieved directly from the tag (Gould, 2000).

To sum up, the biggest benefits in retailing come from the ability to identify products without needing to manually handle them. This enables more efficient processes as visibility to the products in the shelves and in the backroom is achieved. For example, automatic goods receipt and better shelf management makes a truly robust VMI solution feasible. Similarly, the ability to make an inventory count in the households of e-grocery customers also makes totally new service models possible.

New aftersales services can be developed using the possibility to identify products at the individual product level, and the wireless read- and write-capabilities of tags. Globally attainable control attributes can also be used to support customer companies in managing their assets. For example, with mobile assets such as a fleet of trucks or aeroplanes, outsourcing and partnering is facilitated by assets carrying their own electronic identity and links to maintenance records. This is especially valuable in situations where aftersales service providers vary in different locations or in conditions where it is difficult to reach centralised databases (Jones, H., 1999).

Total benefits of wireless supply chain management

The three major challenges posed to supply chain management today is developing new solutions for a more efficient handling of lean material flows, efficient customisation of products and logistic services and information sharing across company limits. The drivers behind these requirements are more sophisticated customer demand chains, and electronic business.

Wireless supply chain management is an answer to these challenges. By attaching a remotely readable tag to each product, the product can be given an item level identity. Interacting with the product while on the move without a need for any handling or holding becomes possible, and the attributes of the product can be made globally attainable over the Web.

The applications using wireless product identification technologies have, like the examples presented in this paper, until now been mostly at the individual company level. However, making item level supply chain management solutions work across company limits greater benefits could be achieved (Stone and Hollier, 2000). Estimates for tens of billions of dollars of cost savings in supply chains have been presented for the widespread adoption of e-packaging using RFID (Burnell, 2000a).

Why are these savings to be realised only with the widespread adoption? When developing applications spanning through several supply chain phases the identifiers can be utilised time and again, widespread use develops visibility to the supply chain, decentralised control can be utilised in the supply chain, and new kind of customer services or applications can be developed (David, 2000; Finkenzeller, 1999; Töyrylä, 1999). Figure 3 summarises the reasons for why the big benefits are only realised when solutions are developed across the chain. We will now present these reasons in more detail.

First, if the use of wireless product identification span through the whole supply chain, functional benefits from new applications in manufacturing, sourcing, warehousing, distribution, retailing, and aftersales can be realised with an investment in one single technology. For example, in the automotive supply chain, component manufacturers that tag their parts could develop new solutions to replenish based on the material situation at the assembly line. The assembly plant could use the same tags, but focus on streamlining handling to reduce disruptions inside the plant. In distribution, the very same tags could be used to route accessories to rendezvous with the car in-transit, and after the delivery to the customer, the tags are a fool-proof way for aftersales service providers to identify what parts are replaced and when. Reebok already utilises single identifiers throughout the whole supply chain for cost savings and information coherence (van Hoek, 2001).

Second, moving the focus from functional to supply chain solutions would finally provide visibility to the supply chain and so increase control of the chain. This would enable the much talked about "replacement of inventory with information" (see e.g. Magretta, 1998). Supply chain visibility improves as automatic identification of the material flow provides information of the material flow in different parts of the supply chain (David, 2000).

Sainsbury is an example of a company that has, with the collaboration of some of its suppliers, moved through three different supply chain stages (from producers through distribution centre to stores) in the development of its new applications of

Figure 3 Supply chain benefits achieved with wireless product identification across the supply chain

- Single investment yields benefits in all supply chain phases
- Increased control of the supply chain through better visibility
- Possibility to restructure information infrastructure (communicate execution process data with the product)
- Value innovations based on product identity

Supply Chain Management: An International Journal
Volume 7 · Number 4 · 2002 · 242–252

wireless product identification. In the Sainsbury application, all shipments of perishable products are RFID tagged as they leave their supplier's inventory, and their route via a distribution centre to the stores is tracked. The results have been a radically improved control of the perishables supply chain, and the ability to eliminate the spoilage problem in addition to increased handling efficiency (Burnell, 2000a; Boxall, 2000; Philips Semiconductors, 2000).

Third, there is a possibility to restructure information systems infrastructure with wireless product identification. Today retailers, distributors, and vendors all struggle in creating a centralised database hub around which everyone else is to build their own solutions. The basis for this struggle vanishes, if we use a decentralised approach. Then, necessary control data for execution processes are linked to the physical product (Finkenzeller, 1999). The result is that this would make supply chains less dependent on central data warehouses, and it would also enable faster implementation of efficient processes as the need to integrate information systems decreases.

Finally, taking a cross-company perspective is essential for using wireless product identification as the basis for value innovations (Kim and Mauborgne, 1999). On a single supply chain stage, wireless product identification technologies in supply chain management sounds like normal improvements in supply chain effectiveness provided by new technology. But moving the focus to the customer, or the customer's customer helps us understand how wireless product identification can start to challenge the fundamentals of both supply chain management, customer service and process control (Töyrylä, 1999). For example, is it the supplier or the customer that is responsible for the customer's inventory? If it is the supplier's responsibility, how does the customer know his or her inventory – from his or her own ERP system or the supplier's? And, how is then shelf space in the warehouse and retail outlets allocated? How do you know which parts belong to a product, or what items to a retail category?

Over the product life-cycle, where will the supplier's responsibility end? And, what will a waste disposal site look like in the future, as recycling is greatly enhanced? If the information of the materials the products contain, and instructions of how to disassemble and handle them is attached to the products in machine-readable form, then they can be effectively sorted and recycled.

Conclusions

In this paper, we have presented the challenges of supply chain management that make the use of wireless product identification valuable for companies. We presented the concept of item level supply chain management and reviewed current supply chain applications of wireless product identification.

Great benefits have been achieved with wireless product identification, but solutions that span through several companies in the supply chain are still rare. As the paper has attempted to show, there are clear benefits in wider solutions. What then are the reasons for their lack?

One significant reason for the lack of comprehensive solutions that span through the whole supply chain has been the lack of a global standard for RFID-based supply chain solutions. At the moment there are numerous proposals for standards waiting to be ratified (Burnell, 2000c; *Frontline Solutions*, 2000). Also, Savi Technology has developed a Web-based reading device that is able to understand all RFID tags in the market (Gould, 2000). Another drawback of RFID technology is that, though tens of RFID tags can be read at the same time, only one tag at a time can be written to, and when reading multiple tags one cannot know which tag is being read (Ackley, 2000). So, in order to treat tags individually they have to be lined up individually.

Another reason is the need for investments in the infrastructure supporting the new, wireless operating model. There can easily be disagreements about the sharing of investments in the technology and the benefits obtained. This is, as always, a difficult issue to resolve for investments where other companies benefit as much as, or more, than the company making the investment. However, current service providers such as Savi and Chep, are already making the initial investments, and companies using these services pay to the service providers for the benefits enjoyed (Dierkx, 2000; Kleijn, 2000). The emergence of comprehensive service providers could make this challenge of shared investments considerably easier to solve.

Supply Chain Management: An International Journal
Volume 7 · Number 4 · 2002 · 242–252

The technology to carry out item level supply chain management is available on the market. Current applications and the evolution of technology have reduced the price of wireless product identification technologies to an affordable level. Now, the challenge is to build up supply chain-wide solutions and new service models using the technology.

References

Ackley, S. (2000), "93i, RFID and bar code synergy", *Tag 2000*, Baltic Conventions, The Commonwealth Conference and Events Centre, London, 24 May.

Ashton, K. (2000), "Internet things – MIT, embedded technology and the next Internet revolution", *Tag 2000*, Baltic Conventions, The Commonwealth Conference and Events Centre, London, 25 May.

Boxall, G. (2000), "The use of RFID for retail supply chain logistics", *Tag 2000*, Baltic Conventions, The Commonwealth Conference and Events Centre, London, 24 May.

Burnell, J. (2000a), "The jury's out in the case for RFID in logistics", *Frontline Solutions*, Vol. 1 No. 6, pp. 18-27.

Burnell, J. (2000b), "Users parlay RFID system success into new business ventures", *Frontline Solutions*, Vol. 1 No. 5 pp. 1, 44.

Burnell, J. (2000c), "Big air! Three more RFID standards proposed", *Frontline Solutions*, Vol. 1 No. 8, p. 50.

Bushnell, R. (2000), "RFID's wide range of possibilities", *Modern Materials Handling*, Vol. 55 No. 1, p. 37.

Butler, S. (1999), "Smart toilets and wired refrigerators", *US News & World Report*, Vol. 126 No. 22, p. 48.

Bylinsky G. (2000), "Hot new technologies for American factories'', *Fortune*, 26 June.

Chain Store Age (1999), "C-store advance technology in the fast lane", *Chain Store Age*, Vol. 75 No. 6, pp. 12A-13A.

Chamberlain, G. (1997), "Shopping becomes a 'smart' experience", available at: www.manufacturing.net/magazine/dn/archieves/1997/dn0922.97/18f151.htm (accessed 27 October 2000).

Christianson, R. (2000), "After the merger: negotiating IT integration", *Public Utilities Fortnightly*, Vol. 138, July, special issue, pp. 44-55.

Christopher, M. (1992), *Logistics and Supply Chain Management*, Pitman Publishing, London.

David, P.A. (2000), "Understanding digital technology's evolution and the path of measured productivity growth: present and future in the mirror of the past", Brynjolfsson, E. and Kahin, B. (Eds), *Understanding the Digital Economy*, The MIT Press, Cambridge, MA, pp. 49-95.

DeJong, C.A. (1998), "Material handling tunes in", *Automotive Manufacturing & Production*, Vol. 110 No. 7, pp. 66-9.

Dierkx, K. (2000), "Taking supply chain visibility to the next level: powering the smart supply chain", Council of Logistics Management Annual Conference, presentation slides, Council of Logistics Management, New Orleans, 26 September.

Feare, T. (2000), "Pump up the volume", *Modern Materials Handling*, Vol. 55 No. 3, pp. 55-9.

Finkenzeller, K. (1999), *RFID Handbook*, John Wiley & Sons, Chichester, pp. 267-9.

Frontline Solutions (2000), "Money well spent", *Frontline Solutions*, Vol. 1 No. 6, pp. 30-1, 59.

Fuller, J.B., O'Conor, J. and Rawlinson, R. (1993), "Tailored logistics: the next advantage", *Harvard Business Review*, Vol. 71 No. 3, pp. 87-98.

Gormley, T. and Cameron, B. (1998), "Extend for collaboration'', *Manufacturing systems*, Vol. 16 No. 7, p. 20.

Gould, L.S. (2000), "What you need to know about RFID", *Automotive Manufacturing & Production*, Vol. 112 No. 2, pp. 46-9.

Hawkes, P. (1994), "Supertag – stock counting off its trolley", *Sensor Review*, Vol. 14 No. 3, pp. 23-6.

Hennessy, T. (2000), "The front-end frontier", *Progressive Grocer*, Vol. 79 No. 4, pp. 93-101.

House, R., Stank, T. (2001), "Insights from a logistics partnership", *Supply Chain Management: An international Journal*, Vol. 6 No. 1, pp. 16-20.

Jacobs, B. (2000), "At last, IT departments can directly track assets to reduce their costs", *Frontline Solutions Online RFID Source Book*, available at: www.frontlinemagazine.com/rfidonline/ (accessed 31 July).

Jedd, M. (2000), "Fulfilment: a crucial e-business challenge", *Logistics Management and Distribution Report*, April, pp. E25-E26.

Johnson, J.R. (2000), "RFID gets the green light", *Warehousing Management*, Vol. 7 No. 4, pp. 28-9.

Johnston, R.B. and Yap, A.K.C. (1998), "Two-dimensional bar code as a medium for electronic data interchange'', *International Journal of Electronic Commerce*, Vol. 3 No. 1, pp. 86-101.

Jones, H. (1999), "Asset management easier with RFID", *Automatic ID News*, Vol. 15 No. 9, p. 52.

Jones, L. (1999), "Working without wires", *Industrial Distribution*, Vol. 88 No. 8, pp. M6-M9.

Kim, W.C. and Mauborgne, R. (1999), "Strategy, value innovation and the knowledge economy", *Sloan Management Review*, Vol. 40 No. 3, pp. 41-54.

Kleijn, F. (2000), telephone interview with Floris Kleijn from CHEP, 6 October.

Kämäräinen, V. (2000), *Internet muuttaa jakelurakenteita – Elektronisen päivittäistavarakaupan liiketoimintamallit ja loppujakelupaikan valinta*, Pro Gradu, Helsinki School of Economics and Business Administration, Helsinki.

Lindström, T. (Rafsec Oy) (2000), personal contact, 17 July.

Logistics Management and Distribution Report (2000), "RFID makers submit standards plan to ISO", *Logistics Management and Distribution Report*, Vol. 39 No. 5, p. 81.

Magretta, J. (1998), "The power of virtual integration: an interview with Dell Computer's Michael Dell", *Harvard Business Review*, Vol. 76 No. 2, pp. 72-84.

Maloyney, D. (2000), "The newest better idea at Ford", *Modern Materials Handling*, Vol. 55 No. 7, pp. 34-9.

Milner, C. (1999), "How radio tags benefit the retailer and the shopper", available at: www.frontlinemagazine.com/rfidonline/ (accessed 3 June).

Modern Materials Handling (1998), "How RFID tags speed parts delivery to assembly lines", *Modern Materials Handling*, Vol. 53 No. 5, p. A11.

Moore, B. (1999), "Bar code or RFID: which will win the high speed sortation race?", *Automatic ID News*, Vol. 15 No. 7, pp. 29-30, 34, 36.

Nelms, D.W. (1999), "Move forward on RFID", *Air Transport World*, Vol. 2 No. 3, p. 2.

Olliver, M. (1995), "RFID enhances materials handling", *Sensor Review*, Vol. 15 No. 1, pp. 36-9.

Omron (2000), available at: http://www.omron.fi/ accessed 4 November.

Philips Semiconductors (2000), available at: www.semiconductors.com/news/content/file_579.html (accessed 25 July).

Reid, K. (2000), "Pass and pay technology", *NPN, National Petroleum News*, Vol. 92 No. 2, pp. 32, 34, 36, 38.

Rickhardson H.L. (2000) "Packaging for today's demanding fulfilment", *Transportation & Distribution*, Vol. 41 No. 7, pp. 72-5.

Security (1999), "RFID asset management system to US Virgin Islands", *Security*, Vol. 39 No. 10, p. 65.

Småros, J. (2000), Personal contact (TAI-Research Centre), 10 July.

Småros, J. and Holmström, J. (2000), "Reaching the consumer through e-grocery VMI", *International Journal of Retail & Distribution Management*, Vol. 28 No 2, pp. 55-61.

Småros, J, Holmström, J. and Kämäräinen, J. (2000), 'New service opportunities in the e-grocery business'', *International Journal of Logistics Management*, Vol. 11 No. 1, pp. 61-73.

Stebbins, J. (2000), "Motorola to use barcode scanner to net connect", *The Australian IT*, 20 June, p. 47.

Stone, T. and Hollier, R. (2000), "Electronic data capture and operational performance monitoring: a supply chain perspective", *International Journal of Logistics: Research and Applications*, Vol. 3 No. 3, pp. 213-26.

Suomi, S. (1992), *Automatic identification*, VTT Offsetpaino, Espoo (in Finnish).

Supermarket Business (1996), "Out-of-Sto_ks ... the details", *Supermarket Business*, Vol. 51 No. 5, pp. 33, 35, 37, 39, 41.

Töyrylä, I. (1999), *Realising the Potential of Traceability – A Case Study Research on Usage and Impacts of Product Traceability*, Finnish Academy of Technology, Espoo.

Turek, N. (1999), "Cargill: on top of app integration", *InformationWeek*, 21 June, No. 739, pp. 110-12.

van Hoek, R. (2001), "E-supply chains – virtually non-existing'', *Supply Chain Management: An International Journal*, Vol. 6 No. 1, pp. 21-4.