The impact of Auto-ID on logistics performance

A benchmarking survey of Swedish manufacturing industries

Ola Johansson and Henrik Pålsson
Packaging Logistics, Lund University, Lund, Sweden

Abstract

Purpose – The purpose of this paper is to examine how logistics performance is affected by the use of different identification technologies and practices for utilising the tracking data.

Design/methodology/approach – The paper uses the survey method. The survey instrument is developed in co-operation with an expert group consisting of both researchers and industry representatives. The data are analysed using multivariate techniques and hypothesis testing.

Findings – This paper indicates better logistics performance for companies using radio frequency identification (RFID) technology, while no significant differences can be seen for companies using Auto-ID in general. In terms of registration, best-in-class firms have more identification points along their supply chains compared to other firms. Best-in-class firms also seem to have more extensive sharing of tracking data with supply chain partners, both upstream and downstream, and in terms of frequency and scope, which contributes to superior logistical performance.

Research limitations/implications – To provide a more robust scientific justification of the survey results, in-depth case studies should be carried out. Further studies are needed to verify the links between RFID and logistics performance.

Practical implications – The findings may enable managers to estimate the potential of using identification technologies and learn of practices which may enable their organisations to improve logistics performance.

Originality/value – This paper presents empirical links between different identification technologies, attributes of the tracking system, use and sharing of tracking data and logistical improvements.

Keywords Benchmarking, Industrial performance, Information management, Logistics, Supply chain management, Sweden

Paper type Research paper

1. Introduction

Since its appearance in the 1980s, benchmarking has been a popular management concept and its value as a practical tool for developing critical areas of a business is indisputable (Anand and Kodali, 2008). Benchmarking is, however, a wide concept comprising many different perceptions of what the term really means (Alstete, 2008). A frequently quoted definition is that "benchmarking is the search for industry best practices that will lead to superior performance" (Camp, 1989), but several alternative definitions exist. Most definitions, however, share some common themes including measurements, comparison, identification of best practices, implementation

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and improvement. According to Maire *et al.* (2005), the many definitions can be seen as an expression of the evolution of benchmarking. Earlier stages of benchmarking were often focused on operational processes or activities, while later ones put more emphasise on strategic issues. Yasin (2002) also points out that the future direction of benchmarking must include more of a systems perspective to be able to handle practices such as supply chain management. More up-to-date research supports that supply chain benchmarking is more than a comparative analysis of historic data. Rather, supply chain benchmarking should focus on identifying and implementing best practices and must encompass a detailed understanding of the information that needs to be shared within a supply chain (Manning *et al.*, 2008). Although much literature on supply chain benchmarking exists, a recent review by Wong and Wong (2008) reveals that empirical studies of supply chain benchmarking are still scarce, and that past literature fails to address collaboration and integration aspects.

2. Literature review

This gap in literature needs further research, because the success of a firm is largely dependent on achieving effective co-ordination and collaboration along its supply chain. A fundamental element of both co-ordination and collaboration is timely and accurate information (Wilding and Humphries, 2006; Zhao *et al.*, 2002). Radio frequency identification (RFID) is increasingly being presented as a technology which has the potential to improve supply chain performance by improving supply chain visibility and increasing information exchange among supply chain partners. RFID technology "promises to offer both process freedoms and near-perfect information visibility throughout the supply chain" (Angeles, 2005, p. 64), "the value proposition will make RFID a must for firms to remain competitive" (Twist, 2005, p. 238) and "the future of RFID technology will hold exciting opportunities for almost every business" (Attaran, 2007, p. 255).

The core of RFID technology is making identification and data capture more efficient, and it offers some unique benefits over other types of identification technologies. Other automatic identification (Auto-ID) technologies (e.g. bar codes) and "human-readable" labels are, however, far more common in industry today and despite the promises of RFID technology, firms seem reluctant to adopt RFID technology at the pace first predicted (Dutta *et al.*, 2007). Some reports even indicate that adoption pace of RFID technology has stalled significantly in the last year (Computer Economics, 2007). This makes benchmarking of different identification technologies for tracking goods apt for several reasons. Not only are there more and more technologies to choose between, but there is a scarcity of knowledge about how to use them and what benefits they may bring. The purpose of this paper is to gain insight into the use of different identification technologies and practices which can enable organisations to utilise collected tracking data to improve logistics performance.

2.1 Measuring logistics performance

Logistics performance could be measured in a number of different ways, for instance, process reliability, frequency of delivery, service cost and delivery flexibility. Depending on what is to be measured, there are numerous individual performance measures, see for example, Gunasekaran *et al.* (2004), for a framework of supply chain performance measurements. However, by summarising the essence of these individual measures, condensed groups can be created. Neely *et al.* (1995) have categorised logistics service performance in four dimensions; quality, time, cost and flexibility. Even though the dimensions are linked to logistics service, they should be applicable to logistics performance in general. Performance measures relating to quality may be defined as conformance to specification. Performance measures relating to time include measures such as manufacturing lead time, delivery lead time, due-date performance and frequency of delivery. Cost measures are related to costs of fulfilling tasks and activities. Performance measures relating to flexibility address the ability of logistics operations to change or respond to different circumstances.

These four condensed dimensions indicate the multifaceted nature of logistics performance, i.e. many different aspects in the order-to-delivery process need to be considered for logistics service performance to be determined. To obtain sufficient logistics performance levels, this process, which includes purchasing, material and delivery planning, order processing, manufacturing, inventory and transport management, packaging and customer management, needs to be effective and efficient. The key lies thus in having control of the material flow in the order-to-delivery process so that managers need to keep track of goods, i.e. capture and manage information related to the location of products or goods. Improved control of the material flow helps streamline the order-to-delivery process, providing companies with a competitive advantage. It helps companies serve customers more rapidly, at a lower cost. However, to reach supply chain excellence in this area, companies need to develop their capability to track goods efficiently.

2.2 Tracking systems

A tracking system is a prerequisite for control of the material flow. However, the capabilities of tracking systems vary. It "[...] may record only the identity of the tracked item, the location of the checkpoint, the arrival time of the item, or combine these pieces of information with additional attributes" (Kärkkäinen *et al.*, 2004, p. 548). The benefits related to these pieces of information are twofold. First, the tracking system is the link between the information systems and the material flow. Second, it offers administrative benefits by reducing paper-based systems, leading to improved information accuracy and reduced waste. Identification of items in a tracking system is either conducted through human data entry or automatically by an Auto-ID technology, such as bar codes or RFID technology.

When setting up a tracking system a number of attributes should be considered. To analyse tracking and tracing systems, Stefansson and Tilanus (2001, p. 205) propose eight attributes:

(1) *Goods identification technology*. E.g. human-readable text, bar codes, RFID technology or a broadcasting system.

(2) *Scope of tracking and tracing systems*. Defined by three dimensions: transport, i.e. transformation of place; storage, i.e. transformation of time; conversion processes, i.e. transformation of form.

(3) *Registration timing and placing*. Only rarely is an entity continuously tracked on its way from A to B.

(4) *Hierarchical level*. Each discrete registration may refer to different hierarchical packaging levels.

(5) *Attributes recorded*. Three attributes may be recorded; the identity of the entity, its location and the point in time when the information was recorded.
(6) *Organisation*. The information system in which the tracking and tracing data are stored may be centralised or shared by multiple participants.
(7) *Accessibility*. Interested parties should be able to follow and find entities travelling from A to B.
(8) *Activity level*. Passive, i.e. entities are registered in fixed places at the moment they arrive or leave, or active, i.e. the progress of an entity is monitored from checkpoint to checkpoint and if something unexpected is registered, it is signalled.

The focus of this paper is not to analyse the tracking system as such, but rather some of its features to improve logistics performance by providing tracking data. Therefore, some tracking system attributes are not evaluated, but their effects are included in our evaluations. Among the eight attributes it may be noted that a key feature of an entity in a tracking system is to be uniquely identifiable. In the current paper, this characteristic is provided through the use of three goods identification technologies, i.e. bar codes, RFID technology and labels with alphanumeric characters requiring human inspection. In the subsequent sections of this paper, labels with alphanumeric characters are termed text labels.

3. Research hypotheses

Based on the literature review, we will define and test hypotheses concerning how different types of goods identification technologies, properties of the tracking system and practices for using and sharing tracking data, all affect logistics performance.

3.1 The impact of Auto-ID

Because of automatic data collection, the quality of the information generated by Auto-ID is usually higher than information from other types of labelling, which uses manual data collection. The error rate for human data entry has been reported to be 1 in 300, while the corresponding level for automatic data collection is radically lower (Smith and Offodile, 2002). Another benefit of automatic data collection is that it may reduce time for data entry (Singer, 1998). Thus, it may speed up the time between data capture and data availability in IT systems, thereby leading to rapid analyses and fast responses to the then-current situation of material flows. The benefits reported for different Auto-ID technologies, i.e. efficient data capture with high accuracy, lead us to hypothesise the following:

H1a. Auto-ID labelled goods have significant positive influence on logistics performance compared to other types of labelling.

Among the different Auto-ID technologies, bar codes are the most frequently used. RFID-technology, however, is rapidly growing and offers some unique advantages over bar codes. For instance, it does not require line of sight, reading distance can be longer, reading is faster and RFID can have both read and write capabilities. The additional benefits of RFID over bar codes have been reported in literature as saving labour costs compared to the manual scanning of bar codes, and reducing inventory, shrinkage and out-of-stock situations through the higher visibility offered by RFID (Lee and Özer, 2007). Based on this, the following hypothesis is developed:

H1b. RFID-labelled goods have significant positive influence on logistics performance compared to other types of labelling.

In a supply chain, movement of goods is constantly taking place. Good decision-making relies on having accurate, timely and reliable information on the whereabouts and condition of items. A prerequisite for this is that the logistics system receives timely updates when different events occur. The closer the system can track the actual events, the better the information quality and decision-making, which should ultimately improve the logistics performance. Thus, the following hypothesis is proposed:

H2. The number of identification points along the supply chain has significant positive influence on logistics performance.

3.2 The impact of information sharing

Efficient logistics rely on having up-to-date information about goods in transit, inventory positions, etc. Such tracking data are captured by Auto-ID technologies or text labels. However, a focal company's logistics performance is highly dependent on access to tracking data captured by its supply chain partners as well. Therefore, information sharing with supply chain partners could be essential for improving logistics performance. Previous research has confirmed that there is a link between information sharing and logistics performance (Closs and Savitskie, 2003; Rodrigues *et al.*, 2004). Kim *et al.* (2006, p. 52) conclude that "high-quality information exchange not only helps co-ordinate with channel partners but also improves responsiveness of the partnership and market performance". It is implied that the information is up to date, which could enable companies to dynamically adjust production, distribution and marketing decisions to the situation at a specified point in time. With dated information, companies run the risk of adjusting to an invalid situation. Thus, it would be reasonable if the frequency of information sharing regarding tracking data affects logistics performance. We therefore hypothesise that:

H3a. The frequency of information sharing of tracking data has a significant positive influence on logistics performance.

Furthermore, the scope of information shared varies. Lee and Whang (2000) discuss how and why information regarding inventory status, sales data, demand forecasts, order status, production schedule and delivery status is shared. However, even though the scope of potential information sharing is quite extensive, companies seem to be somewhat restrictive with information sharing. In a survey, Bagchi *et al.* (2005) found that:

> [. . .] it was clear that although the respondent firms have begun to share some information with supply chain partners, they are quite selective as to how and to what extent information should be available to supply chain partners and who should receive them (p. 287).

This approach may be questioned as the subset of outward-facing manufacturers (i.e. highly integrated with both suppliers and customers) outperforms the other manufacturers in terms of largest rates of performance improvements (Frohlich and

Westbrook, 2001) and that best-practice firms focus on both internal and external information sharing (Stank *et al.*, 2001). Based on these arguments, it would be logical to assume that scope and extent of sharing tracking data might affect logistics performance. Regarding tracking data, we thus hypothesise the following:

H3b. The scope of information sharing has a significant positive influence on logistics performance.

H3c. The number of customers involved in information sharing has a significant positive influence on logistics performance.

H3d. The number of suppliers involved in information sharing has a significant positive influence on logistics performance.

4. Research method

In order to ensure an overall view of the usage of identification technologies and tracking data, a postal survey of Swedish manufacturing firms was conducted across a wide range of industries.

4.1 Instrument

The survey instrument was developed in four stages. In the first stage, focus areas for the survey were identified through literature reviews. Both the capability of being able to track goods along a supply chain and interorganisational information sharing can be seen as signs of supply chain integration. Therefore, literature regarding supply chain integration helped us identify a number of logistics improvements areas when tracking systems are used. Based on the perception that current literature on RFID technology presents many potential benefits of having unique identities on goods, this literature was also reviewed. It provided some additional focus areas. In the second stage, a draft questionnaire with 14 question areas was developed. To gain feedback about the structure and clarity of the questionnaire, it was pre-tested on a group of academics. Based on the feedback, the questionnaire was modified; a number of questions were rephrased, added or deleted. The revised questionnaire was then tested on a group of representatives from industry. This also resulted in further modifications; the survey was reorganised, a few questions were deleted and some questions were rephrased. The final version of the survey instrument included 14 question areas with three to 19 questions per area. The initial questions considered type and registration location of unique identities on a nominal scale. The other questions were based on a five-point Likert scale covering demographic data, information sharing, improvements and visions obtained through unique identities. The response alternatives ranged from strongly disagree to strongly agree, with a neutral alternative in the middle.

4.2 Respondents

The survey was directed at logistics managers in manufacturing companies in Sweden. Several industries were selected to obtain a broad overview of the use of unique identities across different businesses, and manufacturing firms were selected because these were expected to have both complex internal and external material flows. To limit the study, small companies with fewer than 100 employees were not considered. The total population includes 715 companies in nine different manufacturing industries with one hundred or more employees. The sample size and distributions between different groups of company size and industries were discussed with a statistical expert. This led to the conclusion that company size and type of industry could affect survey results. Therefore, a stratified sample was used to avoid disequilibrium among the groups. The companies were divided into three groups according to size; small, medium-sized and large companies (Table I). All large companies, i.e. those with 500 or more employees, were included in the sample. Then, 40 per cent of the medium-sized companies with 200-499 employees were systematically selected and every one small company in four, i.e. with 100-199 employees, was systematically selected to be included in the sample. Thereby, a systematic, stratified sample with approximately equal group sizes was obtained. In total, 310 firms were selected, which equals a sample size of 43 per cent of the total population (manufacturing industries).

4.3 Data collection

The data collection took place in February and March 2008. The logistics managers of the selected firms were posted questionnaires accompanied by an explanatory covering letter and a pre-paid postage return envelope. The covering letter explained the research, asked for the respondents' help in completing the survey and promised a prompt copy of the results of the study to encourage participation (Frohlich, 2002). A unique code was attached to each questionnaire to facilitate follow-up. The use of the code was explained to the respondents and the covering letter emphasised the respondents' confidentiality. Reminder letters including the same package were sent out to non-respondents two weeks after the first questionnaire was posted. Follow-up telephone calls, conducted one week after the reminder mail, were conducted to obtain additional responses. The 152 responses received represent an overall response rate of 49.0 per cent. Of the responses, all but one could be used for subsequent data processing. Table I provides frequency distribution of number of employees and industry. A majority of the non-respondents were reached by phone during the follow-up calls. The reason cited most often for non-response was lack of time, followed by company policy. To check for non-response bias, early responses from the first group of questionnaires sent by post were compared to late responses obtained after follow-up calls. No statistically significant differences were found, which indicates the absence of non-response bias (Armstrong and Overton, 1977).

5. Results

5.1 Descriptive statistics

The survey shows that approximately 95 out of 152 responding companies are able to uniquely identify packages or load carriers through the use of tracking labels. The remainder of this paper, unless otherwise stated, is based on data from the group, which uses unique identities to track the whereabouts of products and goods in their supply chains. The most frequently used Auto-ID technology for assigning unique identities to products or goods is bar codes (84 per cent of the respondents). Seven respondents (7 per cent) stated that they use RFID tags. However, another 23 per cent of all the respondents (from the total sample of 152 respondents) state that they consider implementing RFID technology in the near future and 8 per cent report that they have performed a pilot study using RFID technology. Text labels requiring manual reading are still quite commonly used for tracking purposes (56 per cent).

Table I.
Demographic data

	No. of employees					
	100-199	200-499	Above 499	Responses	Sample	Population
Industry						
Manufacture of chemicals and chemical products	3	9	5	17	32	83
Manufacture of electrical equipment, computers, electronic and optical products	0	1	6	7	17	40
Manufacture of fabricated metal products	8	17	10	35	82	202
Manufacture of food products and beverages	4	4	14	22	43	83
Manufacture of furniture and other manufacturing	2	3	2	7	14	37
Manufacture of machinery and equipment	5	6	14	25	55	117
Manufacture of motor vehicles, trailers, semi-trailers and other transport equipment	2	4	7	13	22	50
Manufacture of pulp, paper and paper products	4	5	8	17	25	52
Manufacture of rubber and plastic products	4	3	2	9	20	51
Responses	32	52	68	152	310	715
Sample	91	86	133	310		
Population	368	214	133	715		

The overall use of tracking labels is similar on all three packaging levels, i.e. primary, secondary and load carrier level. Irrespective of tracking technology, 71 per cent of the respondents state that they use tracking labels on primary packaging, 67 per cent are able to uniquely identify secondary packaging, while 66 per cent have labelled the load carrier level. 32 per cent of the respondents state that they use unique identities on all three levels of packaging, either Auto-ID or text labels. Table II presents the lowest packaging level on which the companies use Auto-ID by company size. Comparing this table with the previous one, it seems to be more common for large companies to use Auto-ID, compared to smaller ones. A χ^2 test shows that the differences between the groups are statistically significant with 95 per cent confidence.

The study surveyed where the respondents have located identification points to register tracking data along their supply chain. The results show that the highest usage of identification technologies can be found in finished goods warehouses where 80 per cent of the respondents report that they read and register uniquely labelled goods. Table III provides a summary of different identification points and their usage.

5.2 Factor analysis

The respondents assessed results obtained through the use of tracking labels in 19 different improvement variables. To identify dimensions in the data material, a factor analysis of these improvement variables is conducted. This approach, i.e. a factor analysis, is judged to be an especially useful tool to evaluate logistics performance (Chow *et al.*, 1994). A principal component analysis is applied, which results in a Kaiser-Meyer-Olkin (KMO) value of 0.883. This is characterised as meritorious (Kaiser, 1974). Three additional tests indicate that a factor analysis of all improvements

Table II.
Companies using unique identities and the lowest packaging level with Auto-ID

			Lowest packaging level with Auto-ID			
		Labels only	Primary packaging	Secondary packaging	Load carrier	Total
Company size (no. of employees)	Small (100-199)	4	8	3	1	16
	Medium-sized (200-499)	3	17	4	4	28
	Large (above 499)	5	28	11	7	51
Total		12	53	18	21	95

Table III.
Registration structure

Identification point	Registrations[a] (%)
By customer for internal use	56
By freight forwarder (outbound)	45
In finished goods warehouse	80
In production	65
In raw materials warehouse	51
At goods receipt	62
By freight forwarder (inbound)	27
By the supplier for internal use	45

Note: [a]Share of respondents registering tracking data at a given identification point variables is suitable; Bartlett's test is significantly large; the extracted communalities do not result in any extreme values (Table IV); and the correlation matrix shows that all variables are correlated to at least one other variable for a value of 0.4 ($p = 0.01$).

A scree plot indicates that it is relevant to use four factors. Interpretation of the rotated component matrix results in the following factors (Table III):

(1) Inventory management.

(2) Service level.

(3) Reduced waste.

(4) External co-ordination.

These factors explain 69.7 per cent of the variance of the results obtained (Table IV) and they represent improvement dimensions the respondents perceive they have obtained through use of tracking labels. The improvement dimensions should be compared with the logistics service performance dimensions; quality, time, cost and flexibility, suggested by Neely *et al.* (1995). Obviously, the factor analysis does not result in these pure dimensions, but rather, each of the four factors identified covers the logistics service dimensions to varying extents.

	Factor loading	Eigenvalue	% of variance	Cumulative %	Communality
Factor 1: Inventory management		9.40	49.47	49.47	
Improved inventory turnover	0.805				0.804
Reduced inventory levels	0.797				0.817
Reduced lead time	0.784				0.751
Improved capacity utilisation	0.768				0.725
Fewer inventory points	0.721				0.749
Reduced transition time	0.713				0.699
Reduced inventory space	0.591				0.733
Improved control of internal material flow	0.506				0.547
Factor 2: Service level		1.55	8.18	57.66	
Improved information quality	0.796				0.740
Reduced delivery errors	0.762				0.660
Reduced delivery costs	0.603				0.534
Elimination of duplication of work	0.551				0.706
Improved service levels	0.468				0.550
Factor 3: Reduced waste		1.20	6.31	63.97	
Less obsolescence	0.781				0.749
Less wastage	0.718				0.694
Reduced labour costs	0.673				0.707
Factor 4: External co-ordination		1.08	5.68	69.65	
Co-ordination of material flows to customers	0.776				0.761
Co-ordination of material flows from suppliers	0.713				0.728
Improved handling of product returns	0.649				0.761

Notes: Extraction method, principal component analysis; rotation method, varimax with Kaiser normalisation

Table IV. Factor analysis of improvement variables

5.3 Hypotheses testing

The improvement dimensions identified through the factor analysis are used to test the validity of our hypotheses in the following sections. The findings are summarised in Tables V and VI.

5.3.1 Findings related to H1. We hypothesised that Auto-ID labelled goods have a significant positive influence on logistics performance compared to other types of labelling. To test the hypothesis, several hypothesis tests on different groups based on what packaging level Auto-ID was applied to were performed, but no significant differences in perceived logistics performance could be detected in any of the tests. The ultimate test was to compare a group consisting of companies using Auto-ID on all packaging levels, with a group using text labels on corresponding levels. This test also failed to detect any significant performance differences. Thus, we could not find any support for *H1a*.

Furthermore, we hypothesised that RFID-labelled goods have significant positive influence on logistics performance compared to other types of labelling. The results of the study show a strong support for the hypothesis on the service level dimension ($p = 0.001$), but no significant support for the other improvement dimensions. Since the number of companies using RFID technology is low and we only find support for the hypothesis on one improvement dimension, we consider the study to only give some support to *H1b*. It should also be noted that our study indicates that uniquely labelled goods, regardless of the type of labelling, have a significant positive influence on logistics performance compared to non-labelled goods, but this is outside the scope of this study.

5.3.2 Findings related to H2. We hypothesised that the number of identification points along the supply chain has significant positive influence on logistics performance. The results of the study show that the more times the labels are read and recorded along the supply chain, regardless of label type, the higher the logistics performance. This is valid for the inventory management dimension ($p = 0.007$), service level dimension ($p = 0.045$), and the external co-ordination dimension ($p = 0.012$). No significant correlation could, however, be found between the number of identification points and the amount of waste reduction.

5.3.3 Findings related to H3a. We hypothesised that the frequency of information sharing of tracking data has a significant positive influence on logistics performance. The study reveals that the more often data are shared with supply chain partners, the higher the service level performance ($p = 0.002$) and the better the external co-ordination ($p = 0.022$). No significant correlations were found for the inventory management or waste reduction dimensions. Based on these results, we conclude that there is support for *H3a*.

5.3.4 Findings related to H3b. We hypothesised that the scope of information sharing has a significant positive influence on logistics performance. Different tests were performed to investigate the impact of various types of information on logistics performance. The results from the study are that sharing of sales data is significantly correlated with service level performance ($p = 0.001$), sharing of inventory status is significantly correlated with service level performance ($p = 0.000$) and waste reduction ($p = 0.016$), sharing of geographic position of goods is significantly correlated with service level performance ($p = 0.002$), sharing of product quality is significantly correlated with improvements in the inventory management performance ($p = 0.048$)

Table V. Results from tests of hypotheses 1, 2, 3a, 3c and 3d

Hypothesis	*H1a* Auto-ID vs other identification technologies	*H1b* RFID vs other identification technologies	*H2* Identification points	*H3a* Frequency of information sharing	*H3c* Information sharing with customers	*H3d* Information sharing with suppliers
Factor	Two-sample *t*-test Sig. (two-tailed)	Two-sample *t*-test Sig. (two-tailed)	Pearson correlations Sig.(two-tailed)	Pearson correlations Sig. (two-tailed)	Pearson correlations Sig. (two-tailed)	Pearson correlations Sig. (two-tailed)
Inventory management	0.188	0.250	0.007**	0.793	0.569	0.375
Service level	0.284	0.001**	0.045*	0.002**	0.015*	0.170
Waste reduction	0.254	0.346	0.365	0.848	0.196	0.018*
External co-ordination	0.446	0.797	0.012*	0.022*	0.006**	0.003**

Table VI.
Results from tests of hypothesis 3b

Hypothesis	*H3b* Sharing of sales data	*H3b* Sharing of inventory status	*H3b* Sharing of geographic position data	*H3b* Sharing of product quality data	*H3b* Sharing of product returns data
Factor	Pearson correlations Sig. (two-tailed)	Pearson correlations Sig. (two-tailed)	Pearson correlations Sig. (two-tailed)	Pearson correlations Sig. (two-tailed)	Pearson correlations Sig. (two-tailed)
Inventory management	0.156	0.257	0.438	0.048*	0.044*
Service level	0.001**	0.000**	0.002**	0.159	0.279
Waste reduction	0.256	0.016*	0.521	0.001**	0.002**
External co-ordination	0.150	0.709	0.105	0.063	0.000**

and waste reduction ($p = 0.001$), and finally, sharing of tracking data concerning product returns is significantly correlated with improvements in the inventory management performance ($p = 0.044$), waste reduction ($p = 0.002$), and improvements in external co-ordination ($p = 0.000$). In conclusion, *H3b* is supported.

5.3.5 Findings related to H3c. We hypothesised that information sharing with customers is positively correlated to logistics performance and the test results show that sharing data with customers does have a positive influence on the service level performance ($p = 0.015$) and on in improved external co-ordination ($p = 0.006$). No significant correlations were found for the inventory management or waste reduction dimensions. All in all, there is support for *H3c*.

5.3.6 Findings related to H3d. We hypothesised that information sharing with suppliers is positively correlated to logistics performance and the test results show that sharing data with suppliers does have a positive influence on waste reduction ($p = 0.018$) and on improved external co-ordination ($p = 0.003$). No significant correlations were found for the inventory management or service level dimensions. To sum up; *H3d* is supported.

6. Discussion

Quite surprisingly, on an overall level, we did not find any proof that the impact of Auto-ID on logistics performance is greater than the impact of text labels. This is contradictory to general opinions and previous studies (Smith and Offodile, 2002). One interpretation of this is that the technology used to collect tracking data is not vital for success, but the essential issue is rather how the data are utilised. As previously stated, text labels and manual data entry generally result in 1 error in 300. Lower error rates are naturally desirable, but reducing uncertainty usually means diminishing returns and the additional benefits of higher information quality through the use of Auto-ID technology may not be so evident (Cannon *et al.*, 2008), especially if only elementary analysis tools and processes are used to handle the tracking data. If this is the case, it is quite logical that there is no significant difference between Auto-ID and text labels for capturing tracking data in terms of logistics performance.

The fact that bar codes are the dominating identification technology for the companies in the current study may also have an impact on this result. 84 per cent of the respondents use bar codes for tracking goods on at least one packaging level, often combined with text labels as a manual backup. Bar code technology has, however, a number of drawbacks compared to RFID technology. In general, accuracy of information is lower due to reading features. In contrast to RFID technology, bar codes usually require manual intervention and line-of-sight. Both aspects are potential sources of missed registrations. Text labels have reading features similar to bar codes, but also include the risk that data entry is incorrect. RFID technology, on the other hand, has none of these disadvantages. Consequently, if the main sources of lack of information accuracy are related to manual intervention or line-of-sight, only RFID technology, and not bar codes, may perform better than labels. Thus, the type of Auto-ID used may play an important role.

In line with this statement, we did find some support for the fact that RFID technology improves logistics performance more than other types of labelling, including bar codes. Our analysis reveals that using RFID technology appears to improve the service level dimension positively, indicating that companies aiming at supply chain excellence may consider implementing RFID technology. This finding regarding the superiority of RFID technology should, however, be analysed with caution, since only seven responding companies are actively using RFID technology. Another concern is that there may be some underlying differences between the companies using RFID technology and those, which use bar codes. Early adopters of RFID technology may, for example, have a more advanced level of technology in general, which could impact on logistics performance. Such aspects cannot be foreseen. Therefore, our results need to be verified in future studies.

The study also reveals that the number of identification points along the supply chain has a significant positive influence on logistics performance on almost all improvement dimensions. This means that once a company has committed itself to using a system for tracking goods, regardless of identification technology, the more often the tracking labels are read and registered, the better the logistics performance seems to become. This also extends to supply chain partners. If tracking labels are used by suppliers and customers as well, improved logistics performance can be expected. This result also points in favour of using Auto-ID for data capture. If the number of registrations increases, the effect of less efficient manual reading and data entry required for text labels should become more evident. In a case when goods are manually registered every time they change location, both the total identification time and the risk of mistakes should be considerable.

One aspect of securing superior logistics performance is that of several identification points in the supply chain. To track goods along the entire supply chain, however, interorganisational collaboration is required, meaning that a focal company needs to share tracking data with suppliers and customers. The current research confirms findings in previous studies of links between information sharing and logistics performance. The novelty of this study is the effect of sharing tracking data on different logistics performance dimensions. Our results show that the frequency of information sharing has a significant positive influence on the service level and external co-ordination dimensions, i.e. companies should update, and receive updates from, their supply chain partners with the latest tracking data frequently, ideally in real time.

Furthermore, the scope of the information being shared also affects logistics performance. First, our study shows that the service level dimension may be improved by sharing information regarding sales, inventory status and geographical location of goods. Second, waste may be reduced by sharing information regarding inventory status, product quality and product returns. Finally, the inventory management dimension can be improved by sharing information regarding product quality and product returns. The information from the tracking system can be shared both downstream and upstream in the supply chain. Our analysis reveals that both impact on logistics performance. By sharing tracking data with customers, companies could improve their service levels and external co-ordination dimensions. By sharing tracking data with suppliers, they could reduce waste and improve external co-ordination dimensions.

The study conclusively demonstrates the value of sharing tracking data in frequency and scope with both suppliers and customers. However, it should be noted that although the findings reported in this study are statistically significant when groups of firms are compared, there are large variations in results obtained by individual firms. Having a tracking system and sharing data with supply chain partners does not guarantee that firms are able to use the increased information, or more importantly, to use it efficiently. To gain a competitive advantage through sharing tracking data relies on having capabilities to leverage on it. In this sense, Auto-ID technology is not different from earlier co-ordination and control technologies which have required firms to re-configure processes and infrastructure to fully realise promised benefits (Cannon *et al.*, 2008).

7. Conclusion

Superior logistics performance relies on having accurate, timely and reliable information. This can be supported by assigning unique identities to products and goods in the supply chain, and through using identification technologies and IT systems for tracking their whereabouts. Somewhat surprisingly, the findings of this study do not support the fact that Auto-ID labelled goods; in general, perform better logistically than goods using other types of identification technologies. We have identified three potential reasons for the lack of support. First, elementary analysis tools and processes for dealing with tracking data may not benefit from improved quality of information. Second, logistics performance is more dependent on how data are utilised, rather than on how data are captured, i.e. the efficiency and accuracy of data capture have less impact than data processing and analyses. Finally, Auto-ID encompasses many different technologies, and the fact that bar codes are the dominating Auto-ID technology in our study may affect the findings. The analyses point towards better logistics performance for companies using RFID technology, while no significant differences can be seen for companies using Auto-ID in general. This indicates that the concept of Auto-ID may be too broad for analysis purposes.

Auto-ID technologies may not result in better logistics performance *per se*, but they certainly provide some characteristics necessary for effective and efficient collection of tracking data. Compared to text labels, which require manual reading and data entry, Auto-ID technologies facilitate more frequent and more extensive collection of tracking data, which both have a significant positive influence on logistics performance. However, collecting tracking data along the supply chain is not enough. To obtain high logistics performance levels, companies need to share their tracking data in real time with both suppliers and customers. The study provides compelling evidence that companies which share tracking data frequently and to a great extent perform better than others.

The present research contributes to existing literature by providing a snapshot of the impact of identification technologies and associated practices on logistics performance in Swedish manufacturing industries today. Furthermore, the study presents empirical evidence of the links between using different identification technologies, attributes of the tracking system, use and sharing of tracking data and logistical improvements. The findings of the study seem to be representative of Swedish manufacturing industries, as the survey study has sampled a large section of the total population of manufacturing companies and achieved a high response rate without any detected non-response bias. The resulting links are also likely to be found among companies in other industrialised countries similar to Sweden.

The practical implication of this research is that firms which intend to start tracking products and goods in their supply chain need to start by thinking about how they will use the tracking data. The choice of identification technology seems to be of secondary importance. Best-in-class firms seem to have extensive information sharing with supply chain partners, both upstream and downstream, and in terms of frequency and scope, which contributes to superior logistical performance. Best-in-class firms also have more identification points along their supply chains making their tracking data more granular compared to other firms. There is no compelling evidence in terms of what identification technology should be used, but having many identification points along the supply chain points in favour of using Auto-ID technologies. In particular, the study provides some evidence of RFID technology being preferable.

This study is, however, not without limitations. The focus of this research has been on comparing different identification technologies and practices for using tracking data. It is, however, clear that although capturing and sharing tracking data with supply chain partners can help improve logistics performance, firms should realise that:

> [. . .] before adopting specific technologies to facilitate inter-firm communication, firms should understand that data flows alone are insufficient to fully leverage bi-directional information exchange and relationship synergy. The various information technologies available merely represent available tools" (Hsu *et al.*, 2008, p. 306).

Further in-depth studies are necessary to provide deeper understanding about how firms are using identification technologies as a mechanism to improve logistics performance. Moreover, the study only includes a few firms, which have adopted RFID technology and the support for the hypothesis that RFID is superior to other types of labelling is quite weak. As more companies start to adopt RFID technology, this hypothesis needs to be re-tested to be able to better assess the impact of RFID technology on logistics performance.

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Corresponding author
Ola Johansson can be contacted at: ola.johansson@plog.lth.se