A New Traceability System for SMEs with Open Source Software

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Abstract: Corporations are currently making progress in their efforts toward traceability, against the backdrop of practical realization of the automatic identification technologies such as RF tags and 2D barcodes. In order to consistently manage and access various types of product-related history information throughout the supply chain, it is necessary to develop information networks and databases for sharing that information between firms, and EDI systems play a central role in that context. The main contribution of this paper is to propose a new distributed traceability system based on open source software which is particularly suitable for small and medium enterprises (SMEs). In this paper, we first conduct an exploratory analysis of factors involved in the adoption of traceability systems by small and medium enterprises, based on a review of previous research on traceability and questionnaire survey data. And then we examine the current situation and issues of RF tags, 2D barcodes and EDI systems, and their linkage with in-house backend systems. Furthermore, we propose a new model of the traceability system using open source software which is suitable for small and medium enterprises based on the above analysis, and discuss the model's managerial implications.

Key-Words: Traceability Systems, Small and Medium Enterprises, Open Source Software, Supply Chain, 2D barcodes, EDI

1 Introduction

In recent years, many firms have built traceability systems and progressed in their efforts toward traceability of raw materials and products. This process has been stimulated by progress in automatic identification technology, primarily RF tags and 2D barcodes, and expansion of their scope of application to inter-firm uses. However, in order to develop the traceability systems using RF tags and 2D barcodes between firms in a supply chain, and then manage and share history information using those systems, it is necessary to develop inter-firm information networks and databases. Approaches to building systems to achieve traceability in supply chains are generally classified into two basic types: centralized and distributed. Distributed traceability systems based on EDI play a central role. However, at small and medium enterprises, there are various issues, such as bearing the costs of introducing and operating a traceability system, and securing staff who have applicable skills.

In this paper we first survey previous research in order to provide an overview of traceability and discuss firm's situation and environment, and then analyze the factors involved in the adoption of traceability systems. Next, we discuss the relationship between EDI and the development of traceability systems in the supply chain. Furthermore, we propose a new model of the traceability system using open source software which is suitable for small and medium enterprises, and discuss the model's managerial implications.

2 Background of Research

In order to understand the background of this research, we will explain the definition of traceability.

2.1 Traceability

The term of traceability generally refers to the ability to verify the history, location, or application of an item by means of documented recorded identification. It means that the history of information relating to an applicable product is managed, and can be followed/

retraced. A "traceability system" is a series of mechanisms or processes for conducting the identification, data creation, data accumulation/ storage and data collation necessary to achieve traceability [1].

There are two reasons for many firms why they are developing traceability systems and strengthening their efforts to achieve traceability today. The first reason is the rise in consumer awareness of product safety, quality and labeling — triggered by social problems such as BSE ("mad cow disease"), fraudulent labeling and concealment of vehicle recalls — as well as societal demands that corporations make a positive contribution to recycling, environmental problems and so on. The second reason is to get work done more efficiently/effectively and to gain competitive advantages in the sale of its products and services, by exploiting the practical realization of the automatic identification technologies such as RF tags and 2D barcodes, and progress in inter-firm information networks. By building traceability systems, firms will expect to get work done more efficiently and reduce costs in areas of quality and inventory control, products inspection, shipment and distribution. The reason is that detailed information of raw materials, parts, products and other items can be followed/ tracked accurately.

We conducted a questionnaire survey (response rate 14.6%) in December 2004. We investigated and collected the data from 500 companies in the Japanese manufacturing, wholesale and retail industries in this questionnaire survey. According to our investigation, 4.1% companies adopted traceability system for almost all of their products/ materials, 37.0% companies adopted traceability system for part of their products/ materials, and 17.8% companies do not adopt traceability system but have plan to do it in the future. The rest of 41.1% companies do not adopt traceability system and have no plan to do it in the future. We divide these companies into two groups, one is for small and medium enterprises, and other is for large-scaled enterprises (LSEs). Table 1 shows the details of our questionnaire survey for these two groups. It is easy to found that the group of small and medium enterprises particularly have time lag in their adoption of traceability system.

Table 1: Details of the Questionnaire Survey (%)

	Almost all	Partial	Non-adopting with plan in the future	Non-adopting without plan in the future
Total	4.1	37.0	17.8	41.1
LSEs	8.8	44.1	8.8	38.2
SMEs	0	30.8	25.6	43.6

Note: LSEs include firms with more than 1,000 employees in this paper.

2.2 Factors of Traceability Systems

In the field of corporate management, the earliest research of the impact of traceability systems on corporate competitiveness began in the 1990s [2]. In most of these researches, traceability system is considered as one of the most important tools for management/access of history information of products. Traceability system is a useful means to improve product quality and business processes.

For instance, Sohal (1997) conducts a case study of traceability system construction at the Australian overseas subsidiary of Denso Corporation, a company of the automotive parts manufacturing industry. In this study, different economic effects, such as quality improvement and lead-time shortening are proved, and successful factors involved in the system are investigated [3]. Jansen-Vullers et al. (2003) classified traceability into two types: passive and active [4]. "Passive traceability" refers to efforts to achieve visibility of information, i.e. a situation where information on products can followed/ tracked from production, through distribution and eventual disposal. In contrast, “Active traceability" refers to active attempts to use the now visible history information to further improve quality control and increase efficiency of supply chain processes.

Based on our questionnaire survey, we examined that what sort of factors have an impact on corporate construction/ adoption of traceability systems (Table 2). In terms of what items have been (or would be) most important when we adopt a traceability system, the results show that the two items "response to requests from business partners or consumers" and "improvement of quality and reduction of management costs for the company's products" have a rather high value, but overall, it is not possible to derive a comprehensive conclusion.

Thus we conduct factor analysis of these 9 items (scale of traceability system), and examine that what sort of latent factors have an effect on traceability system.

First, when factor analysis was conducted using the principal factor method, changes in the eigenvalue are at the sequential series of 3.10, 1.59, 1.39, 0.95 (rest omitted), and thus it was determined that 3 factors structure is appropriate, taking eigenvalue 1 as the standard. Since it is assumed that there is a positive correlation between factors obtained through factor analysis, factor analysis is conducted again assuming 3 factors and using the principal factor method (promax rotation), and items with a factor loading of 0.45 or higher were selected. Table 2 shows the final factor pattern and correlation between factors after promax rotation. The 3 factors before rotation explained 67.5% of the total variance of the 9 items.

Table 2: Mean, standard deviation and correlation coefficient matrix of the factor analysis (5 point scale)

	Mean	*SD*	Correlation coefficient								
			1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Response to requests from business partners or consumers	4.19	0.95	–								
2. Response to trends at other firms in the same industry	3.31	0.98	0.30	–							
3. Response to administrative policies or efforts of affiliated industry groups	3.42	1.05	0.32	0.43**	–						
4. Increased safety/security awareness of consumers or society	3.94	0.86	0.36*	0.19	0.50**	–					
5. Efforts to address recycling and other environmental issues	3.94	0.98	0.16	-0.07	0.08	0.13	–				
6. Improvement of quality and reduction of management costs for the company's products	4.22	0.90	0.15	-0.21	-0.04	0.16	0.37*	–			
7. Improved efficiency of risk management for defective products and accidents etc.	3.39	1.08	-0.16	0.21	0.16	0.18	0.13	0.11	–		
8. Part of strengthening competitiveness, in marketing and sales strategy etc.	3.56	1.00	-0.03	0.17	0.26	0.57**	0.21	0.18	0.48**	–	
9. Enhancing the image of the company or its product brands	3.50	0.88	0.09	0.05	0.39*	0.76**	0.17	0.11	0.39*	0.75*	–

Note: ** means significant at the 1% level, and * means significant at the 5% level.

The first factor is comprised of 4 items, and items relating to improvement of external competitiveness, such as "part of strengthening competitiveness", "image enhancement" and "safety/security awareness", exhibited high loading (Table 3). Therefore, this factor is called "competitiveness". The second factor is comprised of 3 items, and items relating to pressure from the outside environment, such as "requests from business partners" and "response to administration and efforts of industry groups", exhibited high loading. Therefore, this factor is called "environmental pressure". The third factor is comprised of 2 items, and items relating to improvement of in-house operations, such as "improvement of quality" and "cost reduction", exhibited high loading. Therefore, this factor is called "operations". Whereas the first and third factors tend to reflect a proactive, action-oriented company stance toward traceability, the second factor is an inactive response to factors in the external environment, and indicates the passive stance of the company.

When Cronbach's α was calculated to examine internal consistency, the values are α =0.80 for "external competitiveness", α =0.62 for "environmental pressure" and α =0.54 for "operations". Thus adequate values were not obtained in all cases.

Table 3: Factor analysis results for the scale of traceability systems adoption (Factor pattern after promax rotation)

	I	II	III
8. Part of strengthening competitiveness, in marketing and sales strategy etc.	**0.87**	-0.06	0.08
9. Enhancing the image of the company or its product brands	**0.84**	0.08	0.09
7. Improved efficiency of risk management for defective products and accidents etc.	**0.55**	-0.13	-0.04
4. Increased safety/security awareness of consumers or society	**0.51**	0.44	0.12
1. Response to requests from business partners or consumers	-0.36	**0.82**	0.24
3. Response to administrative policies or efforts of affiliated industry groups	0.22	**0.58**	-0.17
2. Response to trends at other firms in the same industry	0.05	**0.53**	-0.37
6. Improvement of quality and reduction of management costs for the company's products	0.07	-0.13	**0.70**
5. Efforts to address recycling and other environmental issues	0.10	-0.01	**0.46**
Correlation between factors			
I	–	0.36	0.19
II		–	0.21
III			–

Note: Items with a factor loading of 0.45 or higher are indicated in bold.

This is partly because the number of items comprising each factor is small, but the "operations" factor was below α=0.6, which is the ordinary cut-off level.

3 Traceability Systems and EDI

Traceability systems and EDI is one of the important issues for designing a new traceability system.

3.1 Two kinds of Traceability System

In general, the following are the two approaches to designing traceability system of the supply chain [5, 6].

(1) Centralized traceability system

In this case, traceability information is centrally under management in a shared database. Also, each firm and involved person performs tasks, for instance, add new data, and update history information, primarily via the internet, based on fixed rules (e.g. access privileges). One example of this type is the search service for central management of traceability information (register) relating to individual identification of cattle throughout Japan.

(2) Distributed traceability systems

In this case, traceability information is saved/ managed in a distributed fashion as the responsibility of each company, and required data is transferred/exchanged primarily using EDI systems. As a rule, firms use the "one step forward, one step backward" system where each company positioned in a supply chain provides traceability information one step forward from itself, and can track information one step backward from itself. This approach is typically adopted in industries such as household appliances and processed food. In particular, the latter distributed type is expected to expand in the future as the major type of traceability system. Therefore, it is expected that there would be a growing role for EDI systems, which have previously developed as the technological infrastructure for sharing information among companies.

For both of these systems, small and medium enterprises will be faced with a large cost burden for adopting/ operating a traceability system. And it is also difficult for them to secure adequate staff with the requisite technical capabilities. However, it is obviously that the "environmental pressure" generally will have effect on the small and medium enterprises. Therefore, a new model of the traceability system for the small and medium enterprises is required.

3.2 Traceability and EDI

We conduct exploratory analysis using the aforementioned survey data, as the first step toward examining the relationship of efforts by corporations to achieve traceability with EDI systems and with in-house backend systems.

First, we divide firms in our questionnaire survey into two groups, an "implementing" group which is making efforts toward traceability and a "non-implementing" group which is not, based on the criteria of whether or not the firm is building a traceability system (i.e. whether or not it is implementing traceability for all or part of its products/materials). Then we analyze the relationships with formation of information networks between companies, and with adoption of internet EDI (Table 4, Table 5). As a result, a connection was found between the existence of traceability system construction and formation of information networks between firms ($\chi^2=7.82$, df=3, $p<0.05$). Similarly, a connection was also found with adoption of internet EDI ($\chi^2=20.0$, df=3, $p<0.00$).

From this result, it is obviously that traceability systems are being built by taking formation of information networks between firms as a foundation. Efforts toward traceability are driving greater openness (standardization) of EDI systems as interfaces between companies [7].

This also shows that small and medium enterprises, which tend to be relatively behind in terms of adoption/ dissemination of inter-firm information networks and internet EDI, are hobbled in their efforts toward traceability.

Next, we look at the secondary use of EDI data, to examine what sort of differences appear in the formation/usage situation of in-house backend systems due to differences in items which are important in driving efforts toward traceability. Here, "secondary use" of EDI data means that EDI systems are not used only for front-end processing between firms; EDI data is also linked with in-house backend systems, and used for various types of work inside the firm. It is obviously that, at present, companies implementing EDI are advanced in terms of secondary use of EDI data in backend systems, primarily for sales and inventory management.

Table 4: Cross/Residual analysis between existence of efforts toward traceability and formation of information networks between firms (%, after correction for multiple responses)

	Implementing N=30	Non-implementing N=42
Fixed connection with specific business partner	23.3	35.7
Flexible, reconfigurable connections with multiple business partners	46.7	35.7
Configuration of a supply chain involving multiple firms to achieve overall optimization	20.0*	4.8*
Not implementing inter-company connections	10.0	23.8

Note: * means significant at the 5% level.

Table 5: Cross/Residual analysis between existence of efforts toward traceability and implementation of internet EDI (%)

	Implementing N=26	Non-implementing N=37
Majority is the internet	42.3**	2.7**
Partially adopted	38.5	64.9
Have a conventional system, but plan to shift to the internet	11.5	2.7
Will continue for a while with a conventional system	7.7*	29.7*

Note: ** means significant at the 1% level; * means significant at the 5% level.

Now, what sort of differences appears in the secondary usage of EDI data depending on the extent of effort toward traceability? We classified firms into an "active" group having a proactive, action-oriented stance on efforts toward traceability, and a "passive" group having a relatively inactive stance, and analyzed the difference between mean values for 8 items relating to secondary use of EDI data. It is decided to use the aforementioned factor analysis results as the classification criterion. That is, we calculate scale points comprised of the mean values of items which exhibited high loading on each of the two scales "competitiveness" and "operations", and firms whose score are at or above the mean for both scales are classified into the "active" group, and the rest are placed in the "passive" group.

As indicated in Table 6, the results show that the "active" group with a proactive, action-oriented stance toward traceability exhibits greater overall secondary use of EDI data. Here, a significant difference was found between the "active" and "passive" groups for 4 items: sales management ($t=1.89$, $df=27$, $p<0.05$), customer management ($t=2.10$, $df=27$, $p<0.05$), production management ($t=1.74$, $df=26$, $p<0.05$) and finance/accounting management ($t=2.28$, $df=27$, $p<0.05$).

Table 6: Comparison of secondary use of EDI, depending on differences in stance on efforts toward traceability

	Active N=9		Passive N=20		t value	Significance probability
	Mean	SD	Mean	SD		
Sales management	4.56	0.73	3.60	1.43	1.89	0.04
Customer management	3.44	1.59	2.25	1.33	2.10	0.02
Purchasing management	3.56	1.13	2.95	1.47	1.10	0.14
Inventory management	4.11	0.93	3.25	1.62	1.48	0.08
Production management	3.00	1.07	2.10	1.29	1.74	0.05
Distribution management	3.56	1.24	3.05	1.61	0.84	0.21
Finance/Accounting management	3.56	1.33	2.40	1.23	2.28	0.02
Management decision making	2.38	1.19	2.05	1.15	0.67	0.25

Although a statistically significant difference was not found, overall secondary use of EDI data at small and medium enterprises was passive, and this also indicates that small and medium enterprises face issues in their efforts toward traceability [8, 9].

4 New Traceability System for SMEs

Based upon the analysis mentioned above, we will propose a new model of traceability system for small and medium enterprises.

4.1 The New System and Open Source Software

Small and medium enterprises face a number of issues, such as bearing the costs of adopting and operating a traceability system, and securing staff having applicable skills. Thus, we propose the framework of a system which holds down adoption costs and reduces the burden of operation/management by building the system on the foundation of open source software [10, 11, 12]. The basis for this is an open source software based system framework for small and medium enterprises which we have previously studied [13]. A robust platform with good maintainability is built by using Linux as the operating system which forms the basis of the system. PostgreSQL, widely regarded as rivaling commercial databases, is used as the relational database system for accumulating and storing data. A highly versatile system, with reduced development and maintenance costs, is built by selecting PHP, a scripting language for Web system development.

4.2 New Model for Small and Medium Enterprises

We propose a new model of the traceability system for small and medium enterprises using open source software. It is assumed that this model will be implemented as a distributed traceability system. Because this type would be expected to expand in the future as the major type of traceability system mentioned above. Thus, 2D barcodes (which are easy to use for small and medium enterprises) are employed as the media for trace information [14]. We also propose a scheme for saving trace information in XML format [15], to enable secondary use in EDI systems and greater versatility (Fig.1).

```
<?xml version="1.0" ?>

<Product>
   <ControlCode>12345678</ControlCode>
   <ProductCode>A1010</ProductCode>
   <ProductName>Product A</ProductName>
   < ManufacturingDate>2008-11-01</ManufacturingDate>
   <ManufacturerName>Sample Corporation</ManufacturerName>
   <Telephone>0123-45-6789</Telephone>
</Product>
```

Fig.1: Example of trace information in XML format

The front end of the traceability system is web-based, and the model aims at designing a new system which has a minimal burden on the staff of small and medium enterprises.

Fig.2 shows the model of a traceability system suitable for small and medium enterprises, based on the above considerations.

By following this model and defining requirements for small and medium enterprises, we can contribute to the construction of traceability systems for small and medium enterprises.

4.3 Secondary Use of EDI

For example, it becomes possible to automatically collate with EDI data sent from the supplier, such as the manufacturer or wholesaler, by reading a 2D barcode at the time of product arrival, as part of arrival and inspection processing [16]. In store management too, linkage with order management can be achieved by using smart shelves and ordering automatically.

Using 2D barcodes for EDI processing in this way is effective for synchronizing flows of products and flows of information. Automation of inspection work facilitates secondary use of EDI data for seamless

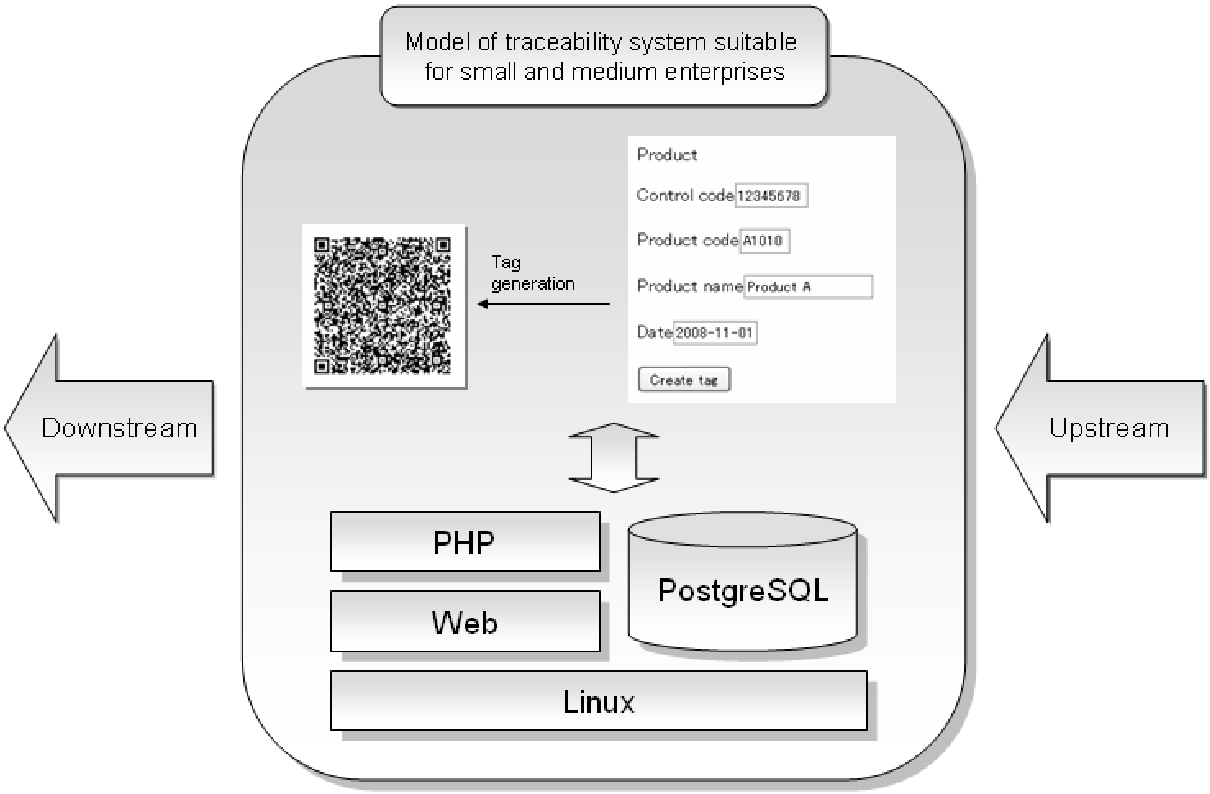

Fig.2: Model of traceability system suitable for small and medium enterprises

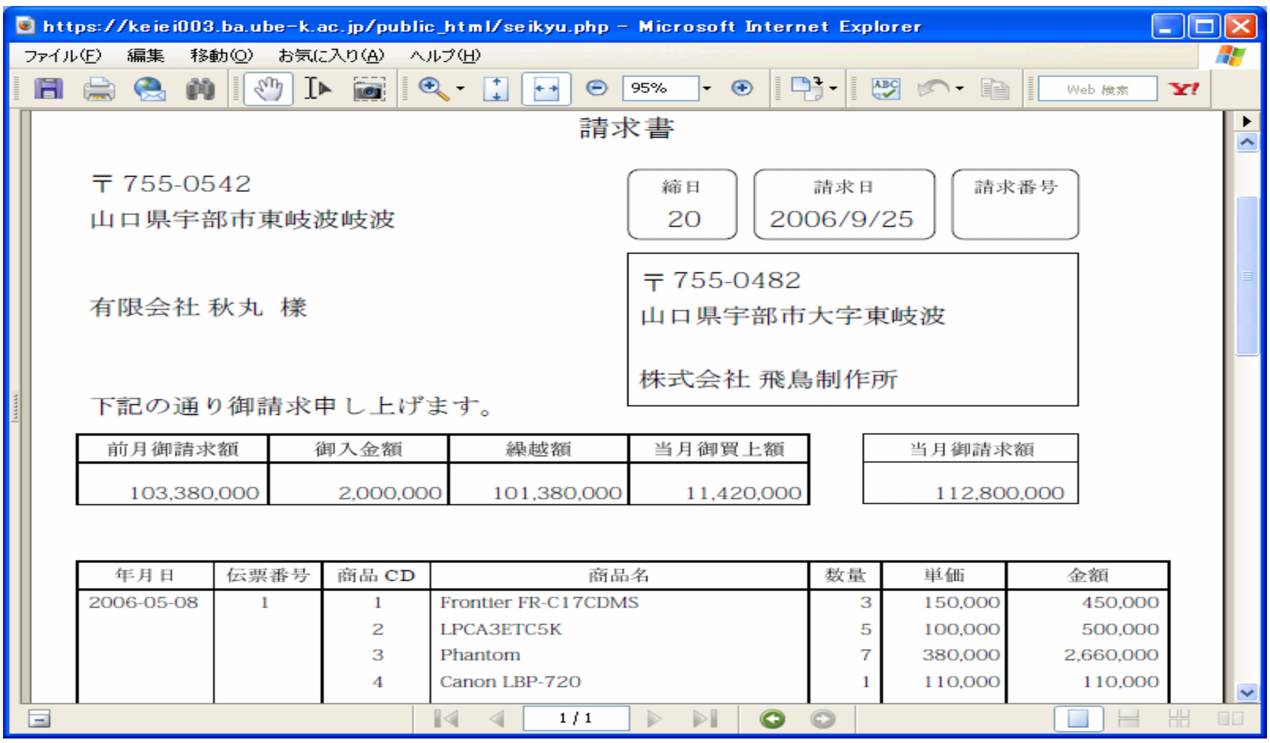

Fig.3: Implementation of a system for automatically issuing billing statements

linkage with subsequent billing processes, and for financial/accounting management and inventory management. Fig.3 illustrates the implementation of a system for automatically issuing billing statements after conducting acceptance inspection based on automatic collation of 2D barcode information and EDI data.

The fact that it is possible to build this sort of traceability system by using open source software will likely be a major advantage for small and medium enterprises who have many limitations on their budget, staff and other management resources.

5 Future work

Based on the analytical results mentioned above, we propose a new model of a traceability system using open source software which is suitable for small and medium enterprises, and discuss its managerial implications.

In the future, more work will be necessary, such as new requirements for the model, development of a prototype of the system, and demonstration experiments. Furthermore, there will need to be evaluation and verification of its effectiveness, such as cost reduction, system vulnerability and so on through an experimental operation of the prototype system proposed in this paper.

6 Conclusion

We review an overview of traceability and traceability system, and examine several issues related to development of EDI-based distributed traceability systems, based on the analysis of the current situation and the survey of previous literatures in this paper.

The main focus is the relationship of EDI with construction of traceability systems in the supply chain. This is an exploratory investigation, and the analytical results of the empirical data show that there is greater openness of EDI systems of the firms which adopted traceability systems, and that secondary use of EDI data in backend systems is more advanced to the extent that a firm is proactive and action-oriented toward implementing traceability. However, although a statistically significant difference is not found, overall secondary use of EDI data at small and medium enterprises is passive, and this also indicates that small and medium enterprises have specific problems in their efforts toward traceability.

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