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The Role of Traceability in Sustainable Supply Chain Management

Master of Science Thesis in Supply Chain Management

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ABSTRACT

Nowadays, sustainability has become a new management principle for firms to steadily compete in the market. On the public side, food crisis has increased consumers' awareness of safety on their consumption. Based on this awareness, governments of many countries have legislated firms in the food supply chains to implement the traceability system in order to identify sources of deficiency and be able to withdraw hazardous products on the market precisely and efficiently. Firms in different industries have implemented traceability systems to increase supply chain performance. By the enforcement of food safety laws, food safety becomes a new important traceability attribute for these firms. This enforcement becomes a great opportunity for firms to start applying new management principles by considering sustainability on all sustainable dimensions. In this thesis, 82 academic papers are reviewed and analyzed. The authors identified the contributions of traceability to sustainable supply chain management by identifying effects on economic perspective, social perspective, and environmental perspective and the mechanism on how traceability can create sustainability by identifying relationships among three perspectives, including other factors that should be considered. At the end, the thesis also presents future opportunities for firms that currently apply traceability to gain higher economic benefits from traceability while increasing public welfare.

Key words: Traceability, Sustainability, Sustainable supply chain management,

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Kraivuth Kraisintu Ting Zhang

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1. Introduction

1.1. Background

Concerns from public and industry over products safety have grown considerably over recent years, especially for food safety (Jansen-Vullers et al., 2003; Beulens et al., 2005; Folinas, 2006; Thakur and Hurburgh, 2009; Doluschitz et al., 2010; Dabbene and Gay, 2011). Concerns of consumers on their consumption are increasing. It becomes more critical for consumers to know the facts of the product origin and production methods, for example, if it is a sustainable source and produced through eco-friendly methods, and if production, transportation, and storage conditions can guarantee product safety. Product deficiency brings customer curiosity and anxiety and creates distrust to products in the market (Chryssochoidis et al., 2009). Also, a series of product safety scandals and outbreaks of food diseases have indicated demand for the implementation of product traceability procedures (Kelepouris et al., 2007; Engelseth, 2009). The *EU General Food Law* which has been applied from 1 January 2005 has a specific emphasis regarding traceability. *"The identification of the origin of feed and food ingredients and food sources is of prime importance for the protection of consumers, particularly when products are found to be faulty"* (European Commission, 2005). The *EU General Food Law Regulation* (178/2002, article 18) defines food product traceability as *"the ability to trace and follow a food, feed, food-producing animal or substance through all stages of production, processing and distribution"* (European Parliament, 2002). Traceability of products (especially food) has not only become a legal obligation within the EU but furthermore, increasingly becomes a global issue. United States and Japan also have similar requirements for traceability of products such as food and drugs (Ministry of Agriculture Forestry and Fisheries of Japan, 2007; U.S.Food and Drug Administration, 2010)

The globalization of products market increases the distance between source of region and consumers, which leads to the situation that mostly consumers have no contact with the places where their product is produced (Bevilacqua et al., 2009). Moe (1998) indicates that traceability is an essential sub-system of quality management. In order to ensure the product quality and identify health related problems effectively at an early stage to avoid contaminated products reaching consumers and to protect public health as well as reduce the potential negative economic impact, accurate traceability systems have been applied in more and more fields (GS1, 2007; Bevilacqua et al., 2009). The reliability and dependability of the traceability system largely rely on the level of accuracy, efficiency of the identification, and authentication technologies. The development of product identification and localization technologies provides a great opportunity to advance the traceability system, struggling product counterfeiting and protecting the reputation, thus achieve the market and customers demands (GS1, 2007; Bevilacqua et al., 2009; Kher et al., 2010).

Under this new situation, customers' awareness involves more and more of quality issues as well as safety and environmental conformity when making their buying decisions. Industry and agribusiness have to respond to these changing consumer demands by increasing sustainability of processes and products (Wognum et al., 2011).

1.2. Research contribution

Nowadays, traceability in food industry has become mandatory for many countries around the world, for example, European Union countries, Japan, and the United States (Bechini et al., 2008). Further to this enforcement, firms have to struggle with increasing cost to apply traceability system (Pettitt, 2001; Regattieri et al., 2007). However, many academic researchers have proved that traceability does not always increase costs (Hobbs et al., 2005; Decker et al., 2009; Roth et al., 2008).. Furthermore, it provides many benefits, for instance, clear ability assignment, higher customer satisfaction, less recall, etc. In some other industries, for example, automobile, traceability is known as a system to help actors in a supply chain increase their operational performance rather than cost burdens (Robinson and Malhotra, 2005).

The first contribution of this research is to provide comprehensive knowledge to firms, especially in food industry, to help them gain the understanding on how to reap benefits from the costs that they are forced to struggle with.

However, to increase the benefits of traceability, firms may have to change their perspectives from cost-based consideration to value-based consideration. The authors use a research by Carter and Rogers (2008), to show that firms' economies can be sustained to a greater extent if they can provide sustainability to the society and the environment. Governments' enforcement on traceability for food safety, as a representative of social sustainability, can be great opportunities for the firms to sustain their economy in long terms.

The second contribution of this research is then, to provide a holistic view to firms in supply chains on how they can migrate their risks of increasing cost from traceability implementation to long terms economic sustainability. For instance, traceability can be used to prevent over fishing (Jacquet and Pauly, 2008). This may reduce firms' profits in a short term. However, it can prolong the extinction and reserve this resource to be used in long terms (Carter and Rogers, 2008).

Finally, this research can contribute to researchers in the supply chain and sustainability areas by providing a comprehensive review to make inspirations for further research areas.

1.3. Scope and limitation

The scope of the thesis is to identify contributions of product traceability in sustainable supply chain management context. In the context of sustainable supply chain management, relationship between traceability and three bottom lines model of sustainability or three sustainability dimensions (environment, society, and economy) will be analyzed and identified from a holistic view. Based on the authors’ literature review it is indicated that in recent years, food industry and food products draw most attention from academe. Further to this finding, the authors have explored more on food perspective and attempted to elaborate the factors of traceability that are involved in the supply chain which can improve product quality as well as safety for consumers.

All in all, the research is a literature review where eighty two journal papers were reviewed having sustainable supply chain context as the restricted scope of the project. Due to the limitations in time and the research project’s specifications the authors have skipped many irrelevant details and have tried to clearly explain the effects of traceability on sustainable supply chains found in the available literature.

1.3. Problem analysis

Based on the literature review, many papers show the relationship between specific levels of traceability and sustainability in different dimensions. For example, one may discuss about only social aspect (Lyles et al., 2008; Chen et al., 2009; Zhou, 2009) or social and economic (Skees et al., 2001; Rabade and Alfaro, 2006) aspects without considering other aspects. Thus, the harmonization between benefits of traceability and three sustainability dimensions are still lacking. The costs have been emerged from governments' regulations. These regulations are enforced in order to retain human and/or environmental welfare by forcing firms to implement traceability systems. The main objective is for recalling contaminated foods or detecting illegally obtained animal that would lead to environmental effect (for example, illegally caught fish) (Jacquet and Pauly, 2008). Relationships between traceability and sustainability in the supply chain are still needed to be identified in order to find out how traceability turns into benefits or burdens of the firms. Consideration of sustainability in holistic view by using traceability would create better future development for all the parties in the supply chain.

1.4. Purpose and research questions

The purpose of this thesis is to identify the role of traceability in sustainable supply chain management and to investigate how traceability affects sustainability in terms of economy, society and environment.

In this thesis, the following research questions will be answered:

Research question 1: How every dimension of sustainability can be supported with traceability?

Research question 2: Regarding traceability, how engagement in social and environmental responsibilities can create long-term economic success for firms in supply chain?

2. Methodology

The research methodology used for writing this thesis is literature review. The primary purpose of the literature review is to achieve a holistic understanding of the research area, to obtain an insight of what kinds of research have already been accomplished related to the research questions, and to identify areas of interests for further investigation.

There are three sections of this chapter. The first section is a brief introduction of the characteristics of the selected databases. The second part is a description of key words and journals that have been used during the literature review process. The third part is the research methods that are applied in the selected journal papers.

2.1. Databases selection

A general search for articles was carried out in three databases called *Emerald, SciVerse Scopus*, and *Science Direct* by the authors. These databases were selected due to their comprehensive content within worldwide business journals, which could provide a large number of articles that are relevant to the thesis' topic. The characteristics of each database are illustrated as follows:

Emerald

Emerald is a long established publisher with over two hundred titles in the fields of management, information science and engineering and all the research journals are peer-reviewed to ensure the quality of research (Emerald, 2011).

SciVerse Scopus

SciVerse Scopus is the world largest abstract and citation database of peer-reviewed literature and quality web sources with smart tools to track, analyze, and visualize research. It offers researchers a comprehensive resource to support their research needs in the scientific, technical, medical, and social sciences fields (Scopus, 2011).

Science Direct

ScienceDirect is a leading full-text scientific database offering journal articles and book chapters from more than two thousand five hundred peer-reviewed journals and more than eleven hundred books. The platform offers sophisticated search and retrieval functionality that enables the researchers to maximize the effectiveness of their knowledge discovery process. Furthermore, many authors have submitted extra value-added content associated with the research, such as audio and video files, datasets and other supplementary content, effectively accelerating research beyond the print format, which could also helpful the researchers to gain a holistic view (ScienceDirect, 2011).

The process of reviewing the academic literature is to identify the current situation in the relevant research areas and existing trends. As quality and quantity of material were identified through the literature review, the authors consider that the selected databases provided sufficient relevant resources to support this thesis.

The reviewed papers the author selected are all from academic journals of these three databases.

2.2. Key words and journal selection

Keywords that were chosen for searching journal papers from the databases can be found below, which elicited the majority of the authors' references. The authors conducted their research within the framework of traceability, sustainability, logistics and supply chain management. At the early stage of the process, the authors searched "traceability" and "supply chain" together in order to get a general idea about the current situation of traceability implementation in industry, and then the results indicate that in recent years, food industry and food products draw most attention from academe.

Combinations of keywords were used to expand the search results: traceability, traceability supply chain, sustainability supply chain, traceability sustainability, sustainable food supply, quality management, environment supply chain, sustainable logistics, food traceability.

In the literature review, the authors have only focused on scientific journals that were published no earlier than 2000, which could provide the possibility to access to the latest achievements in every related field. Since the journal papers have passed review processes, which usually includes a double peer review process and is under control of the editor of the journal, therefore, usually the journal papers have an acceptable level of validity, rigor and reliability. The selection process began with initial checking of literature on abstracts then eliminating articles beyond the scope of this thesis. Then deep review was conducted to each relevant paper. Related topics in relevant papers were searched and passed through initial checking and deep review. Selection process resulted in eighty-two relevant articles from diversiform academic fields, which includes but not limits as follows: traceability technology, food safety, food traceability system, agriculture economics, sustainable food development, operation management, industrial marketing, logistics management and so on.

The following numbers are the eighty two reviewed papers' number which can be found in the reference list at the end:
[1][2][3][4][5][6][7][8][9][10][11][12][14][16][17][18][19][20][21][23][25][27][29][34][36]
[37][38][40][46][47][49][50][52][53][54][55][56][57][58][59][60][61][63][66][67][68][69][70]
[71][72][73][74][75][76][77][78][79][82][84][86][87][89][90][92][93][94][95][96][99][101][102]
[104][105] [107][111][115][116][119][120][121][122][124].

A list of journals and number of paper is shown below (Table 1):

Table 1 The list of journals and the number of papers

Journal's name	Number	Journal's name	Number
Advanced Engineering Informatics	1	International Journal of Logistics Management	1
Agricultural Sciences in China	1	International Journal of Production Economics	2
Assembly Automation	1	International Journal of Retail & Distribution	1
British Food Journal	9	Journal of Agribusiness	1
Business Strategy Series	1	Journal of Business & Industrial Marketing	2
Canadian Journal of Agricultural Economics	1	Journal of Consumer Protection and Food Safety	2
Computer Science	1	Journal of Food Engineering	5
Computers and Electronics in Agriculture.	2	Journal of Marketing	1
Computers in Industry	4	Journal of Operations Management	1
Engineering Applications of Artificial Intelligence	1	Journal of Pharmacy Practice	3
Environmental Impact Assessment Review	1	Journal of Purchasing & Supply Management	1
Eur J Law Econ	1	Journal of Supply Chain Management	3
European Journal of Operational Research	1	Journal Revue Scientifique et Technique	1
Food Control	5	Livestock Production Science	1
Food Policy	4	Logistics Information Management	1
Forensic Science International: Genetics Supplement Series	1	Management and Organization Review	1
Geoforum	1	Marine Policy	2
Industrial Management & Data Systems	1	Marine Pollution Bulletin	1
Information and Software Technology	1	Meat Science	2
International Journal of Production Economics	1	Production and Operations Management	1
International Food and Agribusiness Management	1	Review of Science and Technology Off.	1
International Journal of Physical Distribution & Logistics Management	1	Strategic Outsourcing: An International Journal	1
International Journal of Logistics Systems and Management	1	Supply Chain Management: An International Journal	3
International Journal of Information Management	1	Technovation	1

2.3. Analysis of the selected papers

In order to collect the data from the literature in an efficient way, as well as avoid missing any important information, the authors designed a standard table with multiple columns and items then used it for each paper (See Appendix I). Different types of information that relates to paper's content were filled in the table after reviewing, e.g. paper's research method, relevant industry, traceable objects, scope of traceability, control and management through traceability, technical description, sustainability effects through traceability. Then the authors made statistics of the tables' result and summarized the outcome. Each column and items the table contains will be explained in the following chapters by using the addressing papers as references.

3. Traceability in supply chain management

In this chapter, an overview of current traceability systems will be illustrated, which includes the definition of traceability, necessity of traceability, tracking and tracing, principles of tracking and tracing, followed by two different scopes of traceability in the supply chain, and an introduction about different identification and positioning technologies that are mainly used nowadays. Finally, areas of consideration in traceability in the supply chain will be shown by using some tables. This is for illustrating the current research trends and research areas.

3.1. An overview of traceability systems

3.1.1. Definition of traceability

Several organizations and researchers have defined traceability further to their areas of considerations in the traceability, which are as follows:

- *"The ability to follow or study out in detail, or step by step, the history of a certain activity or a process"* (Webster's Dictionary, 2011).
- *"Ability to trace the history, application, or location of that which is under consideration"* (International Organization for Standardization' 1994).
- *"The ability to trace and follow a food, feed, food producing animal or ingredients, through all stages of production and distribution"* (European Parliament, 2002).
- *"Traceability is the ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales or internally in one of the steps in the chain"* (Moe, 1998).
- *"Traceability is a concept relating to all products and all types of supply chain"* (Regattieri et al., 2007).

3.1.2. Necessity of traceability

According to European Commission (2007), traceability is a cornerstone of the EU's food safety policy. Traceability is a risk-management tool which offers the possibility to response to potential risks that can arise in food and feed, and provide the chance for food business operators or authorities to isolate the problem by withdrawing or recalling and then prevent contaminated or unsafe products from reaching consumers. Many researchers pointed out that efficient traceability in food supply chains has the potential to reduce risks and costs associated with food borne diseases and eliminate food safety hazards. For example, traceability reduces medical costs (Hobbs et al., 2005), reduces labor productivity losses (Kelepouris et al., 2007; Lee and Özer, 2007; Chryssochoidis et al., 2009; Veronneau and Roy, 2009; Mehrjerdi, 2010), reduces recall scope and time (Hobbs et al., 2005; Banterle and Stranieri, 2008; Bechini et al., 2008; Bevilacqua et al., 2009), and ensures the consistent safety of food (Pettitt, 2001; Meuwissen et al., 2003; Beulens et al., 2005; Schwägele, 2005). In chapter 5, a deep analysis with more details of this perspective will be presented.

Another function of traceability is that it provides targeted and accurate information concerning a certain product to the customers and enables the customers to acquire the relevant information related to the food safety and quality issue, thus, customers are willing to pay a higher price for products under certain guaranteed circumstances or coming from a desired origin (Hobbs et al., 2005; Loureiro and Umberger, 2007; Summer and Pouliot, 2008; Chryssochoidis et al., 2009). Consequently, companies that can provide such effective traceability systems for their products not only increase safety precautions in operations but also enhance customers confidence and trust through the assurance of quality and safety (Shanahan et al., 2009, Mai et al., 2010). Effective traceability systems can also add more value of the products then enhance the total profits. This can be viewed as a mutual benefits situation (Chryssochoidis et al., 2009).

Proper traceability systems also have a potential to decrease the probability of a supplier or an operator with responsibility for a product safety problem by providing well-documented traceable data to prove that they comply with regulatory requirements and do not present risks (Meuwissen et al., 2003; Sahin et al., 2007; Fritz and Schiefer, 2009). In that condition, liability claims and lawsuits will be avoided and company image will not be affected (Mai et al., 2010).

3.1.3. Tracking and tracing

van Dorp (2002) points out that there is no uniform understanding of tracking and tracing. The definitions vary from the dimensions of the type of activities that are included and the organizational context in which they are performed. Stefansson and Tilanus (2000) indicate that tracking usually stands for following the entity on its way from A to B, while tracing stands for finding the entity between A and B. Schwägele (2005) defines tracking as *"the ability to follow the path of an item as it moves downstream through the supply chain from the beginning to the end"*, and tracing as *"the ability to identify the origin of an item or group of items, through records, upstream in the supply chain"*. Figure 1 shows information flows of tracking and tracing in the supply chain.

Although the quality of the transportation process could be very high, a tracking and tracing system could still bring benefits from other aspects. According to Stefansson and Tilanus (2000), it could be applied for administrative purpose, for example, serving as a basis for payments to haulers. Furthermore, the collected data could be statistically processed and established into an information system to confirm if the quality of the process is maintained at a satisfied level. Traceability also covers everything related to the products before, during and after the manufacturing, packaging, and distribution process, which involves ingredients, processes, test and test results, environment, resources used, transport methods etc. (Schwägele, 2005).

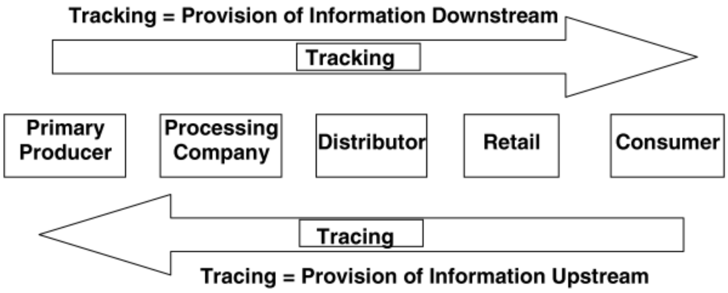

Figure 1 Information flows of tracking and tracing in supply chains (Schwägele, 2005)

Based on van Dorp's (2002) finding, by considering the quality variation on tactical and operational production levels, two types of tracking and tracing definitions could be established, tracking and tracing in a restricted sense and tracking and tracing in an extensive sense (van Dorp, 2002). The characteristics of each type can be found in figure 2. The main difference between tracing in a restricted sense and tracking and tracing in an extensive sense is that the later one encompasses the former one and enables the traceability information to be used in multi-dimensional areas in the supply chain instead of only focusing on tracing products.

Tracking and tracing in a restricted sense	Tracking and tracing in an extensive sense
➢ Provides real-time visibility and disposition ➢ Creates historical record for the traceability of components and usage of each end product ➢ Provides forward and backward traceability	➢ Encompasses tracking and tracing in a restricted sense ➢ Information is used in the control and management of successive stages of production ➢ Provides dynamic lot allocation ➢ Optimizes and controls of processes in and between separate links of the supply chain

Figure 2 Two types of tracking and tracing (van Dorp, 2002)

3.1.4. Principle of tracking and tracing

Stefansson and Tilanus (2000) point out that a tracking and tracing system should include the interface between a physical transportation system and an information system. They classified tracking and tracing systems by eight attributes.

Goods identification technology. For example, alphanumerical codes, bar codes, RFID etc. Descriptions with more details of these identification technologies are in section 3.3.

Scope of the tracking and tracing system. The scope of the tracking and tracing system is defined by the three dimensions of transformation: transportation (transformation of place); storage (transformation of time); conversion processes throughout the supply chain (transformation of form). Scope of traceability with more details from researcher (van Dorp) and association (GS1) will be illustrated in section 3.2.

Registration timing and placing. Sometimes tracking is done at discrete times and places which needs to register the time and place. For example, when the possession of the shipment passes from one hauler to another, which may involve different modes of transportation, in this situation time and place need to be recorded to keep the integrality of transportation information.

Hierarchical level. Discrete registration instance may refer to different hierarchical packaging levels and different hierarchical assembly levels.

Attributes recorded. A tracking and tracing system may record three attributes: the identity of the entity, the current location and the current time. Additional entity attributes such as the quantity, (if the shipment complete when the shipment consisting of several units) and the quality (if any observable damage occurred).

Organization of the information system. The information system that stores tracking and tracing data may be centralized or shared by multiple participants.

Accessibility of the information system. A tracking and tracing system should provide the possibility for interested parties to follow and find entities travelling from A to B. There are two types of accessibilities of the information system. Non-automated, queries have to be made and answered manually; automated, queries can be made automatically no matter the information is centralized or decentralized, by EDI or via the Internet.

Activity level of the tracking and tracing system. A passive tracking and tracing system registers entities in fixed places at the moment they arrive or leave. An active tracking and tracing system monitors the progress of the entity from checkpoint to checkpoint and signals the user if something unexpected is registered.

3.2. Scope of traceability

In this section, two types of traceability scopes from literature will be introduced briefly.

van Dorp's perspective

Companies and organizations usually do not act as a sole party in the large network but often linked and interacted with each other by markets of supply and demand. When it comes to traceability, all these different relationships should be taken into consideration since they may generate different traceability requirements, and thus have diverse impacts on the participants (van Dorp, 2002). According to van Dorp (2002), the business scope of traceability can be depicted with four perspectives shown in figure 3 and followed by a description of each perspective.

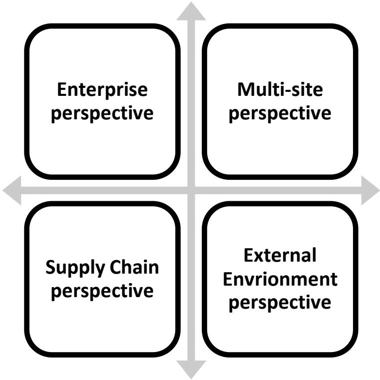

Figure 3 Four perspectives of business scope of traceability (van Dorp, 2002)

Enterprise perspective

The first perspective is enterprise perspective which holds the view within one company, usually refers traceability to trace horizontally. However, traceability scope in the enterprise context should be broadened than just historical record keeping, which means address information in different management level to make it vertically integrated. Under this situation, strategic, tactical and operational control and planning level will be differentiated.

Multi-site perspective

Manufacturers, especially in semi-process industries usually have multiple plants in different sites, sometimes even different countries based on allocation tactic, which results in that multiple material flows as well as information flow and traceability information has to be operated under such complicated context. Consequently, more attention of setting up functional traceability system to meet different processing requirements is demanded.

Supply chain perspective

Supply chain can be considered as a network with two or more enterprises and an integrative approach for dealing with material planning and control from manufacturer, supplier, and distributor until the end consumer. Based on this viewpoint, proper traceability demands accurate management of all types of necessary information from the supply chain.

External environment perspective

External environment involves the official and authoritative control of products by regular inspection to verify compliance with foodstuff legislation with the purpose of protecting consumer’s interests. This perspective also includes functional labeling of products to ensure that consumer acquire necessary information related to composition of the products, manufacturing approach, storing methods and preparation which to protect consumer’s safety. Furthermore, liability for defect product is also mentioned in the literature concerning the liability of the manufacturer for damages or loss caused by defectiveness.

GS1’s perspective

GS1 is an international non-profit association which is dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors. The GS1 system of standards is the most widely used supply chain standards system in the world (GS1, 2011).

Traceability management through the supply chain involves the integration of information flow and physical flow of traceable items (see figure 4.) Based on GS1, each factor must perform its own role properly in order to make the whole chain functional and meet the certain traceability requirement (GS1, 2007).

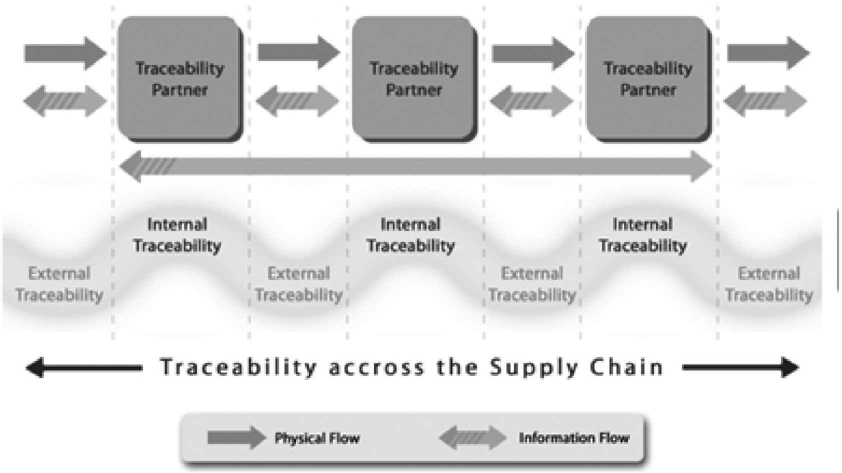

Figure 4 Traceability across the supply chain (GS1, 2007)

The following part will introduce each factor and describe their main characteristics.

Traceable item

"A traceable item is a physical object where there may be a need to retrieve information about its history, application, or location." For example, shipments and logistic units (which may contain pallet or container). (GS1, 2007)

Traceability partner

Traceability partner can be defined as *"All the parties that involved in the supply chain which could be enterprises, organizations and authorities."* (GS1, 2007) Parties that can be viewed as traceability partner include third party logistics provider (3PL), processor/ manufacturer/ primary producer, retailer/point of sale or service operator, warehouse/ distribution centre and authorities.

Internal traceability

Internal traceability takes place *"when a traceability partner receives one or several instances of traceable items as inputs that are subjected to internal processes, before one or more instances of traceable items are output"*. This process must consist of one of the four sub-processes: movement, transformation, storage and destruction. (GS1, 2007)

External traceability

External traceability takes place *"when a traceable item is physically handed over from one traceability partner to another"*. Activities that external traceability takes place can be distinguished into transportation where traceability is used to monitor product/material monitoring during transport and actors' coordination where traceability is used to coordinate activities between firms (Veronneau and Roy, 2009).

Figure 5 illustrates relationships between GS1 traceability scope and each activity in supply chain.

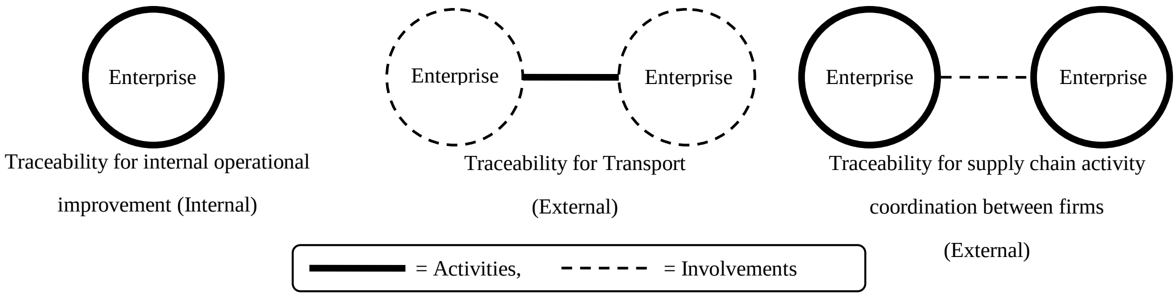

Figure 5 Relationships between traceability scope and activities in supply chain (van Dorp, 2002; GS1, 2007)

Physical flow and information flow

Traceability in the supply chain encompasses all participants and activities associated with the different flows. Physical flow refers to the transformation of goods from raw materials to final products to the end user, as well as the associated information flow which goes to two directions to both upstream and downstream.

A unified view

In summary, van Dorp's scope of traceability is identified in four perspectives (enterprise, multi-site, supply chain, external environment) while GS1 defines the scope of traceability as internal and external perspectives. By using both scopes together, actors and relationships of supply chain traceability can be fully identified. Figure 6 illustrates a unified view of van Dorp's and GS1's scope of traceability. The upper half depicts the scope by GS1 and the lower half depicts the scope by van Dorp.

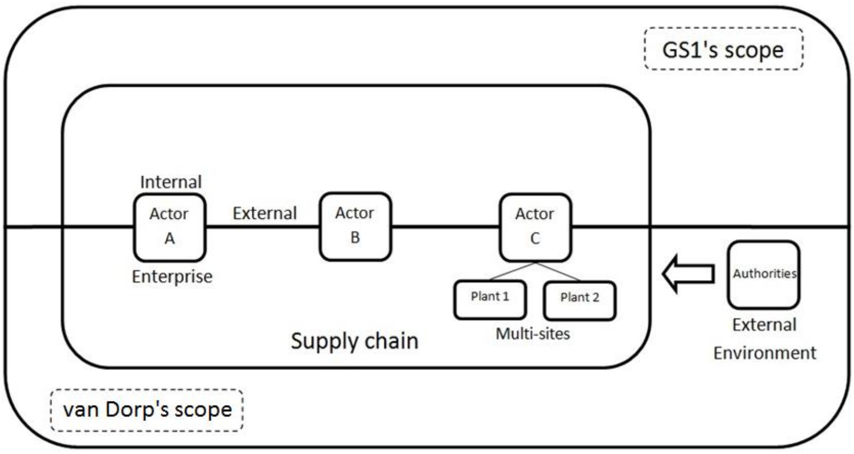

Figure 6 A unified view of van Dorp's and GS1's scopes of traceability (van Dorp, 2002; GS1, 2007)

3.3. Technologies in traceability systems

In order to implement traceability from the concept into action, traceability must be managed by setting up a traceability system, which can keep tracking of product routes and the selected data for further use (Moe, 1998). This results in identification and localization technologies as important tools for traceability. Product identification is significant in the whole product handling process, especially in the traceability of goods and could save a lot of time and labor if dealing properly. The more traceability information that traceability system can record and provide (e.g. production time, batch number, production conditions), the more focused and efficient the product recall can be, therefore, minimizing loss of money and reputation (Moe, 1998). Nowadays, the most common and widely used identification and localization technologies are, mainly, alphanumerical codes, barcode labels and Radio Frequency Identification (RFID) tags, together with the newly developed technologies, GPS and GIS (Rizos, 1999; Lai et al., 2005; Regattieri et al., 2007; Qu et al., 2008; Bechini et al., 2008; Abad et al., 2009).

3.3.1 Alphanumerical codes

Alphanumerical codes are a sequence of numbers and letters of various sizes present on labels, and the labels will be put on products or on products' packages (Regattieri et al., 2007). The design and the principle of an alphanumerical codes system are very simple and economical, but the huge drawback is that it requires a great deal of human resources to operate and manage for both code writing and code reading. This non-automatic process results in large labor cost, while at the same time performance may not be quite satisfied since it is almost impossible to avoid mistakes with a large amount of manual data (Regattieri et al., 2007; Abad et al., 2009). Alphanumerical codes are usually generated by company or organization itself and there is no standard, which makes it difficult for sharing among different parties (Regattieri et al., 2007).

3.3.2 Bar Code

A barcode is an optical machine-readable representation of data, which manifests data of the object property to which it attaches. Bar codes provide a rapid, accurate, and low cost approach to encode information which can be easily read by inexpensive electronic readers. The emergence of bar code has improved the efficiency of handling process along the supply chain and made great contribution to traceability. This automatic, high reading speed, precise technology provides simpler, more economical, and accurate traceability systems (Connolly, 2005; Zhao et al., 2009; Mehrjerdi, 2010).

By implementing bar codes, data can be read automatically thus eliminate the potential errors from manual data input. Bar codes act as a useful tool for business data collecting, processing, transmitting, recording, and managing, which can apply and bring benefits in various fields and industries such as manufacturing, distribution, warehousing, and retail (Flott, 2002; Connolly, 2005; White et al., 2007).

3.3.3 RFID

Radio frequency identification (RFID) is a technology that uses radio waves to automatically identify objects, often considered the next stage in the barcode evolution (Srivastava, 2004; Kelepouris et al., 2007). It contains a wireless microchip attached to an antenna in the tag, and the antenna enables the microchip to transmit the identification information to a reader then the reader converts the radio waves reflected back from the RFID tag into digital information. This makes the reading phase swift and fully automated without physical contacting or sight positioning with the reader (Kelepouris et al., 2007; Abad et al., 2009). Generally, RFID tags are difficult to counterfeit and have extremely high data integrity. Even under stringent operating environments such as snow, dust, corrosion, and vibration it can still function well (Srivastava, 2004).

Major retailers such as Wal-Mart and TESCO as well as their suppliers have implemented RFID at the pallet level (Lai et al., 2005; Lee and Özer, 2007; Zhou, 2009). RFID tags can be read without scanning the object manually such as in traditional bar-codes and this automated data capture process can achieve significant labor savings (Kelepouris et al., 2007; Lee and Özer, 2007; Veronneau and Roy, 2009).

Based on the reviewed literature, RFID is the one that mentioned most in frequency by the researchers, which shows up in thirty five papers of the eighty two reviewed papers, and bar code is the second one which appears in fifteen papers of the eighty two reviewed papers. This matches the current situation that RFID and bar code are the dominant identification and traceability technologies in industry (Lai et al., 2005; Li et al., 2006; Lee and Özer, 2007).

3.3.4 GIS

Geographic information system (GIS) is a computer-based tool for spatial information management. GIS can organize, analyze, manipulate and manage spatial information in an intuitive way and provide the user with visual information accurately (Qu et al., 2007). According to Buckley, an operational GIS has several important components which include hardware, software, data, people, method that integrate together to make the system work (Buckley, 1997).

Since GIS can provide general configuration and features of the earth's surface and implantation of agricultural products, so the cultivated areas can be divided and coded according to the geographical information that GIS obtains. Then each area has a unique code as an ID in the database which connects with the production information, e.g. fertilizer management, pesticides, feeding-stuff and ambient water quality, thus, the origin place of production becomes visualized in the whole supply chain management system. (Deng et al., 2008) Furthermore, the information in the database mentioned above can also be viewed as valuable information for sustainable development since the administration department can use the information to estimate the environment capacity and then control the amount of planting.

Research of the International Centre for Science and High Technology of the United Nations Industrial Development Organization (ICS-UNIDO) also shows that, when applying GIS as a traceability tool under supply chain context, it can offer a considerable opportunity for agriculture practices such as agriculture site planning, land use management, information of soil characteristics, climate conditions, fertilizers, pesticides, water consumptions and production yields, which have potential to lead to better risk assessment, food chain management, food chain sustainable development, thus enable GIS as a useful solution to establish the traceability system for sustainable agriculture products (Ghribi et al., 2010).

It should be mentioned that GIS has possibilities and potential to contribute to traceability. Literature also mentioned that in the distribution process the product information is dynamic, real-time and variable, which leads to that only coding based on a product origin is far from enough, following up and recording the information is also of great significance but beyond GIS capacity. At this stage, technology such as RFID will play its role to supplement the traceability of the distribution process as well as the supply chain (Deng et al., 2008; Qu et al., 2008).

3.3.5 GPS

The Global Positioning System (GPS) is a satellite-based radio-positioning system based on a constellation of twenty four satellites continuously orbiting the earth. It was designed, financed, deployed and operated by the United States Department of Defense (DOD), for its tremendous application as a military locating utility (Rizos, 1999). These satellites are equipped with atomic clocks and send out radio signals of the exact time and their location. These radio signals are picked up by the GPS receiver then it can triangulate its precise location on the ground (i.e., longitude and latitude) from the known positions of the satellites. With four or more satellites, a GPS receiver can determine a 3D position (i.e., latitude, longitude, and elevation) (Rizos, 1999; Dana, 2000; Hart, 2007).

Since GPS can provide real-time, three-dimensional positioning and navigation all year around and all over the world, GPS has a rapid development in civil use and has demonstrated a useful positioning tool world-wide. (Rizos, 1999; Dana, 2000). In transportation applications, GPS assists pilots and drivers in pinpointing their locations and avoiding collisions (Rizos, 1999; Hart, 2007). GPS can be used as a tool of the traceability system in fishing process to collect information regarding fishing grounds, catching time and landing time. With such information each vessel's location and consequently the fishing grounds could be identified, i.e. where the fishing took place, which is essential information as it is the first step in a traceability system and associated with raw material quality control as well as help to avoid over-fishing for regional fishing sustainble development (Galvao et al., 2010).

3.4. Areas of consideration in traceability

Within this section, some outcomes from literature review will be illustrated, including countries mentioned in the literature and supply chain traceability with food supply chain traceability as an example. Presentation of such results will provide insights that are already published within this research area.

3.4.1 Geographical focus

When it comes to traceability of products, the reviewed papers cover most of the continents in the world except Africa. Europe draws most of the researchers' attention, followed by Asia and North America. Table 2 shows the times that the continents are focused or mentioned in the literature.

Table 2 Geographical focus of traceability in different continents

Countries	Number of paper
Europe	47
Asia	22
North America	17
South America	9
Oceania	4

Within Europe, most papers discuss the traceability issue without pointing a specific country, partly because laws related to traceability of products are legislated by European Union, thus researchers view European countries as a whole. Table 3 shows particular times each European country is mentioned in the literature review.

Table 3 Frequency of countries mentioned

Countries	Number of paper	Countries	Number of paper
General	18	Denmark	1
UK	6	Iceland	1
Italy	5	Switzerland	1
Norway	3	Sweden	1
Netherland	3	Greece	1
Finland	2	Ireland	1
Spain	2	Germany	1
France	1		

As the main exporters of European food market, more and more Asian countries have realized the importance of traceability and started paying more attention to implement traceability system

(Shinkuma and Huong, 2009; Antonio and Lau, 2011; Belton et al., 2011). Table 4 shows Asian countries that are involved in traceability of products in the reviewed literature.

Table 4 Asian countries mentioned in traceability of products

Countries	Number of paper
China	9
Japan	6
Vietnam	4
Thailand	1
Cambodia	1
Bangladesh	1

Table 5 shows countries mentioned in South America, North America and Oceania.

Table 5 Countries mentioned in South America, North America and Oceania

Countries	Number of paper	Countries	Number of paper
US	15	Peru	1
Brazil	4	Chile	1
Australia	3	Argentina	1
Canada	2	New Zealand	1
Colombia	1	General	1
Ecuador	1		

3.4.2 Traceability applications in different supply chains

Based on the literature review, 61% (50) of the reviewed papers discuss traceability of food or food supply chain, and 5% (4) of the reviewed papers talk about traceability of drugs. It is obviously can be seen that food is the main focus of traceability research. Among the fifty papers, seventeen of them discuss traceability of food generally, eleven of them discuss traceability of meat and eleven of them discuss traceability of sea food. The rest of them discuss fruit and vegetables, farm products, water and cheese. Table 6 shows the number of papers traceability mentioned in different industries.

Table 6 Traceability in different industries

Industries	Number of paper
Food in general	17
Meat	11
Sea food	11
Fruit and vegetable	5
Farm products	4
Cheese	1
Water	1

Some papers do not have specific traceability object but discuss from technical perspective or the development of traceability, whose information are not illustrated in this table.

4. Sustainability in supply chain management

Literature shows that in recent years, the focus on optimizing business operations has extended from a specific section or one participant to an entire supply chain, which is a step for the wildly adoption and development of sustainability since the supply chain involves products from initial processing of raw materials to delivery to an end customer (Linton et al., 2007; Seuring and Muller, 2008).

This chapter will introduce the definition of sustainable development and sustainable supply chain management and then illustrate the interaction between sustainability and supply chain management.

4.1. Key concepts

Sustainable development

In 1987, the report of the World Commission on Environment Development in General Assembly of United Nations defined sustainable development as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* and emphasized this should be a central guiding principle of the United Nations, governments and private institutions, organizations and enterprises (United Nation, 1987). This definition is the most well-adopted and most often quoted one in the literature.

Sustainable supply chain management (SSCM)

Supply chain management is defined by Cooper et al. (1997) as *"the integration of business process from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders"* (Cooper et al., 1997). While diverse comprehensions of sustainability exist, one central concept that could help to develop sustainability is the triple bottom line approach, illustrates that a minimum performance is to be achieved in the environmental, economic and social dimensions (Seuring and Muller, 2008). By integrating sustainable perspective into supply chain management, Carter and Rogers (2008) define sustainable supply chain management (SSCM) as: *"the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains"*. This definition is based on the triple bottom line model which is shown in Figure 7. In this model, environmental and social sustainability mean contributions for environment and society, while in the economic dimension, sustainability refers to contributions to firms' economies in supply chains. There is another definition by Seuring et al., (2008) for SSCM is that "*the management of material and information flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social, and stakeholder requirements into account*".

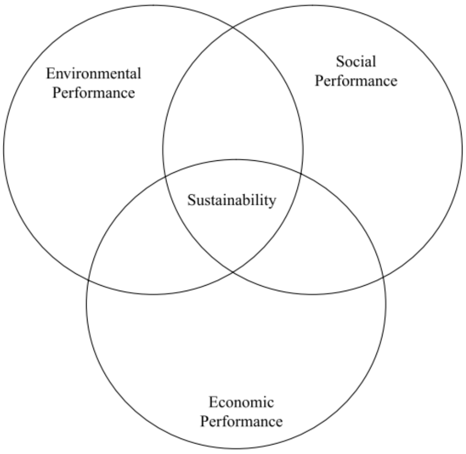

Figure 7 Triple bottom line model of sustainability in supply chain (Carter & Rogers, 2008)

4.2. The interaction between sustainability and supply chain management

Carter and Rogers (2008) found that creation of sustainability involves some factors as causal antecedents in which are required for sustainable supply chain. Regarding these factors, four supporting facets are: risk management, transparency, strategy, and organizational culture.

Risk management

Shrivastava (1995) indicates that within sustainability context, firms should not only focus on short-term financial results, but also take the potential risk factors into consideration such as harm (resulting from products, environmental waste), workers, and public safety. Zsidisin et al. (2000) define supply chain risk as *"the potential occurrence of an inbound supply incident which leads to the inability to meet customer demand"*. Based on the research of Carter and Rogers (2008), such supply chain risks can result from natural disasters, legal liabilities, inadequate demand forecasting and failure to coordinate demand requirements across the supply chain, shipment quantity inaccuracies, and poor environmental and social performance by a firm and its suppliers which may lead to costly legal actions. Finally supply chain risk management is defined as *"the ability of a firm to understand and manage its economic, environmental, and social risks in the supply chain"* (Carter and Rogers, 2008).

Transparency

Transparency or visibility is created from consumers' demand for companies to maintain legitimacy. Carter and Rogers (2008) note that due to rapid speed of communication via internet and globalization of supply chain, maintaining the secrecy of corporate wrongdoings has become very difficult and extremely risky. They emphasize that *"The actions of a company's facility or supplier this morning in a remote part of the world may be this evening's headline news"*. Transparency does not only include sharing information to stakeholders, but also engaging stakeholders and using their feedback and input to both secure and improve supply chain processes. Transparency makes things simpler, and simpler is cheaper in the long run.

Besides transparency in supply chain perspective, transparency that public needs is the transparency ensures that firms have complied with proper safety standard (Hobbs et al., 2005), merchandise high quality product (Banterle and Stranieri, 2008), properly practice with labors forces (Folinas, 2006), and abides law and regulation to maintain or increase public welfare (Ling, 2006). In the environment perspective, public requisition is also to make sure that firms do not violate environmental law and regulation and preserve the environment (Jacquet and Pauly, 2008; Martinsohn and Ogden, 2008).

Strategy and organizational culture

A summary from Carter and Rogers (2008) about strategy and culture is to set a company goal to include sustainability. By including sustainability in the goal, the firm's strategy will be set to achieve sustainability. Other processes and operations in supply chains will be built around this goal.

With these supporting facets above, a more specific figure (Figure 8) is indicated by Carter and Roger (2008). From their point of view, the area which covers all three dimensions would be the best practice for sustainable supply chain management.

In the analysis part, the authors will make efforts to figure out how traceability can bring benefits from multi-dimensional perspectives for sustainable supply chain management. Furthermore, several case studies that cover one sustainable dimension, two sustainable dimensions and three sustainable dimensions will be selected and analyzed in chapter 6 and 7.

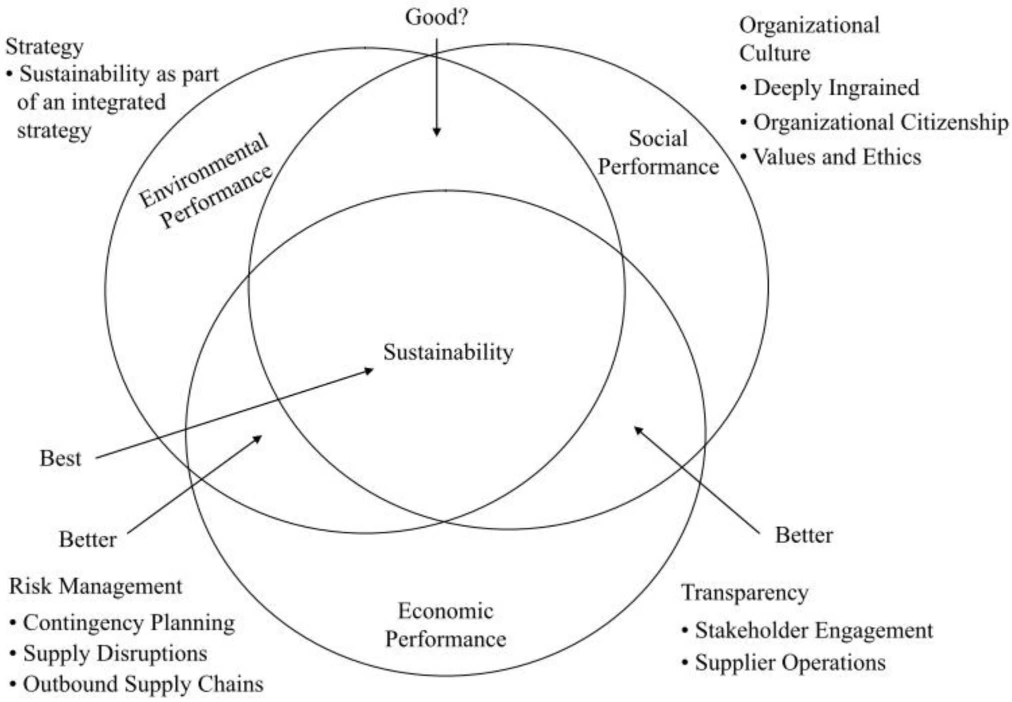

Figure 8 Sustainable supply chain management (Carter & Rogers, 2008)

5. Traceability and sustainable supply chain management

This chapter identifies effects of traceability on each sustainability dimension. In the literature review, traceability has either or both positive and negative impacts. These different impacts occur due to the different ways traceability functions on each dimension. Three case studies will be provided related to single and multiple sustainability dimensions.

5.1 Traceability for economic sustainability dimension

Traceability has both negative and positive effects on the economic dimension. Positive effect refers to any process or activity enabling monetary gain or protection from monetary loss. On the other hand, negative effect refers to monetary loss. The following categories explain how traceability creates positive and negative economic effects on firms in supply chains.

Cost saving

Cost saving is an attribute which is obtained by traceability as protection against monetary loss. There are several incidents that firms in supply chain have to face with declination of profits and/or revenue when they fail to implement traceability. For example, products recall leads to high monetary loss for firms, damages firms' reputation and reduces stock price (Skees et al., 2001; Chen et al., 2009). Skiltons and Robinson (2009) mention a case of a complex supply chain of a food company ConAgra that made recalls for pasta and meatballs regarding ingredients contamination. Since it has complex supplier networks and could not trace the origin of these ingredients, several hundred thousand of products were recalled. When traceability is applied by firms in supply chain, for example, in manufacturing and designing processes, they can closely monitor products conditions. Monitored products will have fewer possibilities to be defected and will meet specifications set by the firms, consequently ensure the quality to a certain level. Product monitoring enables cost saving against defective product recall (Lyles et al., 2008).

Another factor that can reduce the cost of recall is precisely identifying the source of contamination or defection. Kumar (2006) mentions that in case of recall, traceability would enable withdrawal from a specific production line instead of massive recall. Some literature (Hobbs et al., 2005; Bechini et al., 2008; Charlier and Valceschini, 2008) mentions similar terms about precise item identification for recall that would reduce costs. Meuwissen et al. (2003) state that traceability enables recall at a higher level (for example, batch level) which leads to cost saving from massive recall.

Cost saving also can be gained by improving operational performances in a supply chain. Traceability in this context usually involves implementation of RFID technology (in which will be further called as "RFID traceability"). RFID traceability capacitates resource reusability. Martinez-sala et al. (2009) and Chryssochoidis et al. (2009) denote that RFID creates better management of returnable transport items (e.g., tote bags and pallets) and hence enables asset cost savings. Pallets can be tracked for their usage and location and then being reused again. RFID traceability also creates possibilities to reduce inventory cost. By using RFID tag attached to a product, all activities related to these products can be precisely coordinated based on the product itself by providing information to instruct actors about what, when, and how to deal with the product (Chryssochoidis et al., 2009). This could decrease coordination cost since all parties in supply chain do not need to invest in the information systems to store the data for each item locally in order to process the items (Chryssochoidis et al., 2009). If manufacturing time or delivery time on an RFID attached item is shared by all parties in the supply chain, this coordination may lead to non-early arrival of items to be stored then the storage cost could be reduced (Kärkkäinen et al., 2003). Lee and Özer (2007) and Mehrjerdi (2010) have conducted literature review on how inventory cost can be reduced from RFID traceability of products and raw materials, their summary shows that traceability with RFID can reduce inventory cost regarding more visibility for products. For example, discrepancy between recorded items and actual items caused by theft, damages, misplaced can be easily detected. Beulens et al. (2005) also point out that traceability could help to detect/prevent the discrepancy. Accurately recorded inventory leads to stock reduction then cost reduction (Mehrjerdi, 2010). Veronneau and Roy (2009) studied about cruise supply chain and indicated the same cause and additionally mentioned that by precisely identifying numbers of items in the inventory, the cruise company can store fewer items as safety stock. However, cost saving can be insufficient if relative labor cost for manual inspection is very low. An evaluation of a cost-benefit framework on electronic traceability system conducted by Chryssochoidis et al. (2009) also emphasizes that having inventory accuracy leads to lower inventory costs in the real practice.

Labor cost is a main consideration for RFID traceability. Literature studies from Lee and Özer (2007) and Mehrjerdi (2010) show that RFID system can reduce labor cost for goods receiving, stock counting, item scanning and checking in general supply chain operations, while Kelepouris et al. (2007) also indicates that RFID can reduce the cost of manually barcode scanning (which can be considered as another type of traceability). Veronneau and Roy (2009) show that RFID can reduce arrival item checking time consequently can reduce working hours for labor force (however, the cost has to be balanced between RFID implementation cost and labor cost since sometimes cost for manual operations by labor force is cheaper than RFID systems). Traceability with RFID can reduce manual transaction recording cost by labor force and also reduce transaction cost itself by ease of finding information and higher speed of communication (reduce the cost of maintaining accurate information, and time consumed from searching of irrelevant data) (Chryssochoidis et al., 2009).

RFID traceability can reduce transport cost by monitoring condition of products inside. By closely monitoring item conditions and handling conditions within vehicles, especially temperature abuse of fresh food (storing food at inappropriate temperatures), for instance, fish and vegetables, the cost of product return, removal, and disposal by inappropriate handling can be cut off (Kumar and Budin, 2006; Abad et al., 2009; Decker et al., 2009; Mai et al., 2010). Moreover, cost of reshipping can be reduced as well as increase shipping throughput (Decker et al., 2009). Traceability of vehicle usage enables better transport planning and real time decision making; for example, re-routing, scheduling, travel times monitoring, and traffic conditions monitoring (Marchet et al., 2009). Transport cost can also be reduced by better purchasing planning and replenishment planning because the number of total transport trips could be minimized from a better calculation of the delivery amount (Sahin et al., 2007). If a perishable product condition is tracked and traced, real expiration date would be acquired then purchasing and replenishment quantity could be optimized, which leads to lower transportation cost for less frequent shipping as well as cost reduction from discarding products that are not really expired (Sahin et al., 2007).

Reduction of failure and error can reduce costs in the supply chain. RFID traceability enables better control of product and process in the supply chain. For example, Jansen-Vullers et al. (2003) mention that RFID traceability systems maintain specification of material input and output not to be deviated from a standard and thus reduce the cost of failure. Rabade and Alfaro (2006) point out that implementation of RFID traceability can detect abnormalities in the production, which leads to decrease cost further to specification compliance as mentioned previously. Veronneau and Roy (2009) indicate that reduction of inventory picking error would decrease the cost regarding fewer working hours. Packaging and labeling error also create cost when companies have to recall their products (Kumar and Budin, 2006). A literature study from Mehrjerdi (2010) shows that administration errors from humans, for example, an error in manual recording item in the inventory usually creates cost while RFID traceability can mitigate and this matter is emphasized by Bertolini, Bevilacqua and Massini (2006) that human error in recording operation is a failure factor in the food supply chain.

Traceability can be used to optimize process and resource in supply chains. On-line tracing information can optimize and control processes among different links in supply chains (Jansen-Vullers et al., 2003). The purpose of traceability in this case is to manage the quality of information along the chain which is important for making smooth activity synchronization, for instance, historical relations between lots and/or batches, lot operations and/or batches operation, and production means applied in the operation. Later, by modeling or applying some methods to this information to find the best possibility, supply chain process can be optimized. Robinson (2005) emphasizes the flow of information as *"A smooth and synchronized linkage between dissimilar processes and/or operations is critical to an efficient and operative supply chain."* in which refers to both external and internal supply chain context. By keeping item tracing information, product customization can be achieved easier in production planning and control and made changes between product variants (for example, manufacturing the same car model with different options) more effective (Meyer et al., 2009). The achievement is obtained by higher speed of finding components and tools to manufacture different variants as well as lower error in production process. Improvement of production planning and control can be obtained by acquiring information of operations clearly in which refers to visibility of the internal supply chain. Tracing on information of all parties in a supply chain also improves operational performance (to attain information of how other parties perform), collaborative planning (promotional, production line change), and responsiveness (response to occurred problem). Thus, some firms are able to create unique resources which others could not imitate (Barratt and Oke, 2007). In terms of asset management, Holström et al. (2009) explain that the close loop of asset management will prolong the usage of assets, so the period for the investment can be longer. In this context, it means that information sharing and asset usage tracing allow better asset management and utilization (e.g. in transport boxes and operational equipments). Longer depreciation periods of the asset will directly lead to less frequent purchase and thus reduce the cost (Holmström et al., 2009). Veronneau and Roy (2009) emphasize the importance of asset visibility importance. They conducted a study on a cruise company and explained that missing important technical items in cruise daily operation is costly, since a project team has to be idle until the missing part is available. Connolly (2005) also points out that the lack of visibility of item location would lead to bottlenecks, for example, affecting delay of manufacturing process. Zhou (2009) states that item level visibility using RFID would reduce randomness of component matching in manufacturing, thus a product lifetime can be increased.

Increasing profit/revenue

Traceability has the possibility for not only reducing costs of firms in supply chains but also increasing revenue/profit. By applying traceability in products, quality can be ensured and consequently consumers' confidence is increased. With such confidence, customers show more willingness to pay for safer products (Miles et al., 2005; Hobbs et al., 2005; Chryssochoidis et al., 2009). Consumers' confidence may not depend solely on product safety but also effects to the environement. For example, non modified genetically organism (GMO) products can be sole at a higher price (Roth et al., 2008). Loureiro and Umberger (2007) conducted a survey about how different types of traceability (certifications by government sectors, origin, for example) can ensure consumer's confidence on meat quality. The result shows that different types of certifications have different effects on consumers' willingness to pay but having any kinds of certifications would all increase willingness to pay. Meuwissen et al. (2003) and Fritz and Schiefer (2009) also emphasize that traceability for meat would increase consumers' satisfaction from perceiving safer products. Hobbs et al. (2005) conducted experimental sales on sandwiches with different characteristics of traceability on meat fillings, for example, traceability for inspected processing plant, traceability for animal raised facility, and traceability for meat origin. The result shows that traceability attributes to 35%-40% increasing in sandwich price. This could increase the profit if a producer can maintain the cost of traceability below incremental price (Hobbs et al., 2005). Traceability also creates more responsiveness in supply chains, for example, response to changes of customers' requirements and be able to adapt production activities further to the requirements in a shorter time frame would lead to improvement in customer's satisfaction and so increase profit (Chryssochoidis et al., 2009). A survey conducted by Mai et al. (2010) indicates that traceability in fish supply chains would provide access from a local market to overseas market and attracting new domestic customers.

If distributors or suppliers have visibility on retailers' inventories (be able to trace the retailers' inventories), they would better predict demand at retailers’ side or share information about consumers' orders for better sales (Lee and Özer, 2007), which can increase revenue and potentially will lead to more profit. In the same way, controlling inventory level of retailers enables better product replenishment by monitoring items in shelves and thus increases total sales of replenished items (Lee and Özer, 2007; Zhou, 2009; Mehrjerdi, 2010).

Sales reduction protection

By being inactive in traceability implementation, firms may lose their customers by not being able to prove the quality and safety of the product in the case of a hazardous incident, for example, massive recall may happen if a firm does not implement the traceability system, causing reputation loss, which can last for a generation of people. This situation highly affects sales of the firm (Kumar and Budin, 2006). Traceability, then, can help maintaining sales and reputation. Furthermore, shippers may have to implement the traceability system from customers' requirement in order not to lose their customers (Lumsden and Stefansson, 2007).

Liability assignment

Liability assignment is one of the main utilities of traceability. Traceability can illustrate all participants that are involved in a supply chain when a problem occurs and assigns the responsibility to the right participant, for instance, in case of food borne disease, which participant has to pay for the incident. In freight transport, by implementing RFID traceability of each item (smart item), shippers will be accurately responsible for the lost and/or damaged items (Decker et al., 2009). Sahin et al. (2007) mention that traceability helps identifying actors abusing temperature in cold chains (fresh food). Some fishery firms also use traceability as a tool to prove temperature compliance (Mai et al., 2010). However, liability assignment can be justified to be either benefit or cost. Firms that avoid paying for the catastrophe will get benefits for this kind of traceability while firms that have to pay may suffer bankruptcy (Chen et al., 2009).

Cost increasing

Implementation of traceability is costly. The more precise traceability system is, the higher cost it will generate (Hobbs et al., 2005). In the RFID traceability system, attaching RFID tags to every item is costly (Abad et al., 2009). Not only the tags, but also infrastructure cost is very high (Lumsden and Stefansson, 2007). Loureiro and Umberger (2007) mentioned that both benefits and costs need to be assessed when implementing traceability system. In the case of food industry (e.g. meat), benefit is customers' willingness to pay or price premium, while the cost is an investment of a traceability scheme. Hobbs et al. (2005) and Fritz and Schiefer (2009) also point out that by implementing traceability, benefits and costs are still unclear. In order to gain benefit from traceability, the price in the market, including traceability cost should be at market tolerable level (Regattieri et al., 2007). Therefore, implementation may only increase cost without showing any obvious benefit. Even so, some major retailers can force their shippers to implement the traceability system at no subsidy (Holmström et al., 2009). For firms that are forced to implement traceability without relevant knowledge of how to reap benefits from traceability, it may become costly investment that cannot create any profit (Zhang et al., 2010).

From all attributes in traceability for economic dimension, the authors have generated a summary table of positive effects, negative effects, and the effects that can be both positive and negative on this dimension. Table 2 represents positive effects of traceability for economic dimension. Category refers to in what context the issue relates. All the reviewed papers are numbered, so by the number each paper can be found in the references.

Table 7 Positive effects of traceability on economic dimension

Effects	Category	Issue related	Paper number
Cost saving	Recall	Reduce recall cost from precisely identified defected products	[4][6][11][18][20][38][49][58][59][69][57][111]
		Reduce recall risk	[68][69][105]
	Supply chain performance improvement	Resources reusability	[20] [72]
		Lower inventory cost (shrinkage, lost, miscounted, misplaced)	[10][20][54][57][61][76][116]
		Lower labor cost	[20][57][61][69][76][116]
		Lower transaction cost	[20]
		Lower transport cost	[25][71][94]
		Reduction of return of defect item	[25]
		Damage reduction during transport	[1][25][59][69][72]
		Less failure/error	[9][53][59][68][82][89][116]
		Lower coordination cost	[54]
		Lower defective goods removal cost	[25]
		Process and resource optimization/ better management and cooperation	[5][10][21][50][53][55][69][78][92][116][124]
		Reduce discarded products that are not expired but "best before" date is passed	[94]
Increasing profit/revenue	Product improvement	Increasing of consumers' willingness to pay	[20][38][49][66][69][77][79][101]
	Supply chain performance improvement	Better order prediction	[61]
		Better product replenishment	[61][76][124]
		Enhance collaboration (faster respond to customer order)	[20]
		More responsive production	[20]
Sales reduction protection	Recall	Bad reputation of massive recall	[59]
	Customers' expectations	From unmet customers' requirement on traceability	[67]

Table 8 represents negative effect (-) end effect that can be both negative and positive (+-) of traceability for economic dimension.

Table 8 Other effects of traceability on economic dimension

Effect	Paper number
- Increase implementation cost	[1][38][49][50][66][67][90][112]
+- Assign liability to the right parties	[25][69][77][94]

5.2 **Traceability for social sustainability dimension**

Traceability for social sustainability contributes to increase social welfare. Based on the literature review, benefits of traceability for social dimension are elaborated in this section.

Consumer and public protection

In literature review, most of the papers are found that they involve reduction, prevention, and control occurrence of food hazard regarding the regulatory framework by governments, for instance, EU food labeling policy (Loureiro and Umberger, 2007), EU laws for traceability (Regattieri et al., 2007), Canadian Agricultural Policy Framework (APF) (Hobbs et al., 2005), and US Food and Drug Administration (FDA) policies (Bechini et al., 2008).

Many academic researchers based their research of traceability on these policies to improve supply chain performance and/or cope with regulatory enforcement (totally 34 papers, see table 9). Regulatory framework for food safety is to control these following hazards:

- Diseases that can be transferred from livestock to human, e.g. Bovine Spongiform Encephalopathy (BSE) (Meuwissen et al., 2003; Loureiro and Umberger, 2007)
- Chemical contaminations, e.g. Medroxy Progesteron Acetate (MPA) and Dioxin (Meuwissen et al., 2003)
- Livestock epidemics, e.g. Hog cholera, foot and mouth disease, Aujeszky’s disease, Johne’s disease, and Scrapie (Pettitt, 2001)

Traceability controls food hazard by tracking and tracing various data from a farm gate to a consumer plate. For example, in the meat sector, newly birth calves are tagged and registered, while these calves are moving to other facilities until they grow up. All farms involved will be recorded. When cows are slaughtered, slaughter house may register this process and label on product batches (Pettitt, 2001). However, regulatory requirements on livestock traceability vary from a country to another country. Some countries may require every step in process, while some countries may require only animal origin (Kumar and Budin, 2006).

Genetically modified organism (GMO) food can also be considered as a potential harm for public health. Even effect from GMO products with human health has not been clearly identified but consumers have the right to know or be able to trace back to producers to make sure whether the food they are going to buy is GMO or not (Miles et al., 2005; Regattieri et al., 2007).

Mislabeling of food, for example, mislabeling one type of fish to another type, may cause food hazard since some type of mislabeling fish come from contaminated water area (for example, water area that contains mercury and lead). Another consequence is that improper labeling information may lead to consumer’s allergy problems (Jacquet and Pauly, 2008).

By better tracing of contaminated food, scope of food borne illness can be under control (Hobbs et al., 2005). Public medical cost is reduced and public is prevented from losing productivity by reducing illness. Traceability also forces firms to expose real information to public. In liability perspective, traceability can turn to be a tool for consumers concerning food safety. Since traceability expose which participant in a supply chain has to pay for food hazard incident, firms along the chain tend to be more careful with their operations and activities (Hobbs et al., 2005).

Concerning liability, traceability does not only increase welfare by oppressing firm paying the fine in the food hazard incident, but it can force these firms to be more responsible for their products by closely monitoring product quality to prevent problems. Thus, consumers get higher quality and safer products (Kher et al., 2010).

Apart from food, some papers identify consumers' welfare in terms of other types of products. As the authors mentioned earlier in economic dimension, traceability in a whole supply chain enables a focal firm to monitor its suppliers to control their manufacture and design quality. This control does not only reduce the cost of the supply chain, but also increase consumers' welfare by providing higher quality and standard complying product (Hamprecht and Corsten, 2005; Lyles et al., 2008).

Another aspect on consumers' welfare is to pay for a product regarding its condition. For example, in food manufacturing, by analyzing traceability data in cod fish, analyzed information can be used to improve fishing and other related practices to improve product quality and safety (Galvao et al., 2010). Quality of products can turn to be selective attribute for customer choice. Sahin et al. (2007) note that traceability of temperature sensitive food can provide more price alternative for consumers. Consumers may would like to pay more or pay less further to products' shelf lives.

In contrast to increasing choice for consumers, swindling is a factor that negatively affects consumers' selection. Intentionally, mislabeling from one type of fish to another type, for example, channel catfish to southern trout, would increase fish price and hence make customers unintentionally pay more for a lower value product (Jacquet and Pauly, 2008). Traceability exposes the real information to customer and prevents producers from swindling (Roth et al., 2008). In terms of counterfeit product, Lai et al. (2005) summarize literature on how RFID creates benefits on this issue. They mention that, by tracing products from consumers to manufacturers, it is feasible to detect if products are faked (i.e. electronic devices, toys, etc.).

Drug is also a main consideration of counterfeit product. Since there are many counterfeit drug cases filed to U.S Food and Drug Administration, RFID traceability is widely implemented in drug industry (Bernstein and Shuren, 2006). Counterfeit drugs were estimated to be around 5-8% in the market in 2004 (Mehrjerdi, 2010). RFID tags can be used as electronic pedigree (e-pedigree) to confirm movements, business transactions, regulatory requirements, and genuineness of drugs

(Bernstein and Shuren, 2006; Celeste and Cusack, 2006; Ling, 2006). Counterfeit drugs are separated from other counterfeit product since in drug industry, illegal issues are not limited only to counterfeit. The other problems are stolen, mislabeled, adulterated, illegally sold hazardous drugs, and illegally obtained drugs (Ling, 2006). Illegally obtained drugs refer to authentic drugs that are not obtained from legitimate approach. For example, wholesalers purchase drugs from clinics or hospitals at cheaper price (because the price is substitute for patients in order to buy at acceptable price) and resell at normal market price. Electronic-Pedigree can also identify if drugs have been speculated earlier for price incentive, for instance, speculating when the price is low then sell later with discounts when the price is higher (Ling, 2006). Consumers have to pay for additional cost of traceability to secure themselves.

Local business protection and competition protection

Global sourcing together with hiding the fact that food ingredients are sourced from other countries may affect domestic farm business (Roth et al., 2008). Traceability would help exposing this issue and help society decide whether they want to preserve socio-economic assets or not (Wier et al., 2008).

On the fair competition perspective, hiding information of low cost foreign suppliers could block other companies to access the same sources. This situation hampers competition and lead to monopolistic, which is not good for the society in the economic point of view (Roth et al., 2008).

Animal protection

As stated earlier, social dimension does not only involve human welfare but also involve moral practice in a society. Animal abuse might be eliminated by adopting traceability (Kumar and Budin, 2006). By keeping monitoring labor activities in food processing plant, animal abusing, which can be occurred by improper labor practice (Meuwissen et al., 2003; Kumar and Budin, 2006) or by improper nurture can be avoided (Pettitt, 2001; Filho, 2004). Animal treatment can also be a selective factor for consumers to choose a product that treats animal better than others (animal treatment can be certified by quality certification schemes, in which require traceability) (Hobbs et al., 2005). Food organizations around the world have released many food certification schemes to provide better animal treatment. For example, Butlers' Choice certification scheme from the Netherlands ensures quality and ethically sourced food (Belton et al., 2011). By implementing of such a certification scheme, each operation in food processing will be traced and tracked to ensure that food producers follow certain terms and rules of the certification in which can increase animal welfare. Furthermore, it reduces the death rate by lowering density of living space (Belton et al., 2011).

Labor protection

Consumers may refuse to buy a product if they suspect that a firm uses child labor to produce it. Traceability can ensure customer confidence and prevent children from being labor force before reaching the legal ages (Folinas, 2006).

Further to all factors in traceability for social dimension, the authors generate a summary table of positive effects for this dimension (since there is no negative effect based on review). Table 9 represents positive effects of traceability for social dimension.

Table 9 Positive effects of traceability on social dimension

Effects	Issue related	Paper number
Consumer protection	Reducing /preventing/ controlling occurrence of food hazards	[1][4][6][10][11][16][27][34][36][46][47][49][52][53][56][57][58][59][66][69][75][77][79][59][84][87][89][90][95][96][105] [107][119][120]
	Protecting consumers from unsafe drugs (counterfeit, stolen, mislabelled, adulterated, and other hazardous drugs)	[8][17][63][76]
	Increasing consumers' welfare from quality safety complied products (not related to food)	[40][47][68]
	Protecting consumers from price swindling	[52] [93]
	Increasing consumers' choice	[94]
	Increasing consumers' welfare from more responsible producers	[58]
	Protection from counterfeiting products	[60]
	Reducing fraudulent obtained drugs	[63]
	Reducing drug speculations	[63]
Animal protection	Avoid animals abuse (torturing during slaughter process, illegal handling)	[7][34][49][59][77][84]
Local business protection	Protection of domestic farm business	[93][119]
Public protection	Preventing loss of public productivity	[49]
	Reducing public medical cost	[49]
Competition protection	Protection from anti-competitive acts	[93]
Labor protection	Preventing child labor abuse	[36]

5.3 Traceability for environmental sustainability dimension

In environmental dimension, traceability contributes to environmental welfare in which may directly or indirectly create positive effect. All factors will be elaborated in this chapter.

Controlling Genetically Modified Organism (GMO) products

Effect of GMO products to the environment is still unclear (Regattieri et al., 2007). Traceability can be used to keep tracking of GMO products in order to evaluate and prevent any environmental effect in the long term by withdrawing products from the market (Miles et al., 2005).

Preventing illegal fishing and avoiding fish extinction

Some fish species are mislabeled and sold as others since their species are prohibited from catching due to the shortage (Jacquet and Pauly, 2008). Traceability can be taken on this issue to force fishery firms to identify fish origin (if it is a prohibited area) or fish type and apply a certification scheme to ensure legal practice. United Nations Food and Agricultural Organization (FAO) have developed a fishing scheme called the ‘‘International plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing’’ (IPOA-IUU) (Borit and Olsen, 2011). This fishing scheme forces fishing operations and related data to be recorded to ensure quality, safety, legality, and thus can prevent extinction of fish species (Martinsohn and Ogden, 2008; Borit and Olsen, 2011).

Improving environmental resources

Improving marine environment resources is an example of a contribution that traceability can selectively create positive effects to the environment. Jacquet et al. (2008) illustrate a case that farm-raised shrimps from Thailand are labeled as wild-growth shrimps. Farm raised shrimps can destroy mangrove habitats thus cause environmental loss. Another aspect of traceability is that seafood manufacturers can provide trustable information on how their products can contribute to any improvement on marine environment (Caswell, 2006). However, even traceability can expose or provide this information, it is not illegal to raise shrimps in farms and also not legally required for seafood manufacturers to protect the marine environment. It is consumers who will decide if they want to preserve the environment or not. Traceability, in this case, only provides visibility as a selective attribute for better environment.

Food organizations around the world have released many food certification schemes to provide better environmental treatment (Belton et al., 2011), for example, Pangasius Aquaculture Dialogue from World Wildlife Fund ensures quality and environmental practices (Aquaculture Certification Council, 2011). By implementation of such a certification scheme, each operation in food processing will be traced and tracked to ensure that food producers follow terms and rules of the certification that can preserve the marine environment. Another example is a study by Hamprecht et al. (2005) showing, that, at Nestlé Company in Switzerland, dairy farmers' activities are recorded and traced to make sure that they add nutrients into soils to prevent degradation.

Using traceability for protecting environmental resources can also become a primary tool for corporate social responsibility. For example, Antonio et al. (2011) conducted a case study on a Hong Kong purchasing firm on important issues for a selection of suppliers. The attribute which is important for customers is Corporate Social Responsibility (CSR). Firms are trying to provide better image for public by being environmental friendly. Under this context, responsibility is bonded to suppliers to apply traceability system to make sure that their practices are environmental friendly. Another similar example is in a case study by Antonio and Lau (2011).

They shows that lumber firms implemented CSR with the purpose to ensure woods from their suppliers are not from preserved forest or illegally cut logs.

Preventing pollution

A research by Shinkuma and Huong (2009) indicates that, currently, there is no traceability for electronic waste (e-waste) from Japan to China, Vietnam, or Cambodia. Recycling or reusing e-wastes without proper handling would create pollution to the environment. Removing valuable metals from circuit boards with acid can create very toxic wastewater. When water run-off directly from a river, soil and air will be polluted as well (Shinkuma and Huong, 2009). Traceability for recycling process would help enforce proper handling for e-wastes and reduce pollution. Quality scheme such as Hazard Analysis Critical Control Point (HACCP) also controls and provides traceability-related direction for food manufacturing practice (Filho, 2004) as a guideline to ensure that chemicals in manufacturing process would not be released to the environment causing pollution as a consumer selective attribute (HACCP Australia, 2011).

Regarding all attributes in traceability for environmental dimension, the summary table of positive effects for this dimension is generated. Table 10 represents positive effects of traceability for environmental dimension.

Table 10 Positive effects of traceability on environmental dimension

Contributions	Paper Number
Preventing illegal fishing catching and avoid extinction of some fish species	[12][52][73]
Preventing air/soil/water pollution	[7][34][102]
Protecting environmental resources	[16][47][52]
Control Genetically Modified Organism (GMO) products not to contaminate natural plant	[2][79][90]

5.4 Effects of traceability on single and multiple sustainability dimensions

In this section, three case studies from literature review are provided based on effects of traceability on different sustainability dimensions to show how firms deal with traceability and how they create benefits from it. Case 1 provides an example from ECOMOVISTAND where design of traceability in combination with an optimal solution for transport unit can provide economic sustainability. Case 2 provides an example from Parmigiano Reggiano where traceability is initiated from legislation. The company illustrates that, by consideration of factors for traceability, they could cope with legislation with acceptable economic effect. Case 3 provides an example from Nestlé Company where quality is considered as the corner stone for business success and involves all the three dimensions of sustainability.

Case 1: Traceability contributing to one sustainable dimension (economic dimension)

Martinez-sala et al. (2009) have conducted a case study investigating increasing efficiency and improvement in a fresh product supply chain by automating valuable data flows. The case study is conducted with a Spanish company ECOMOVISTAND. In general, supply chain from producer to a grocery includes these following operations: First, products are packed and put into pallets from producer to distribution center. Second, when a warehouse receives batches, they will be stored and shipped to a retailer when an order is released. Finally, when the retailers get the batches, they store the batches again, and then some of the batches are displayed on the shelf. Many manual operations, for example, plastic film wrapping and removing, inventory arrangement, and displaying are labor intensive.

The company developed a new transport unit called MT for the whole supply chain from the producer to groceries that can be used with the entire product life cycle. MT is used as a package for a producer, a transport unit, warehouse storage, and a display stand (figure 9). By attaching active RFID tags to MT, MT itself and product inside can be tracked and traced in real time and provides valuable data to improve supply chain performance.

In terms of traceability, the main advantage of MT is that products will be placed in MT all the time. That makes it feasible to see product condition in real time (especially condition during transportation). This is suitable for cold chain to avoid temperature abuse, which is a potential risk factor and would significantly reduce a cost for disposition. Lateral benefits are inventory management and resource reusability. Using RFID tracing on the MT, it can be identified easily together with all products within the case so that time consuming from finding product can be lessened. Resource usability is gained on the same basis. By tracking and tracing on the usage of MT, it can be reused efficiently and save packaging cost.

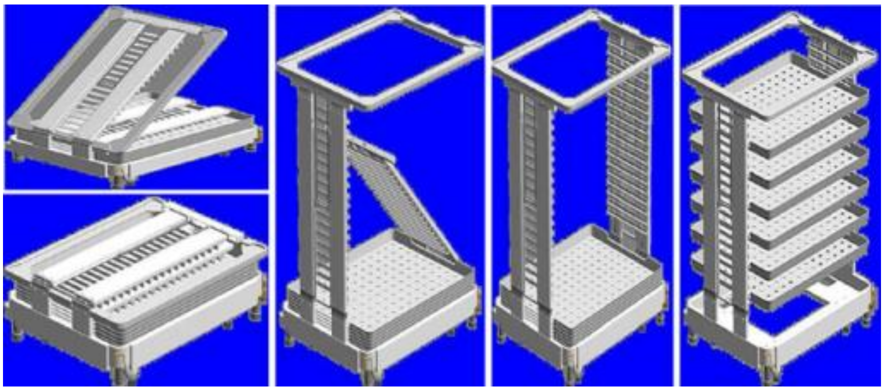

Figure 9 MT transport unit (Martinez-sala et al., 2009)

Case 2: Traceability contributing to two sustainability dimensions (economic and social dimensions)

Regattieri et al. (2007) studied a case on an Italian cheese producer Parmigiano Reggiano. The firm implements traceability further to European Union laws on traceability, which was going to be enforced in 2005. The essence of the laws is to strengthen food safety by avoiding previous food hazard incidents happening again, such as bovine spongiform encephalitis (BSE). The firm decided to use RFID for traceability and framed its own traceability system to be complied with regulation. The traceability system is based on four core considerations:

- Product identification. This consideration refers to physical characteristics, for instance, volume, weight, and dimension.
- Data to trace. This consideration refers to the characteristics of information to be managed such as numbers or typology (structure of the data to be stored).
- Product routing. This consideration refers to product life cycle recording.
- Traceability tools (such as identification technologies). This consideration refers to evaluation of requirements and benefits of tools. For instance, using barcode is cheaper but time consuming and labor intensive, while RFID can avoid these drawbacks and provides more benefits of reinforcing stock control and improve perishable items management

Elements in four considerations are thoroughly selected for greater efficiency in the traceability system especially for the second and the fourth that have significant effects on benefits and costs. In the second consideration, information that is worth being traced (information that directly affects product quality) will be selected, for example, production date and production parameters (temperature, humidity, etc.). Using the traceability system that information, structure, and technology are prudently selected, the company can produce safe products that comply with government regulation and consumer demand for food safety along with acceptable cost that does not create a negative effect to their financial status.

Case 3: Traceability contributing to three sustainability dimensions (economic social and environmental dimensions)

Hamprecht and Corsten (2005) conducted a research in Nestlé, the world's largest food and beverage Company. As described by Nestlé's CEO, quality is the cornerstone for business success and important differentiating factor for the company in the market since the company expresses itself in the market as "quality and trust". By manufacturing trustable products with high quality, it is critical to source high quality raw material. Raw materials (for instance, milk, coffee, cocoa, and cereals) are obtained from 300,000 farmers worldwide. Having large numbers of material suppliers (farmers), performance measurement is sophisticated. The company has to control every process to make sure that the company and farmers' activities comply to the controlling variables in order to achieve the sustainability goal. For example, herbicides that farmers used are frequently reviewed to ensure minimal impact on biodiversity. Controls of environmental and social performance are integrated with economic controls and links to supply chain control in quality, food safety, and cost. To control these variables, Total Quality Management (TQM) framework is selected as a basis for integrating supply chain control. Traceability is used as a tool to confirm that quality control is done at the upstream.

In TQM, suppliers are traced back to the preliminary step, to see if a supplier of agriculture material can identify his/her own suppliers or not (in order to identify the origin when a problem is occurred). In later step, raw materials, for example, wheat, are randomly traced back to farmers. In every stage, there will be check points for quality and safety control. Another important control method is on hand-over point (moving materials from one actor to another actor) in order to be certain that materials that have been accepted comply with quality and safety standards.

Besides quality control, Nestlé also considers sustainable control and management. For example, in environmental perspective, Nestlé requires dairy farmers to calculate the nutrition demands of their soils annually. Over fertilization is forbidden. Compliance with this regulation will be controlled by an independent party. The transport provider will only accept and collect fresh milk from farms that are complying with the scheme. Thus, existing food safety and quality controls are complemented with an environmental performance aspect. In social perspective, labor standard is integrated in supply chain control. At the first hand-over in the supply chain, the buyer can ensure that the farmer complies with certain standards. With the help of following hand-over documents in the supply chain, this information can be passed downstream until reaching food processing factory.

The methods for implementing traceability integrated controls of sustainability are illustrated in figures 10

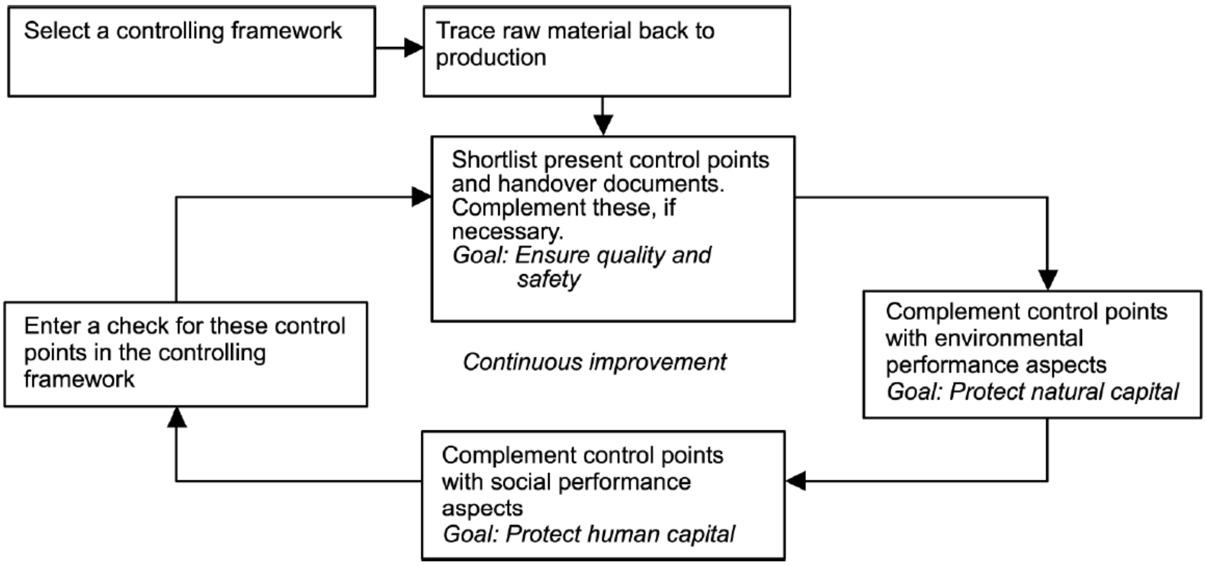

Figure 10 Method for implementing controls of sustainability of Nestlé (Hamprecht & Corsten, 2005)

Additionally, the efforts of the farmers will be rewarded if a farmer improves the quality of his/her fresh milk production. Financial bonuses from Nestlé will be given to that farmer. This is to support improvement of environmental performance in farming operations financially and to motivate the farmers persist in taking proper agricultural actions in the long run.

6 Discussion

In this chapter, contributions of traceability to sustainability dimensions, how traceability can create these contributions, how fulfilling environmental and social sustainability can create better economic sustainability, and how to achieve better traceability performance will be discussed. The discussion is divided into three topics. First, the results of the literature review showed that sustainability created from traceability appears in many conformations, for example, sometimes, application of a traceability system in a firm contributes to sustainability only from economic perspective, while some other firms can create sustainability in two or more dimensions. This issue is going to be identified. Second, Carter and Rogers (2008) indicate that four supporting facets are requisite for sustainable supply chain management. This chapter identifies how traceability, as a part of supply chain, is related to the four supporting facets. Finally, in earlier chapter, performance of traceability is sparsely identified together with factors of traceability for sustainable supply chains. This chapter is going to discuss performance of traceability for better sustainable supply chain in a holistic view.

6.1 Benefits of traceability for different sustainability dimensions

Further to the explanation by Carter and Rogers (2008), creation of sustainability in environmental dimension and social dimension can improve the economic dimension of sustainability, which is able to be implemented in firms. However, benefits of traceability in the reviewed literature are appeared in many conformations. For example, several papers mention that traceability may contribute to only economic dimension of sustainability, while some other papers advert that traceability contributes to both economic and social dimensions and even all the three dimensions (economic, environment, and social). Initiative of traceability is the main factor that explains why in some cases traceability contributes to one dimension, two dimensions, or three dimensions. In this section, traceability for one dimension, two dimensions and three dimensions of sustainability will be elaborated respectively.

Traceability affecting one sustainability dimension

The reason that benefits of traceability are appeared in only one dimension is that traceability is initiated by main actors in each dimension concerning only their own benefits. As mentioned earlier, actors in economics dimension are firms, while actors in environment and social dimensions are public.

Traceability affecting economic dimension of sustainability only

Traceability affecting only economic dimension of sustainability is initiated by firms that use traceability for improving supply chain performance (performance-driven firms). Benefits of traceability on the economic dimension can be seen in Table 7, in supply chain performance improvement category.

Firms that use traceability to improve the economic dimension of sustainability usually do not manufacture or involve with food products. Traceability, as mentioned earlier, is applied to create transparency by closely monitoring processes and activities in supply chains. These processes and activities are performed in order to avoid potential risks that could reduce product quality, while decrease errors, and decrease operational delay, which may also lead to cost reduction and increasing profit/revenue. However, traceability performance depends on how traceability is applied and the degrees of benefits of traceability vary from firm to firm depending on their abilities to implement and operate. The issue of traceability performance will be discussed in section 6.4.

Traceability affecting social dimension or environmental dimension of sustainability only

Traceability will affect only social or environmental dimension of sustainability when it is initiated under product safety issues (usually food safety). The main consideration of traceability in this case is regarding regulators (governments, consumer care organizations, etc.), trying to enforce traceability system for consumer product companies to withdraw hazardous products from the market (requested from regulators) and to increase public confidence by producing safer products (requested from consumers). Both governments and consumers can be considered as public. In the literature review, most of the product hazard cases involve recalling. Recall cases are frequently emerged from food hazard. In food safety, traceability is focused on origin of products and product owners to identify undertakers and the cause of hazard. Other minor aspects in social dimension of sustainability are drug safety, swindling protection, anti-competition protection, and animal food safety (because contamination in animal feed also affects consumers). Considering firms and public attention on traceability for environment, the result of literature review shows that effects on the environment gain less attention from firms and public (when consider only the usage of traceability).

Contrary to traceability affecting economic dimension only, traceability affecting social or environmental dimensions only has negative effects on economics dimension since there is no sustainability factors for such a firm in economic dimension. Firms that are not able to cope with costs emerged from public enforcements (maladaptive firms) are under pressure, while the public directly gain benefits from safe and qualified products.

Traceability affecting two dimensions of sustainability

Traceability affecting two dimensions of sustainability, in some cases, is initiated from firms that possess the value of creating sustainability on other dimensions apart from economic. Conversely, traceability may be implemented only under governmental enforcement without realization of benefits from firms (the same basis as traceability affecting only social or environmental dimension).

Benefits on these two sustainability dimensions can be separated into three cases.

First, firms that creates sustainability on economic and social dimensions (self-enforced firms). These firms usually produce products that deficiencies of quality will highly affect consumer health or that cannot be sold at all, for instance, food manufacturing firms. Some of them tend to have *ex ante* practice for two sustainability dimensions. For example, they use traceability to monitor fresh food in transportation process or condition on a shelf not to be putrid since it will create cost of disposition and products could not be sold. This situation creates benefits on both social and economic dimension since the consumers get safer food, while firms can save their costs.

Second, traceability can affect sustainability in two dimensions when firms that can adapt themselves to create two sustainability dimensions (adaptive firms). This case can be distinguished into *ex ante* realization and *ex post* realization. In *ex ante* realization, firms may have awareness to extend traceability from only economic dimension to economic and social/environmental dimensions (profit/revenue-driven). For example, firms that produce safe food may get better reputation, greater willingness to pay from consumers, and price premium. Contrarily, firms may not be aware of benefits on the social dimension of sustainability in the first place but realized after traceability for social welfare is enforced by a government (*ex post* realization). On the other hand, firms may not realize benefits of sustainability on the social dimension at all, but try to improve supply chain performance within an acceptable cost when implementing traceability (cost-driven). Apart from being cost-driven only or profit/revenue-driven only, some firms implement traceability based on both cost driven and profit/revenue driven.

The last case of traceability affecting two sustainability dimensions is when traceability affects both social and environmental dimensions. This case is the same as traceability affecting only social or environmental dimension. However, government enforcement is not only limited to one dimension but both. The enforcement affects maladaptive firms that cannot cope with increased cost.

Traceability affecting three dimensions of sustainability

Firms that create sustainability in three dimensions can be categorized into two types. First, firms may be in the same condition as traceability affecting two dimensions where they can manage to cope with either social dimension or environmental dimension. However, traceability affecting three dimensions means that firms can settle themselves with both social and environmental dimensions to cope with government regulations on both aspects (highly adaptive firms). The second type is the firms that fully realize benefits of traceability where creation of sustainability in three dimensions is initiated by the firms themselves (value-integrated firms). This type of firms can be illustrated by the third case study in section 5.4.

Figure 11 illustrates different types of actors in each dimension of sustainability including intersection areas.

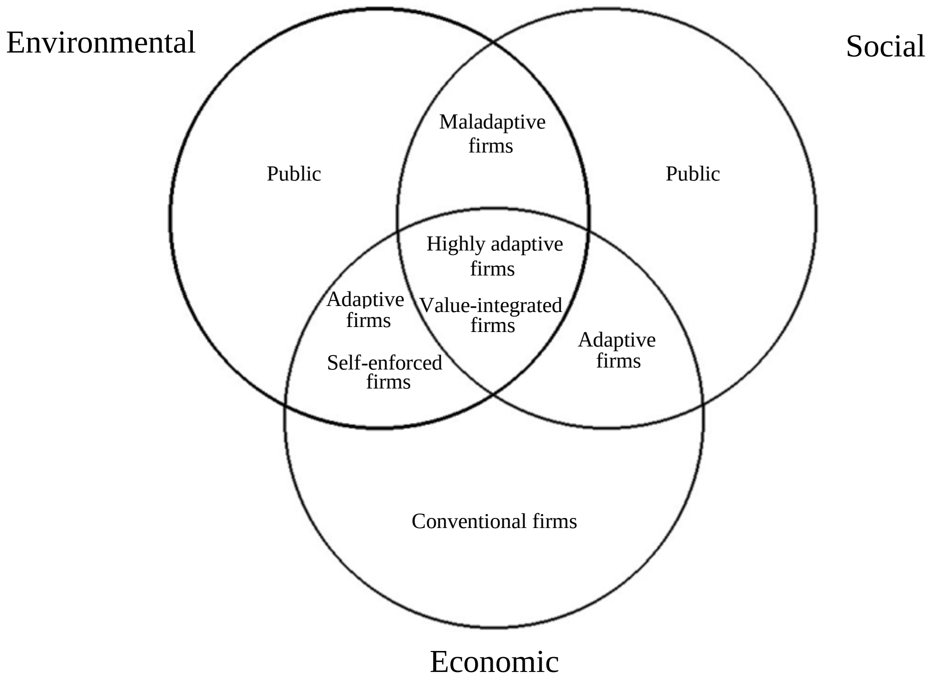

Figure 11 Actors in sustainability dimensions

6.2 Sustainable supply chain and four supporting facets

Carter and Rogers (2008) explain that four supporting facets are requisite or essentially important for sustainable supply chain. To illustrate how they are important to traceability, as a part of supply chain operations, factors contributed to sustainability dimensions will be linked with these facets, which will be elaborated in this section.

Traceability in risk management perspective

Considering contributions of traceability on the public side in three dimensions of sustainable supply chain management (SSCM), if traceability cannot be used, it would lead to following risks.

First, lack of monitoring of activities and operations in supply chains might lead to deviation from preferred standard and thus probably lead to the creation of products that may be harmful (Lyles et al., 2008). Second, lacking of traceability makes firms in supply chains unable to identify the origin of deficiency in a food hazard incident (Abad et al., 2009). Third, incapable of identifying precise batches of product in the food hazard incident may cause massive recall and impact financial means (Kumar and Budin, 2006). Finally, considering contributions of traceability on the firm's side, without traceability some firms may not handle wastes properly in order to cut cost, which may create pollution (Shinkuma and Huong, 2009). With traceability system, firms could prove that they do not violate the laws (Jacquet and Pauly, 2008). They can also prove their value adding activities, for example, proper animal treatment and environmental friendly production (Pettitt, 2001).

When it comes to traceability for improving supply chain performance, potential risks without traceability might be: First, firms are unable to well coordinate activities along a supply chain that lead to failure and error in supply chain operations (Charlier and Valceschini, 2008). Second, firms are unable to fulfill customer demand from not being able to predict precise item quantity to deliver and unable to make adaptation for order changing (Lee and Özer, 2007; Chryssochoidis et al., 2009). In summary, risk management can be viewed as the enclosure of traceability (figure 12).

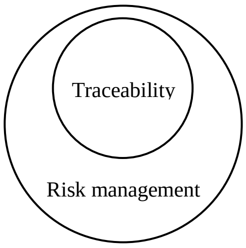

Figure 12 The relationship between risk management and traceability

Traceability in transparency perspective

Traceability is known to create visibility or transparency in supply chains (Veronneau and Roy, 2009). The creation of transparency along a supply chain is not about a firm that implements a traceability system but also an agreement of all actors in the supply chain (Skilton and Robinson, 2009). Implementation problems occur when some actors do not accept to invest or implement the traceability system because the benefits are perceived differently from one actor to another (Karlsen et al., 2011). On the other hand, some other firms may be reluctant to implement traceability because they want to escape from being identified as a potential suspicion of a safety accident (Sahin et al., 2007).

Not only different perceptions of traceability system but also level of knowledge that firms have may hamper the implementation process. Many firms are aware that traceability would create transparency and know the approach or mechanism of how traceability creates transparency, but they have not realized how to reap benefits from transparency for their sustainable development (Lee and Özer, 2007). For the firms that do not have knowledge to manage traceability system, traceability becomes a burden since the cost is significant and could not be transformed into profits.

Another obstacle of traceability implementation would be the awareness of opportunistic behavior where actors mistrust each other and try to avoid any possibility to reveal their valuable information to someone else (Zhang et al., 2010). Therefore, it is suggested that preliminary requirements of traceability is to create sustainability along the supply chain. These should be done by means of creating trust among each actor and communicating vision, goal, and benefits of transparency with all actors for achieving mutual understanding and increasing willingness to share information in order to create profits (Beulens et al., 2005). However, benefits and costs may not be distributed to all actors equally. Power of a large firm in supply chain and dependencies of suppliers to the firm are also factors that creates benefit imbalance (Gadde and Håkansson, 2001). For example, Wal-Mart, with very strong purchasing power, forces its product suppliers to implement RFID traceability system with no subsidy and profit sharing (Holmström et al., 2009). Government regulations are also a factor that forces manufacturing firms, especially food manufacturing firms, to implement traceability (Skees et al., 2001).

When actors in supply chain reach agreement to share information with each other, the next step is to well utilize information sharing to improve supply chain performance. By revealing necessary information to all actors, the actors will clearly find out the sequence of operations and activities and therefore be able to coordinate each other activities along the chain (Kärkkäinen et al., 2003; Lumsden and Stefansson, 2007) and enable down-stream firms to monitor and control upper-stream production quality (Lyles et al., 2008). However, implementation of traceability is not the absolute way of solving operational problems. Even with traceability along a supply chain, sources of failures may still not be specifically identified if traceability does not cover all crucial points that problems may occur (Bertolini et al., 2006).

The reason of using traceability to monitor and control upper-stream suppliers is mainly to control product quality from the upstream. Lee and Özer (2007) mention that product quality problems that emerged from manufacturers in China were occurred due to inability to create transparency with their suppliers and detect where the mistake comes from.

The objective of traceability for activities' coordination is to control processes and activities in a supply chain (Kärkkäinen et al., 2003). In other words, it is to inform actors in the supply chain about time and places to perform the activities.

Technologies and tools of activity coordination, for example, may come in the form of RFID attached product, so called intelligent product or intelligent item (McFarlane et al., 2003; Lumsden and Stefansson, 2007) to inform actors in supply chain about the operations that each product has to be processed. This may come in the form of barcode attached products as well.

Traceability in strategy perspective

The relationship between strategy and traceability is in top-down approach. Traceability can be initiated as a tool to gain benefits from strategic point of view. However, traceability may or may not be a tool for strategy. As advocated by Porter and Kramer (2006), *"Strategy is the creation of a unique and valuable position, involving a different set of activities"*. Barratt et al. (2007) explain that implementation of traceability can enable firms to create unique resources that others could not imitate. This statement emphasizes that traceability, at least, can differentiate a firm from others and may become a useful tool for strategy. Canavari et al. (2010) also support this assumption by showing that traceability can be used as a tool for competitive strategy in fruit supply chains as the product can be marked as high quality and safe. Even so, many firms do not turn traceability into a tool for strategy but use it as a regulation mandatory tool as they are forced to implement the traceability system.

Traceability in organizational culture perspective

Culture is the way an organization communicates its vision to personnel in the firm to have a mutual mindset to achieve the goal (Carter and Rogers, 2008). For organizational culture and traceability, the relationship is still non-identifiable. Culture and strategy may involve in each other. However, apparent relationship between organizational culture and traceability still cannot be found within the scope of literature review.

The importance of traceability and four supporting facets

As mentioned earlier, four supporting facets are the important factors to create sustainable supply chain management. The key factor is that traceability can contribute to sustainable supply chain by creating transparency, which is one of the main contributions for sustainable supply chain management.

In terms of risk management, contributions that traceability can create for this facet are also derived from transparency. Hence, the authors propose that four supporting facets may not always be seen as separate factors to create sustainable supply chain but they can be complementary to each other. In this case, risk management can be seen as an alternate perspective to view traceability. However, concerning other two supporting facets, traceability does not appear to be involved with these facets (within the boundary of the authors' literature review).

Another aspect that emerges from the authors' literature review is that supporting facets can create better understanding on how three dimensions are linked to each other, how supply chain activities can construct economic sustainability, social sustainability and environmental sustainability at the same time, and provide the holistic view on how benefits on sustainability dimensions are created, which will be elaborated in section 6.3.

6.3 Mechanism of traceability on sustainability dimensions

Benefits of traceability can be illustrated with table 7, 9, and 10. However, procreation of these benefits also needs an important support element. For example, several reviewed papers illustrate that trust is the important element to be used with traceability to achieve plenary benefits on sustainability dimensions (Meuwissen et al., 2003; Roth et al., 2008; Skilton and Robinson, 2009).

Traceability may not be distributed to all actors along supply chain. However, to achieve higher benefits on economic dimension, traceability has to be implemented by all actors in a supply chain. For instance, if contamination occurred on a batch of meat products and requires for recall, at least the product type, product owner and product origin have to be identified (Bechini et al., 2008). In this case, if traceability is implemented at the minimum requirements and the livestock at a farm of origin is proved not to cause the contamination, only the product owner, in the first place, will solely take the responsibility. In order to minimize impact on this issue, considering a supporting facet by Carter and Rogers (2008), transparency on each actor has to be created. The benefits on economic sustainability from increasing transparency along the supply chain additionally create more social sustainability. In liability perspective, traceability can turn to be a tool for consumers concerning their food safety. As mentioned in section 6.2, if firms in supply chain are forced to be responsible for liability, they tend to be more careful on activities and operation and hence produce safer and better products. This would proactively create welfare and could be considered as a better alternative than reactive action such as recall, since the procedure is made after the incident occurs.

In an ideal case, if one firm can do all activities in supply chain by itself, this may become an exception for supply chain traceability which no longer requires all actors to be involved but can create product safety since one actor could create transparency for the whole supply chain (full traceability). However, it may not be possible for firms to have no supplier at all. Several academic authors mention about this issue, for example, Gadde and Hakånsson (2001) state that businesses cannot be done without suppliers and there must be a substantial continuity in supplier relationships. Skjøtt-Larsen et al. (2007) also emphasize that *"No organization, whether business, government, or non-profit, can stand-alone. It depends on connections to other organizations in a network relationship"*. In summary, a relationship of traceability, transparency, and trust can be illustrated as this following figure (figure 13)

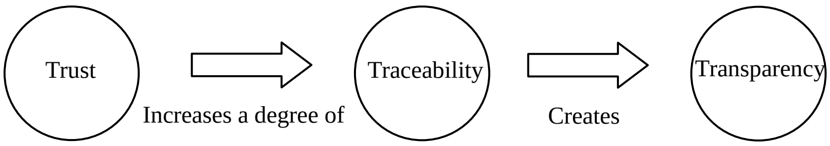

Figure 13 The relationship between traceability, transparency, and trust

According to the relationships of four supporting facets, three sustainability dimensions, traceability and trust, a diagram is created to illustrate how they are related to each other. Traceability is always considered as a part of risk management. By applying traceability, the firms create transparency as a key input for three bottom lines and hence create sustainability. However, to improve transparency, trust can be involved as a mechanism to create more sustainability in economic dimension. Traceability, on one hand becomes a tool for firms to improve performance in supply chain, to provide better mean for financial status, to create reputation, and to meet customer demand. On the other hand, public (social) forces/pushes or requires firms to use traceability to increase public welfare and/or to preserve the environment. In return of preserving environment, the firms can sustain their material resources (Carter and Rogers, 2008) and also gain more willingness to pay from customer when the environment is protected or improved. Hence, traceability system for sustainable supply chain can be considered as a "firms-centric", where economic dimension becomes the medium dealing with environmental and social dimensions, while these two latter dimensions do not directly cope with each other but indirectly impact via the medium. Since traceability is firms-centric, it can be explained by improvement of benefits on three sustainability dimensions greatly depend on improvement on economic dimension incentives. Figure 14 illustrates how each actor in sustainability dimensions interacts with each other within the boundary of traceability.

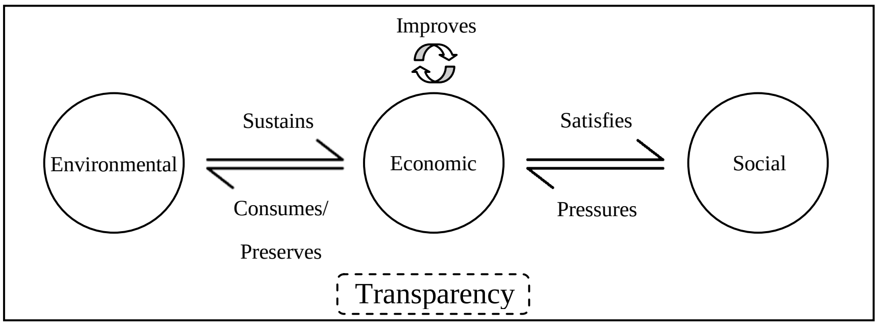

Figure 14 Interactions between actors in different sustainability dimensions using transparency

6.4 Traceability performances for improving sustainability in supply chain

The last aspect of traceability for sustainability supply chains is performance of the traceability system. In the reviewed literature, traceability performance has mainly affected sustainability in economic dimension. Also, it has some effects on the social dimension. Considering traceability performance that can improve positive effects on the economic dimension of sustainability and elements mentioned in earlier sections, eight types of performance factors can be identified.

First, traceability performance depends on optimization of value adding activities and processes. By optimizing value adding activity and process, in the first case study, Martınez-Sala et al. (2009) illustrate that achieving benefits in economic sustainability dimension involves designing of the traceability system (a new transport unit) that can facilitate actors in the supply chain (Martınez-Sala et al., 2009).

Second, traceability performance also depends on engineering tools (Bertolini et al., 2006). Engineering tools for traceability performance improvement refer to tools to simulate and analyze effects of the traceability system. For instance, Failure Modes Effects and Criticality Analysis (FMECA) can be used to define a probability of failure in each part that traceability is applied (Bertolini et al., 2006).

Third, financial power can improve traceability performance (Rabade and Alfaro, 2006; Holmström et al., 2009). Financial power is the buying power of an actor in the supply chain. As mentioned earlier about Wal-Mart, it has a very strong purchasing power so its suppliers have to unconditionally apply traceability system so the whole supply chain can be performed in a more effective way.

Fourth, identification of critical information is a key of effectiveness for the traceability performance (Regattieri et al., 2007; Karlsen et al., 2011). In the second case study, Parmigiano Reggiano illustrates that how cost of implementing traceability can be reduced. The company only focuses on tracing the processes that are critical for their product safety instead of covering all aspects, therefore, achieving product safety, while the cost of traceability is low.

Fifth, traceability perfromance involves a large amount of information sharing (Barratt and Oke, 2007). Improvement of traceability along a supply chain can be achieved if all actors share their information to each other. However, as mentioned earlier, trust is also a very important issue among all the actors in the supply chain to guarantee that the information sharing process is going smoothly.

Sixth, traceability performance is varied upon different specific traceability levels. For example, traceability on a batch level provides more activity automation on a pallet level (Fritz and Schiefer, 2009).

Seventh, when a firm implements a traceability system, technology and technological analysis can be a main factor that affects performance (McFarlane et al., 2003; Decker et al., 2009). Adopting the right technology will provide economic benefits to a company. For instance, in some situations RFID may provide more benefits than barcodes, since barcodes involves manual transactions which may lead to a higher labor cost. However, even firms believe that some technologies are better than others, assessment still needs to be done to make sure that they provide better benefits.

Finally, firms may implement of costs-benefits model to asses traceability performance (Decker et al., 2009). All seven factors mentioned earlier have to be assessed in order to be aware of their costs and benefits. The goal of obtaining benefits on the economic dimension of sustainability contains two aspects: One is to reduce costs, which can be achieved from operational improvement. The other is to increase profits/revenues where the customers' willingness to pay is the main factor.

7 Conclusions

In order to identify the role of traceability for sustainable supply chain management, a framework of the sustainable supply chain by Carter and Rogers (2008) is used to explain the concept of sustainability and sustainable supply chain management. Sustainability in supply chains contains three dimensions: economic dimension, social dimension and environmental dimension. Economic sustainability is related to positive financial means for firms, while the social dimension is related to public welfare and environmental dimension is related to environmental welfare. Other important factors for sustainable supply chain are four supporting pillars, which are risk management, organizational culture, strategy, and transparency.

The research question 1, *"How every dimension of sustainability can be supported with traceability?"* can be answered by indicating benefits of traceability that could contribute to sustainable supply chain management. Benefits of traceability can be identified separately in each sustainability dimension. In economic dimension, factors that create economic sustainability are cost saving, increasing profit/revenue, sales reduction protection, and liability assignment. In social dimension, traceability mainly provides social sustainability by reducing, preventing, and controlling occurrence of harmful food. In environmental dimension, traceability mainly contributes to environmental sustainability by protecting environmental resources and preventing pollution. Three case studies are provided as examples for perception of traceability from enterprise side about how traceability creates sustainability within supply chain management context.

Although benefits of traceability and how they affect different sustainability dimensions are identified, the holistic view on how traceability creates these benefits is still left unidentified.

The research question 2, *"Regarding traceability, how engagement in social and environmental responsibilities can create long-term economic success for firms in supply chain?"* can be answered by analyzing the relationships and interactions among the three sustainability dimensions. Using four supporting facets concept from Carter and Rogers (2008), the major factor that enables traceability to create benefits on sustainable supply chain management can be identified, which is transparency. From economic dimension, transparency could make firms push themselves to enhance their internal performance as well as monitor other actors in the supply chain. From economic and social interactions, with information transparency achieved by the traceability system the consumers could acquaint useful information related to product safety and quality, thus they tend to pay more for safer products, meanwhile, firms' revenues will be increased. This would create a mutual benefit situation both for consumers' welfare and for the firms' sustainable development. From economic and environmental interactions, when firms try to protect the environment by applying traceability system to control the consumption of natural source and avoid scarcity, they will not only attain good reputation in business circles but also make efforts for their own sustainable development in the long run. This would create a win-win situation between economics and environment.

8 Further research area and development

Traceability for sustainable supply chain management presents many interesting areas for future research and development. Since benefits of traceability for sustainable supply chain management can still be increased, there are many possibilities that future research can be done within this area to seize this opportunity.

Apart from benefits of traceability for sustainability, quantitative measurement of implementing traceability can also be considered as an area for future research. Since the way that traceability is implemented and managed will largely affect the performance of traceability, traceability could be implemented in an effective way and there is a lack of comprehensive understanding from academic research about identifying/distinguishing the potential benefits that traceability can contribute.

In most recent researches on traceability, Dabbene and Gay (2011) emphasize that direct measurement and optimization of the traceability system should be adopted in order to effectively deal with a crisis. Karlsen et al. (2011) also suggest that finding of optimal level on the scale of traceability should be conducted. Costs and benefits of traceability perceived by different actors is also an issue to be discussed (Mai et al., 2010)

In terms of traceability for sustainable supply chain management, the authors suggest that quantitative empirical studies should be conducted in each part of a supply chain separately as well as the holistic view. These can be done in order to quantify effects of traceability for sustainable supply chain and to optimize usage of traceability. The quantification is suggested to be made by measuring total monetary effects of focal firms, while considering all sustainability dimensions. For example, in case of a product type deficiency, how much financial loss has been created such as a penalty from a government, cost of prosecution from consumers, or scarcity of raw material resources due to devastatingly use of these resources. Costs from these factors can be compared with investment in supply chain activities to estimate effects in short and long term.

Strategy of implementing traceability for sustainable supply chain management can be another interesting area to conduct a research since traceability is still rarely raised as a strategic issue to create value for each dimension of sustainability.

Finally, researches on a unified view of benefits of traceability for sustainable supply chain management for each actor in every dimension, especially for actors in economic dimension, should be done in order to raise the awareness of the importance on traceability to optimize benefits of traceability for sustainable supply chain management.

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Appendix

Appendix I: Review table

Paper info.	Research methods	Industries	Geographical focus	Scope of traceability	Technical description	Sustainability effects through traceability			Other suggestions
						Environment	Society	Economic	