Traceability in Product Supply Chain: A Global Model

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Abstract. Products undergo through various processes in their lifecycle from production till use across the complex supply chain. Multiple actors are involved in these processes, generating ample amount of data. All the actors must share these data to make supply chain agile, effective and efficient to enhance the production control process. A traceability system companies use to trace these data. The current system is based on one step up and one step down principle, that is, immediate neighbouring actors share the information among themselves. No all the actors in supply chain share information among themselves which prevents collaboration. But, all these information are needed across the supply chain to enhance the quality of the product. In this work, we propose a global model for traceability to enhance the collaboration among every actors in supply chain with sharing of all the required information. Based on the model, we propose our data model.

Keywords: Traceability, Product Supply Chain, Global Traceability, Modelling.

1 Introduction

Products move from various points in supply chain before reaching to the end users. There are multiple actors in the supply chain having multiple roles and objectives. For example, the manufacturers may be buyer of one product and it may be the seller of some other products. Similarly, a supplier may be supplying more than one products manufactured by multiple manufacturers to more than one manufacturers. This results the supply chain management, a complex process. The actors generate much information at every point in supply chain from production till use of the product. These information are needed for the manufacturers to enhance quality control process. There are many examples of hazards happened in the food products. Mad cow disease, horse meat scandal are a few among them. The food and pharmaceutical products are directly related with people's health. A minor contamination with such products causes a big hazards to people. Companies need to recall the product from market after such contamination. They must pay attention to each and every process involved from production till use of the product. They need to know the cause of contamination. They must focus to enhance

the processes involved from production till delivery of the products to end users to prevent such happenings in the future. There are some other issues like brand protection, reducing the time to go to market, the companies must focus so as to compete in the market. To achieve all these issues, the actors must need information associated at each point in the supply chain.

As described in the above paragraph, companies are facing with lot many of similar challenges. A timely extraction of information generated at each point is essential for them to cope with the above stated challenges they are facing with. Traceability is a method the companies have been using since a long to trace these data in the supply chain. It is the process of tracking the location of the product in downstream and tracing the process involved during various phases of product development in upstream. As per APICS (American Production and Inventory Control society), traceability is registering and tracking of parts, process and materials used in production by a lot or serial number [1]. In another definition given by GS1 (Global Standards), an organization working in the field of developing various standard, traceability is the ability to follow or study out in detail, or step by step, the history of a certain activity or a process [2].

Enhancing the product quality, delivering the product on right time in the market, fighting product counterfeiting to protect the brand are the key challenges companies must have to cope with. A proper trace and track mechanism is quite helpful and essential to cope with these challenges. There are many actors in supply chain separated around the globe having multiple roles and objectives, make the modern day supply chain: a complex system. Tracing all the information at each point is still a challenge. Many works are found in literature in this area. The authors implement traceability system in pharmaceutical supply chain using RFID (Radio Frequency Identification), EPC global (Electronic Product Code) and ebXML (Electronic business using eXtensible Markup language) [3]. I. Charfeddine et. al. proposed an intelligent framework for traceability of containerized goods based on multi agent system and semantic web technology[4]. A traceability system to trace the data is developed in vegetable supply chain [5]. The authors use 2D barcode to identify the product's data from cultivating to marketing and use web based technology to extract these information [5]. In another work, a system is developed to track the information related with beef slaughter till packaging in the beef supply chain [6]. A traceability system is developed and implemented in frozen shrimp products and verified and validated to evaluate the system's performance [7]. In another work, need of traceability system is studied to ensure the food safety [8]. In their work, R. Badia, P. Mishra et. al identify the advancement in technology in the recent traceability system which tracks the information from farm to fork through smart phone [9]. A tracefood framework is developed to exchange the information among actors to solving the proprietary nature of the internal system [10]. But, none of the work guarantee to implement the global traceability system

exchanging the information among every actors in global supply chain. In modern traceability system, the actors manage internal traceability using ERP (Enterprise Resource Planning), MES (Manufacturing Execution System) etc. These systems are linked with immediate neighbouring actors. In other word, we can say that output produced by an actor is not linked with input of all the actors. This is a key challenge of modern day supply chain network, which creates a barrier of tracing the cause, when some problem occurs at any point in the network. The purpose of this work is to develop a model to enhance the collaboration among every actors by sharing the traceability data.

The rest of this paper is organized as follow. Section 2 describes the research problem and objectives, A bi-graph model to represent sharing information is described in section 3, proposed data model is described in section 4 and finally section 5 concludes the work.

2 Research Problem & Objective

As discussed in section 2, SCM (Supply Chain Management) is a complex process. There are multiple actors having multiple roles and objectives. They are separated at multiple points around the globe. Large amount of data is generated at each point through these actors in entire life cycle of the product. The actors must share these data among themselves to make product visible across the supply chain to make it agile and transparent. At one point, among these data, some are very crucial and sensitive, while all the actors are not known to each other in the global supply chain on the other, cause them not to share all these data. But the collaboration must be needed by sharing all the necessary information to address the issues discussed in section 2. This work aims to address the issue formulating a research question: how to make collaboration among multiple stakeholders across global supply chain?

3 Bi-graph model for the global supply chain

To show the collaboration among multiple stakeholders, we adopt bi-graph model proposed by [11]. But, we consider all the stakeholders in global supply chain in contrast to few. In graph theory, bi-graph (Short form of bipartite graph) is a graph, whose vertices are divided into two disjoint independent sets U and V of which there is an edge from every vertices in U to that of in V, such that $U \cup V$ = All the vertices in the set and $U \cap V = \varphi$ that is null. There are two entities in the supply chain process: Actors and the Products. There exist a multiple relationship between these two entities. [11]. Bi-graph has strong ability of reasoning and logic that attracts researcher from academia and industries to use it [11].

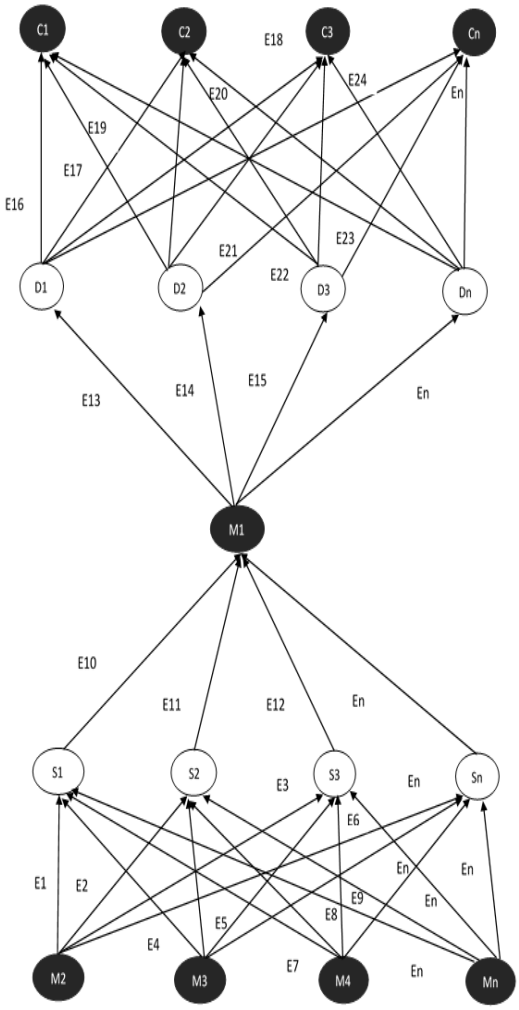

Fig. 1. Supply chain process

Bi-graph is a strong tool that can be used to show these relationship. It is used to model many complex network, modern coding theory etc [11]. In this work, it

helps to show the various relationship among the entities, which is used to trace the required information at every point through an algorithm, as our future work.

We consider a main manufacturing company M1 producing the product by taking sub products, raw materials etc supplied by more than one suppliers. Fig. 1 shows supply chain process of the various actors.

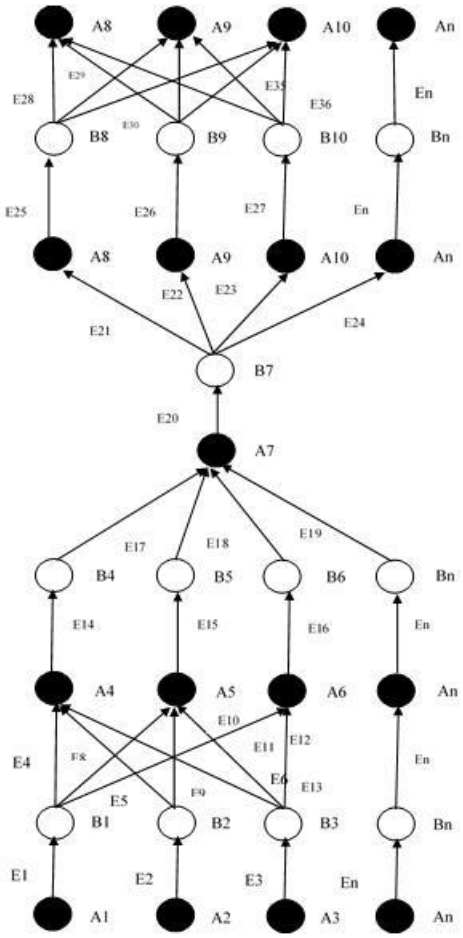

Fig. 2. Bi-graph Model of Supply chain process

The symbol M, S, D, and C stands for manufacturer, supplier, distributer and customer respectively. More than one suppliers supply the product to main manufacturer (M1) manufactured by more than one manufacturers (M2 to Mn). The main manufacturer after its internal process (producing, packaging, etc) produces the main product and sends them to various customers through various distributers. The customer may be a retailer, a wholesaler or an end user. The relationship is shown by various edges from E1, E2….En.

We model this scenario using the bi-graph technique as shown in figure 2. Let us consider G (A, B, E) be a bi-graph where A= A1, A2…..An represents the actors (Manufacturer, Supplier, Distributer and Customer) shown in dark circle. B= B1, B2…..Bn represents the sub-products, raw materials or finished product shown in white circle. E= E1, E2……En represents the edges connecting the two vertices. The edges represents the relationship between two vertices sets. The relationship is one to one, one to many, many to one and many to many.

The model is applicable to any product manufacturing company. It is necessary to identify the specific point through which the product undergoes. This depends on the type of industry. For example, if we consider a food industry, the product moves from farm to the manufacturer to the distributer or transporter and finally to the end users. Actors produce information through internal process at all of these points. For example, at farm, the farmers do the cultivation, maintains the soil information, bow seeds etc. Similarly, the manufacturer maintains the supplier's information, processing information of raw materials, packaging information etc. It is also necessary to identify the type of the products. The product may be semi-finished or the final one.

The traceability system stores all these information produced by actors at each link that is traceable if needed. In the next section, we explain the data model we developed to show the types of data generated by the actors and the relationship between them.

4 Data Model

The information sharing and management requires the logical representation of data produced by each actors. Fig. 3 shows the data model we propose. It is assumed that there is one main manufacturer who manufactures the final product by assembling or processing the semi-finished products supplied by more than one suppliers. Suppliers in turn supply the semi-finished products manufactured by more than one manufacturers. There are more than one distributer delivering the

finished product to many customers. We consider each actors of supply chain and address the issue of complexity. Some works related with data models are found in literature. Thierno et al develop a data model to handle unitary traceability based on IEC 62264 and GS1 global standard [12].

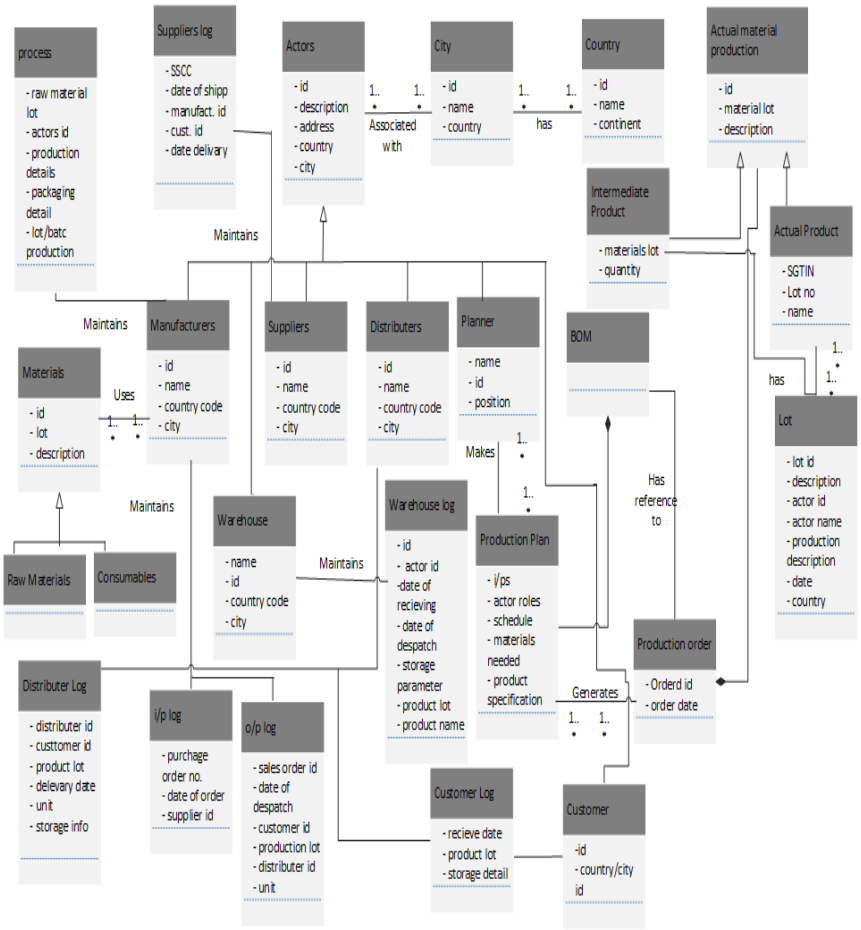

Fig. 3. Data Model

The authors aims to represent the internal traceability data to find the root cause and facilitate data exchange. In another work, a data model is proposed to support the traceability process in the food supply chain [13]. Similarly, M. khabbaji et al propose data model to manage the lot traceability on the basis of make order [14]. The model is said to support to control the material flow in all quality and production process. Some other works [14, 15], develop internal traceability data model in terms of materials and process data registration. We propose to address the global traceability data model tracing each data at each point from production till the use of the product. It starts with company planner who makes the production plan based on which the order is generated. The production plan also contains the BOM of the product. Each actors are assigned with unique identification number. The actors are linked with city and country to show the geographic distribution. The country and city has unique identification code which act as the foreign key for all the actors. All the actors maintain its own log storing all the necessary information. The manufacturers maintains i/p log that contains date of order, order id and supplier id to show on which date it receives the semi-finished product and which supplier is responsible to supply that product. It also maintains o/p log and processing information. The output log contains the sales order and customer information with distributer id. The processing data contains how the products are manufactured, the actors involved in packaging, warehousing etc. The supplier, warehouse and distributer also maintain their own log having the information like date of delivery, date of receiving, storage information, SSCC (Serial Shipping Container Code), customer's information, product lot etc. The product lot has relation with all the actor with reference to country id to track the location of the product with lot id, description, actors involved etc.

The final product contains SGTIN (Serialized Global Trade Item Number), lot number and name of the product having the relation with lot, intermediate product and actual material production.

The data model shown in figure 3 has all the traceable data and their relationship. These data are traced putting lot-id as keyword through a novel algorithm as our future work and implemented in a user friendly web based system based on cloud. We use EPC global network as a standard and use case for the validation.

5 Conclusion

The product's safety in the global supply chain is still a challenge. Companies need to enhance the product's quality and make it safer to prevent some sort of problem across the chain. To achieve this, a global traceability system is needed to trace all the required information. But, the actors don't share all the information among themselves. All the actors are not well known to each other. They produce

various sensitive information which they do not share in the network, which prevents the collaboration among them. In this paper, we propose a bi-graph model to show the relationship among all the stakeholders. Based on this model, we propose a data model to show types of data generated at each point and link between them. The model reduces the supply chain complexity by increasing the collaboration among every actors.

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