

Supply chain data management : towards tracking and tracing in the agro and food industry

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Supply chain data management: towards tracking and tracing in the agro and food industry

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Abstract

There is an urgent need for safe, wholesome food which hasn't been harmful for the animals and is environmentally benign. Government and consumers require guarantees with respect to quality and production and they should be able to choose a product on the basis of reliable and full data. Therefore, the history of a product should be traceable, and in case of exception handling, products should be recalled from the market. However, today's Enterprise Information Systems can not handle the necessary inter-enterprise communication because of the dynamic behavior of the business environment.

The main problem caused by such dynamic behavior is how to generate all relevant product data at any time, which requires that the data should be stored somewhere and that it could be coupled to a specific product. Therefore, tomorrow's Enterprise Information Systems distinguish product independent data, connected to an article code, and product dependent data, connected to an individual product or a batch of products.

The data can be stored either at one or more parties in the supply chain, or at a third party, "above" the supply chain or at the product itself. If it is stored centrally, one should be aware of the strategic impact this data could cause. Once the location is chosen, the level of aggregation has to be considered; first the level of product aggregation and secondly the level of data registration.

There are several view-points whether to collect data or not and they should be balanced depending on the specific situation each enterprise has to face. Since it is very expensive to collect data that describes the product history, the reasons to do so very much depend on the strategic aims of the enterprise in the supply chain.

1. Introduction

The public, government and consumers require more and more of agricultural products. There is an urgent need of safe, wholesome food, which hasn't been harmful for the animals and is environmentally benign. Consumers and government like to know the way in which products are produced and composed. They need guarantees with respect to the quality and the production process and they should be able to choose on the basis of reliable and complete data. Therefore, producers should have a 'face', should be communicative with respect to their products and services, and should make their products traceable.

To fulfil these requirements, product history data such as production processes and production means are necessary (Evens & Rose; Jansen 1994). These data can be derived from the phases a product has passed through: product design, selection of raw materials, production, distribution, use and waste (or recycling) (Zürn 1994). In the product life cycle in the meat chain, one refers to these phases as: breeding, increasing, fattening, slaughtering, retailing and consuming.

Usually, at least one supplier is involved in each phase of the product life cycle of a product and these suppliers have to communicate to deliver the products to their customers. However, each supplier can frequently be substituted by others (Brown et al. 1995), which creates a problem in the communication between these enterprises. In the above mentioned example, quite a few fatteners deliver to a slaughter and each of them can decide to deliver to another slaughter. At the moment, Enterprise Information Systems, which can be used to store product data like quality data and environmental issues, are designed for internal use and have to be adapted to communicate with other parties in the supply chain. However, today's Enterprise Information Systems cannot handle the dynamic behavior caused by frequent substitutions in the supply chain.

The main problem of such dynamic behavior is how to generate all the relevant product data at any time, which requires that the data should be stored somewhere and that it could be coupled to a specific product. In this paper, we first consider the goods flow and its data flows and examine the aims for local data storage (internal flows) and the aims for data storage in the supply chain (external flows). The second step to be taken is the coupling of the goods flow with its matching data flows; the matching can be made on several levels, which is illustrated by the application of the EAN code system. The remaining steps are to consider the location of data storage and the appropriate level of aggregation, both with respect to product aggregation and data aggregation.

2. Goods flows and data flows

When considering goods flows, we distinguish company internal flows and external inter-company flows. In this section we first go into detail for internal, local registration and secondly, we consider goods flows in supply chains.

2.1 Internal flows

The production of goods carries with it the generation of data. This data is registered mainly because of business economic reasons: business valuation, budgeting and invoicing. Furthermore, this data is used by subordinates who have to justify the management of goods and the control of the goods flow. Last but not least, the data are used by the enterprise itself to justify the production means and methods with respect to quality, logistics and effects on environment and common health. Related to the latter, for several enterprises it is important to be able to recall products from the market by tracking the product during its life (forward in time) or to trace the history of products (backwards in time).

Apart from business economic reasons, enterprises use their (historic) data for product development and user- and service documentation. This kind of data is used in decision support systems, and for simulation and knowledge management.

The data should be registered as soon as a certain phase has been finished: by change of ownership or value, or by transition of management, control, or uncertainty. We distinguish (1) state independent data, in which case we are collecting data on the level of product types,

and (2) state dependent data, in which case we are collecting data on the level of specific products (individual or in batches).

2.2 Flows in supply chains

In general, several enterprises are involved in the product life cycle and therefore in registration of the goods flow. To fulfil the demand of a buyer at the end of the supply chain, two data flows are necessary: (a) down-stream flow: product properties, which include production means and methods, product specification and transaction information; (b) up-stream flow: consumer demands, which include actual demand and historical market data.

The exchange of the above mentioned data requires a lot of communication between enterprises which usually are spread all over the country or even all over the world. The use of electronic data interchange (EDI) eliminates many of the drawbacks of geographic borders, the volume of data and the synchronization between buyer and supplier. Therefore, supply chain information systems that are based on EDI are a means to communicate trade orders, market data and production data with (1) the direct buyer, with respect to strategic alliances, (2) the final consumer, as a guarantee for trade-marks, hall-marks and certificates, (3) government, for regulation and policy and (4) public community.

Other applications of supply chain information systems include the coupling of product and product data (a) for production control, (b) for tracing (exception handling) and (c) for tracking of products that are considered valuable or risky: parcel-post for which a third party is responsible, waste which is harmful or regulated, or opium which is risky when it is used in the wrong quantity.

In this paper, we consider data flows in supply chains and we especially focus on the data storage in behalf of tracking and tracing.

3. Object identification in supply chains

3.1 Definitions

The coupling of a product with its data requires unique identification of the product concerned. Especially for agricultural products this is not trivial, as will be shown in this section. We distinguish product types, product batches and individual products.

A *product type* is the definition of a group of products, which can be referred to by its article code. A product type is described by state independent data, like the bill-of-material, its dispensing, and packing, and can typically be found in a catalogue. The main characteristic of a product type is that it doesn't exist physically but only as an abstract description of physical products. An example of a product type is boeuf Bourgignon; when you order this plate, the cook will serve the kind of beef you expect, but you cannot distinguish it from the one that is served to your neighbor.

A *batch* is a group of physical products, that have some properties in common, apart from the state independent properties. We have for example a batch of meat that is supplied by one farmer and processed by one slaughterer at a certain day. The main characteristic of a batch are (1) that there is a certain point in time before which the batch didn't exist and after which it does exist; (2) that there is a certain point in time after which the batch doesn't exist anymore; and (3) between these two points in time, the physical products undergo the same actions. The batch can be identified by a batch code attached to an article code, and has to be described by state independent data (attached to the product code) and state dependent data (attached to the batch code).

An *individual product* is a batch with size one. In general, this implies that there is a property which distinguishes two products. In a slaughter, for example, cows will be supplied by several farmers and therefore in several qualities. However, at the moment, the slaughterer only has one article code for beef and the batch code is not related to the farmer. If one of the farmers supplies cows that turn out to have a disease and therefore the beef cannot be used, the slaughterer has to recall all the beef of that production day.

The coupling of goods with its matching data can be interrupted by disturbances in the supply chain. The location where this interruption appears is called an *information decoupling point*. At an information decoupling point, the available (up stream) data is gathered, aggregated and attached to the product or batch; after the decoupling point, only new (down stream)

information is attached, gathered at the locations that have added value to this product or batch. It can be considered as the Markov property of a product or batch with respect to a specific aspect and it implies that there are decoupling points for production control, but also for quality data, environmental issues, etc.

3.2 Identification of product types

All enterprises use their own enterprise information system, with their own internal article codes. When goods are supplied, the store-keeper immediately translates the external delivered codes into internal product codes. Communicating product codes therefore causes a lot of misunderstanding, especially when these codes often change due to engineering changes. To handle this problem, a system is needed which can be used by any enterprise to translate their internal product code into a universal product code. The internal code can still be used within the enterprise, only the universal code will be exchanged.

The European Article Numbering (EAN) organization has built such a coding system, which is compatible with the Universal Product Code (UPC) that is used in the USA and which enables the store-keeper to couple the goods flow and the data flow automatically. The EAN code system distinguishes the following units: articles (consumer units and packages), trade and order units, supplementary information, locations, shipment units and deposit tickets.

The EAN article codes are decentrally attached to the product types, at the source. The code is constructed as follows:

	System code	Connection nr.	Article nr.	Control nr.
Location	13 12	11 10 9 8 7	6 5 4 3 2	1
Example code	8 7	5 2 3 2 7	6 1 8 1 0	6

The system code identifies the EAN code distributor; the connection number identifies the enterprise that is responsible for the product, usually the manufacturer or the owner of a hall-mark. The article reference number is decentralized attached by the owner of the connection number.

Using the same article codes enables the enterprise to exchange data automatically; this is referred to as Electronic Data Interchange (EDI). Apart from the benefits of EDI that are

mentioned in section 2.2, there are some other effects that have a great impact. First, planning and prognosis data can be retrieved for suppliers and customers to improve their internal production and logistics. Secondly, shorter delivery times can be achieved by preliminary ordering and level supply control, which gives the supplier a clear insight into the market. In addition, electronic parcel tickets enable the customer to do the control of goods delivery automatically, price lists can be delivered electronically and invoices are no longer necessary

3.3 Identification of batches

A problem with the EAN-13 article code, however, is that the article code is attached to a product type and thus all products of that product type are considered to be equal. In reality, however, all products of a product type are not equal, *e.g.* food products which are perishable. The expiration date is a key factor for delivery to optimize the stock value. Other examples of data that can not be modeled by EAN-13 are batch numbers, serial numbers, forward codes and weight indications.

To solve these problems, the concept of an Application Identifier (AI) is added, using the EAN-128. code as an extension of the article code. The AI standard defines data blocks, each block starting with an identifier of 2-4 characters for the meaning, format and length of the field. A number of common identifiers are predefined and new identifiers can be asked for. Note that EAN-128 is usually applied to trade units, whereas EAN-13 is applied both to trade units and consumer units..

The benefits of EAN-128 for the manufacturer are in internal logistics: product registration and pallet structure (which articles, quantities, batches and tenability). The main benefits for distribution are sorting, routing, tracking and tracing.

3.4 Bottle-necks

The EAN coding system is very useful if it is necessary to distinguish specific products or batches of products. The unique coding of products or batches, however, is not applicable in all cases, because it is either not possible or too expensive. The coupling of goods and data can be interrupted by disturbances in the supply chain at so called information decoupling points. In the meat chain for example, pigs are supplied in the slaughter with unique numbers which make them uniquely identifiable. After the pigs are slaughtered the (numbered) head is removed and the carcass can no longer be distinguished from the others. This situation is not.

desired but can hardly be avoided, however, since other business applications require this way of aggregation.

Except for disturbances, identification of products can also be difficult due to the product itself. At a certain point in time (parallel case), it is not always beneficial to distinguish products because the customer doesn't want or isn't able to distinguish them. In the slaughter case again, this appears when the farmer supplies numbered cows. Before they are processed, they can be distinguished, but afterwards, when all beef of the day is in the box marked "beef" and all filet in the box marked "filet", no one will ever know which beef and filet belonged to cow number 12345. If only for this application, the cows could be supplied without numbers, thus saving the costs of registration.

It is not always possible to recognize a product at a different place or time in the supply chain, due to changes in name, number or composition. For example, computers are sold with a unique serial number, that is translated into an internal code to be used within the company. After some time one decides to change the configuration. Although it will be internally registered, the supplier won't know and if the translation is lost, he even cannot know these changes.

Furthermore, coding may be undesirable, mostly because uniquely identifying products requires a high level of detail that leads to costs. Especially products with low value and risk that are produced in large quantities are not suitable for unique identification; decreasing the level of detail probably yields a better cost/profit balance.

4. Location of data registration in supply chains

Once we have determined which data should be stored, we have to consider where it can be stored. The location for storing product data depends on the applications that will use that data later on. One way of data storage can be applicable for one goal but too expensive or even impossible for another. Therefore, an overview of the alternatives is given.

4.1 Central registration

Central data storage implies that all parties in the chain have one location in common to store their data, either in the chain or at a third party.

When the data is stored in the chain, it is possible to store the data (1) at the first party, usually the manufacturer, which enables tracking, (2) at the final party, usually the consumer, which enables tracing, or (3) at any information decoupling point. For all cases, it follows that identification of the goods and coupling with product data is not trivial.

An example of data storage at the final party is the production of slaughter chicken for the German market. In Germany, it is required that the chicken slaughterer be able to know which increaser supplied which chicken to which fatter and which breeder supplied it in the beginning. One advantage of the application of the first example can be shown by a case of tainted baby food. In this case, the manufacturer has been able to trace a quantity of tainted baby food back to a subcontractor of one of his meat suppliers. However, he was not able to recall the complete batch since he didn't know which buyers were using it and he had to recall the products of the full production day.

Secondly, the data can be stored at a third party, either a chain manager or an independent organization. The concept of a chain manager works only when the chain manager is a powerful party. In many cases, however, the power is divided into a number of small parties and in such a case the data should be stored at an overall or inspecting organization. In the Dutch processing of cows, for example, this role is played by the national cattle syndicate which stores all data on cows in the national herd-book.

The main benefit of the central concept is that tracking and tracing are easily implemented. Nevertheless, in the opinion of many chain parties the concept is not satisfying because the central storage of data empowers one party to use the collected data strategically, thus wielding power on the chain.

4.2 Distributed registration

In the case of decentralized data storage, the product data is stored at the location it has been produced, thus avoiding the above mentioned disadvantage. However, to be able to follow goods in the supply chain, products still have to be identified. If the data is registered at

several locations, this is frustrated by the use of different concepts, but nevertheless it is still possible if a central control on data management is admitted, which can be used as a basis for tracking and tracing. A variant of the decentralized concept is to store data only at decoupling points, implying central data storage in parts of the chain.

Decentral data storage has one main drawback, however: it usually ends up with many different, non compatible systems, which is the price to be paid for avoiding shifts of power in the supply chain. However, using this option also enables parties in the chain to implement systems independently so that they can be part of internal production systems.

4.3 Attached to a product

Different from data storage at one or more parties is data storage on the product itself, for example in a covering document or in a covering or even attached chip. The coupling between a product and its data is easily done; tracing is possible by retrieving the enterprises that have added information. Tracking is not possible, unless additional databases in the chain are set up, as is the case for communication of order data.

5. Other issues

5.1 Aggregation of products

Aggregation of products in batches is possible if they can be considered to be identical. In this context, identical means that there is no distinction of products relative to a certain criterion. This is usually not the case in food industry, since two products are never exactly the same. Example: for the production of slaughter-chicken, chickens are considered to be identical if they have their genetic material in common and are kept and fed under the same circumstances. On the other hand, in the production of beef, cows are considered to be different, because they differ significantly in genetic material and weight. In both cases, the criterion is that the animals are considered to be equal or not, depending on their quality, shape and composition (in the opinion of the buyer).

5.2 Aggregation of registration data

If the quality of a product should be determined, it can be done either by measuring of the end product, or by describing its history. Measuring of the end-product is sometimes easy and

should be preferred. However, this way of quality determination often is very complex and thus expensive and sometimes quality is determined by attributes that cannot even be measured on the end product, like production methods that are not harmful for the animals.

When a product is produced by only one enterprise, a quality assurance system can be used during the production. When a product is produced by a number of enterprises, as is the case for the above mentioned kinds of meat, the quality registrations have to be coupled, either directly or indirectly. These registrations are usually part of an assurance system that can be certified by a standardization organization like ISO. A certificate is a means to aggregate product data and production data. ISO has certificates for quality assurance (ISO 9000), quality assurance systems (ISO 9002), environmental quality (ISO 14000), etc. Once an organization has a certificate, it is known which production rules are used (as is the case for ISO certificates), and sometimes it is known that these production rules meet (standard) requirements (as is not the case for ISO certificates, but it is, for example, for the quality mark McDonald's attaches to its hamburgers).

Certificates can be used to aggregate the information that is collected within the enterprise and should be communicated to parties in the supply chain. Several levels of data interchange can be distinguished, using the above mentioned certificates. On the first level, the only requirement is that the supplier is certified and this is communicated by a simple yes or no. On the second level, the supplier has to be certified as well. The communication, however, is extended by the criterion on which the certificate is based. For example, the buyer requires that the supplier has an ISO 9000-certificate that includes environmentally benign production methods. On the third level, the supplier also has to supply the data that is collected to meet the requirements of the certificate. For example, it is specified that the production should be environmentally benign, implying that the caused water pollution is less than x .

Apart from these three levels, the product quality can be guaranteed by the following extensions. First, the product history can be communicated if the path of the supplier and the supplier's suppliers is registered, either directly or indirectly. Secondly, the quality control that is recorded by means of the certificate is not only applied to the supplier, but can be specified to particular shipments, batches or even individual products.

6. Conclusion

To meet the requirements of tomorrow's dynamic behavior of the business environment, Enterprise Information Systems distinguish product independent data, connected to a product type or product code, and product dependent data, connected to a batch of products. The way this data should be registered depends on the desired communication in the supply chain and the political relations.

There are several view-points whether or not to collect data and they should be balanced depending on the specific situation each enterprise has to face. Since it is very expensive to collect data that describes the product history, the reasons to do so very much depend on the strategic aims of the enterprise in the supply chain. This implies that the following, dependent, issues should be balanced:

- aims and scope of the enterprise, often related to the general enterprise strategy
- aims for the supply chain: supplementary investments are necessary, because external automation is a prerequisite for effective and efficient communication
- level of aggregation of product types, batches and individual products
- level of aggregation of registration for the above mentioned level of products
- location of registration, with respect to the goals and the political impact

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