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INDUCTION OF A REFERENCE DATA MODEL FOR TRACKING AND TRACING

C. van Dorp
University of Wageningen

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C. A. van Dorp
University of Wageningen
Kees-Jan.vanDorp@users.info.wag-ur.nl

Abstract

In this paper research on tracking and tracing is described. The objective of the research paper is the establishment of a general set of requirements and a general modelling solution for tracking and tracing. A reference modelling solution is obtained from different cases through the method of requirements induction. Several manufacturing situations are selected for the gathering and analyses of the requirements: a slaughter facility, a food processor and a pharmaceutical manufacturer. The paper describes the traceability requirements of these manufacturing situations in natural language and accordingly induces a general modelling solution: a reference data model. The model obtained, can represent all raw materials, parts, intermediates and subassemblies, which a process transforms into a particular end product, through the sequence of operations. Using the model, one can determine the composition of a material item out of component items and list all material items, having consumed a certain component of specific interest. The reference data model can be used in blueprinting information systems for tracking and tracing.

Keywords: Tracking and tracing, reference models, information systems

Introduction

This paper describes the induction of tracking and tracing requirements and the modelling of a general solution. Three enterprises are described on their production steps and their traceability considerations. An overview is given of induced requirements and a reference data model is proposed that prescribes how the induced requirements should be represented. Tracking and tracing represents in a formal way and in accordance with stakeholder and integrity requirements, historic information on properties of objects in the object system. A broad array of definitions can be found in literature on tracking and tracing (e.g., Töyrylä, 1999; Eads and Undhein, 1984; Steele, 1995; Kim et al., 1995; MESA, 1997).

Multiple Case Studies

Case studies held a prominent place. Case studies were the base for the requirements induction and reference data modelling. Case study research included the analysis of three production situations: a slaughter facility, a food processor and a pharmaceutical manufacturer. Next, the results of the enterprise analysis are described. For each case, the production steps are outlined and the main traceability considerations are discussed.

Slaughter Facility

The first enterprise researched on tracking and tracing requirements, produces beef products (figure 1). The enterprise under discussion is a slaughter facility. It supplies customers with such beef products as quarters with bone, technical parts (no bone) and snits.

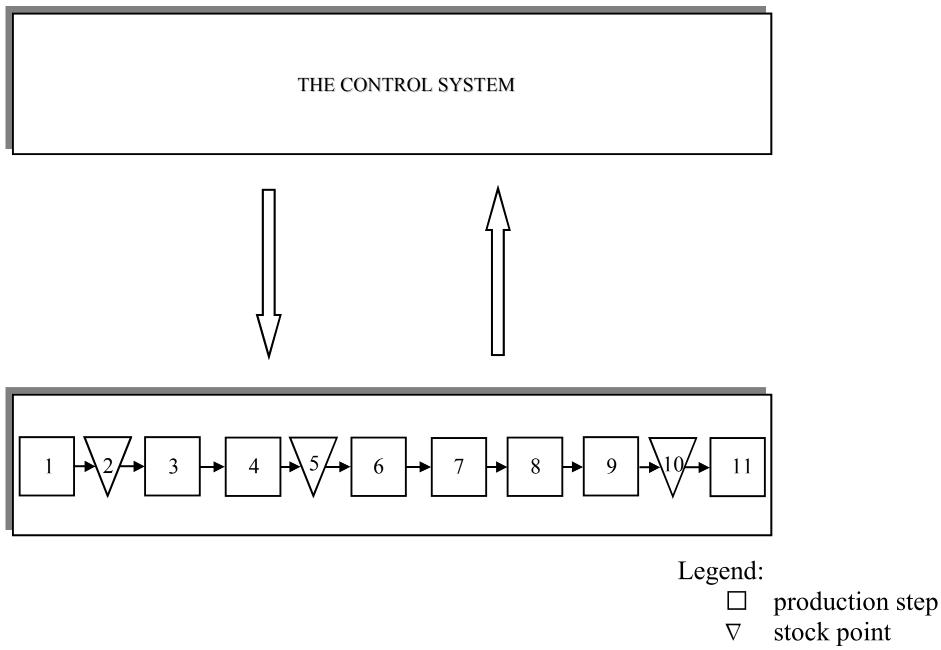


Figure 1. Production Situation of Beef Products

Production Steps

A transportation company brings the animals from the farm location to the slaughterhouse. At receipt, the animals get an entrée inspection (1). They can be canalised to a certain stable section or hall section (2). Animals with quality certificates for example, are to be separated from the others. Successively, the animals are slaughtered batch-wise (3). The slaughter process includes, amongst others: a neck stain, bleeding, de-skinning, organ removal, weighing and classification and assignment of a slaughter label. The label includes a sequence number that relates the carcass to the animal identification of entrée. Following, the carcass is chilled (4). Chilling is a method of speed-cooling carcasses before they enter the actual cooling room (5). Once in the cooling room, the carcasses are assigned to customer orders (i.e. become destined products). They are allocated based on their on quality characteristics. When the destination of the carcasses is known, they are disassembled into quarters (6). Quarters are meat parts with bone. Depending on the allocation made, quarters can be cut further into technical parts, these are meat parts without bone (7) and also, into the more small parts, snits (8). Successively, quarters are packed or wrapped while technical parts and snits are put into crates and boxes (9). All products are assigned with product labels and put in a storage room (10). In the storage room, the products are grouped and the crates and boxes are palletised. Following, the expedition to the customer commences (11). The orders are then picked and delivered.

Traceability Considerations

Cattle batches are supplied to the slaughter facility. The animals carry unique identification. The identification is coded on the ear-tag of the animals. The code gives access to historic data stored on the animal, in a national database. The chain actors enter these data, in different stages of the supply chain (e.g. on import of cattle, on farming of cattle, etc). On processing cattle into beef products, slaughterhouses must take notice of legislation. Contemporary legislation states that product batches may not include animal parts of a different country origin: batches processed should have homogeneous country characteristics. To ascertain the integrity of the first production step in that respect, i.e. the slaughter process, the ear-tag of cattle must be scanned as to acquire verification from the central computer system on the origin of the cattle. Cattle may be joined into larger (economic) processing batches, as long as batch integrity is maintained.

In the cooling room all carcasses remain identified by a label. These carcasses are then assigned to customer order based on quality selection. The carcasses are further cut into technical parts and snits and registration must take place. Depending on the product amount and the required quality, the associated production steps may mix parts from different animals into crates or boxes. This is no problem, as long as the crates or boxes remain traceable to their constituting cattle parts and maintain their homogeneous country characteristics. The batch identification placed on boxes and crates is to disclose any information on the cattle processed. This identification should therefore maintain related to the actual identification numbers of the processed cattle (or their associated slaughter sequence number).

The slaughterhouse notes that under legislative circumstances, more efficient data exchange with the (national) computer system is needed. It is required to determine cattle quality on entrée (e.g. quality certificates), optimise internal slaughterhouse control activities and realise efficient printing of product specifications on consumer products. It seems a pre-condition to obtain real-time retrieval of data from the central computer system. Data exchange on the quality of cattle (batches) would additionally help the slaughterhouse to optimise the planning and control of the allocation of cattle carcasses to customer orders. In this respect, an advance notice on the animals for slaughter and the expected classification of the animals is thought of. Such information can be send to the slaughterhouse by farmers. The information enables the slaughterhouse to optimise planning and control over supply (quality). Analogous, such information as the actual time of slaughter and the assigned classification to animals, can be send (back) from the slaughterhouse to the farmer, as to enable the farmer to assess its own performance, the performance of the transportation company, and that of the slaughterhouse. The farmer can then trace any quality anomaly (e.g. due to delay and/or animal stress). With respect to sales, the slaughterhouse views it important to track products to customers. It enables a more narrow recall on calamity. Consequently, sales orders of the products shipped, should be supplemented with (batch) identification.

From the case described here, specific requirements for tracking and tracing could be distilled. The main requirements are listed in table 1.

Food Processor

The second enterprise researched on tracking and tracing requirements produces canned food products (figure 2).

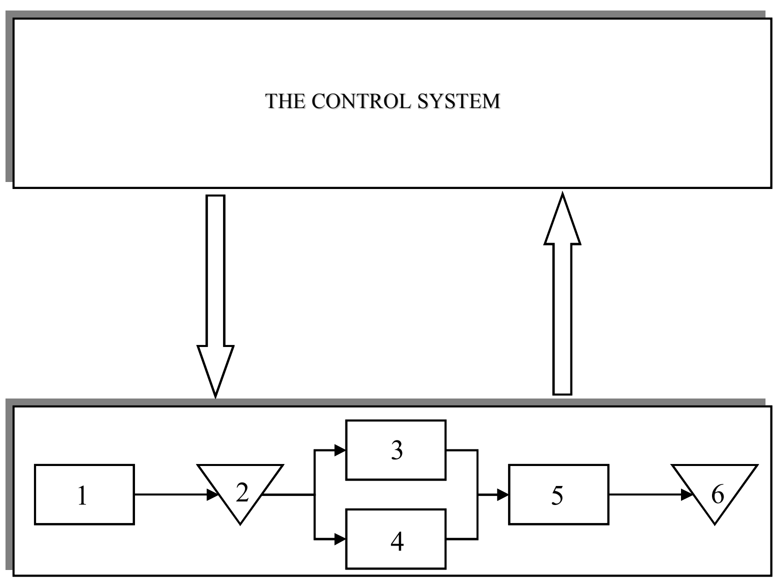


Figure 2. Production Situation of Canned Food Products

Production Steps

The products generated by the enterprise are distinguished into canned sausage products and canned sauce products. In the enterprise under discussion purchased materials such as potatoes, vegetables, meat, dry herbs and spices and packaging materials are unloaded and received (1), in the vicinity of a central stock point (2). The stock point is abstract and should be decomposed into multiple separate storage points for the incoming materials: one stock point for herbs, spices, packing materials and left over food cans, and one stock point for herbs and flower (silo), two cold storage rooms for frozen raw materials and one cooling for products that require conditioning (potatoes, vegetables, meat, etc. are fresh raw materials and enter the enterprise in cooled or frozen state). Also, two intermediate storage points exist prior to production, so-called shop floor warehouse points, these are used to temper frozen products (defrosting). Production of sausages and other products takes place in the production units (3 and 4). Unit 3 is dedicated to producing the sausages. An almost continuous production of sausages takes place in production unit 3. Unit 3 is also responsible for filling the cans and sterilising the product. Unit 4 is used to manufacture all other products besides the sausages (i.e. sauce produces with food substances). The packaging unit (5) successively labels all food cans deriving from the production units. The cans are placed on trays, which are stacked on pallets. Finally, all products resulting are stored in the Distribution Centre (DC) of the enterprise (6). From thereon, logistic service providers rout products to customers.

Traceability Considerations

Raw material batches that enter the organisation are assigned a unique number. The number is pre-generated on ordering. Due to the fact that only one batch number is assigned to the (purchase) order line, traceability problems can occur. After all, a supplied batch of raw materials can be composed of multiple batches from supplier production runs. Assigning one unique number and removing the supplier numbers, implies generalisation over supplier production runs. When this information is lost, it becomes more difficult for the supplier to localise a particular problem on calamity. Moreover, no stock allocation system is present, making it hard to localise (track) certain batches or lots within the enterprise. Further, considering shelf life restrictions, products are to be released using FIFO (First In First Out). Indeed materials are booked FIFO using back flushing. However in practice, stock is released in a less stringent manner, resulting in a mismatch between registered material usage and actual material usage.

Not all materials are consumed in production. Some materials will be returned to the warehouse. But as some batches loose their label in production, certain goods can no longer be identified as they return. The cause goes back to the problem of physical identification of lots in production. The production environment and the labelling technique cause a problem. The registration of lots is done manually, by writing down the applicable identification numbers. The papers and stickers used as identification labels get wet in the shop floor warehouses and/or are blown away by ventilators present. Moreover, the manual procedure takes a long time (i.e. is inefficient) and not very reliable. Consequently, the enterprise is helped with the introduction of identification technology and bar code scanners.

Another point noted, is the percentage of active components in batches. In many cases, the raw material used by production, is meat. Meat batches that are supplied can vary in composition with respect to fat percentage. Because of such variations, often a mix of meat batches is used for production, instead of applying the FIFO method. To be able to perform more systematic selection of batches for production, data on these batches should be registered. Different quality classes of batches may enable more optimal allocation to production. It then is required that all raw material lots are identified and their characteristics be recorded. The optimisation should be extended to also include batches actually in production. This implies the registration of process variables on every batch level in production. In the given situation only the sterilisation step registers variables on batch level. Finally, the lack of contractual agreements with suppliers concerning the organisation of their tracking and tracing system, is noted to compromise the integrity of the tracking and tracing system.

From the case described here, specific requirements for tracking and tracing could be distilled. The main requirements are listed in table 1.

Pharmaceutical Manufacturer

The third enterprise researched on tracking and tracing requirements, produces pharmaceutical products for testing (figure 3).

Production Steps

The enterprise under discussion has high quality and safety standards. The first step of the goods flow is the receipt of the raw materials (1). Pharmaceutical enterprises have very stringent quality requirements on receipt, demanding detailed registration of data on supplier lots. A certificate accompanies purchased goods with data on lot characteristics. Such data is checked and elaborated with tests. In pharmacy, the number of different materials required by production usually is very high while the consumed quantities are usually low. Because of the high costs associated with the materials, stock control is tightly arranged and the location is determined by the enterprise (2). The first production phase (3) consists of manufacturing generic pharmaceutical products and complementary products for testing. The separate items are stored in different warehouses (decomposing abstract stock point no. 4). In the production unit that follows, the separate items that belong together, are packed into a kit/test-box (5). The final products, derived from compiling these test kits or boxes, are then stored in a warehouse (6). Shipping of end products to customers is the last step (7). The kits of the latter production unit (5) are compiled on the bases of customer orders.

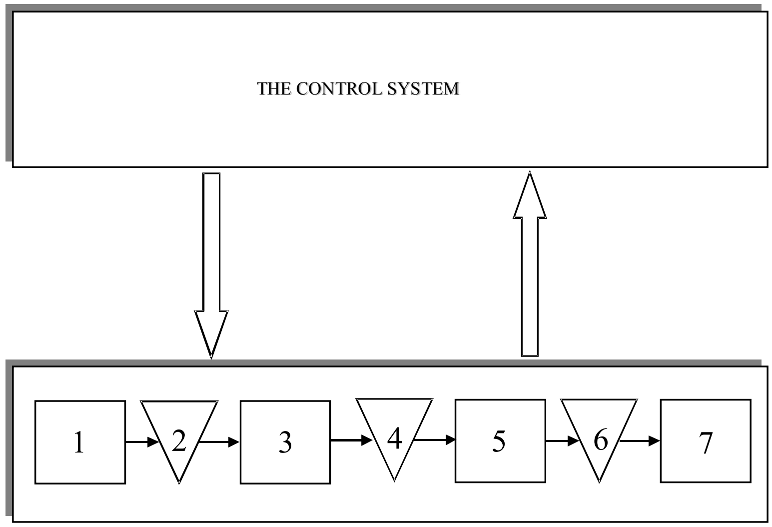


Figure 3. Production Situation of Pharmaceutical Test Products

Traceability Considerations

Despite the already stringent quality regime on the enterprise and its suppliers, analyses of the enterprise system revealed some improvements are possible. Given the stringent quality requirements of the industry, a sophisticated registration on quality and engineering of raw materials, is needed. In warehousing and production, therefore, registration of data on batches is required. The required functionality often transcends that of traditional Enterprise Resource Planning or ERP (Wortmann, 1998). Most often, dedicated systems for management of data on quality and engineering are required. The enterprise under discussion uses a Laboratory Information Management System (LIMS). As the LIM system is extensively used for tracking and tracing, the evaluation of the enterprise system on tracking and tracing is ambiguous: much functionality for registration of data on lots or batches is handled by LIMS.

As much of the data on lot characteristics are stored by LIMS, the enterprise is not able to run production planning with the quality data, as the required information is not fed into the enterprise system. Systems integration has not been established and lot-based production is impossible, though very much desirable. It is desirable, as lot-based production optimises the allocation of lots to production. Similar, pooling and segregation of material in warehouses and the batches in production, is not registered by the enterprise system, though desirable on the enterprise level. Also, registration of data on batches in production is not accounted for by the enterprise system. This also is desirable, as the data can be used to optimise recipes of subsequent production steps.

The quality of items is priority in the pharmaceutical industry. Suppliers must be certified before they are allowed to supply the enterprise. Consequently, a certificate depicting manufacturing and testing according to required standards accompanies each delivery. Supplied lots, extracted from different production batches however, are likely to show *some* variation with respect to quality properties. Batches individually therefore, carry unique identification to which test results are linked. Evidently, the pharmacy applies a secure way of working. With respect to production for example, batches typically are not to exceed half-day production time (restriction on the batch size) and moreover, lot or batch numbers must be available before production can commence. Also if the demand for a certain material exceeds the available quantity of the lot available, then the production batch size should be diminished.

From the case described here, specific requirements for tracking and tracing could be distilled. The main requirements are listed in table 1.

Table 1. Natural Language Description of Important Requirements

Slaughter facility	• Registration of cattle numbers • Registration of data on cattle (origin) • Registration of data on quality (certificates) • Registration of crate/box numbers • Cattle (identification) on box/crate level
Food processor	• Registration of lot numbers • Registration of lots/batches consumed in production • Registration of process variables on batch level
Pharmaceutical manufacturer	• Registration of batch/lot numbers • Registration of pooling and segregation • Registration of batches consumed in production • Registration of process data on batch level

Induced Requirements

Case studies have been researched and described on their requirements with respect to tracking and tracing. In the case of the slaughter facility, the identification of cattle, the registration of data on origin and quality of cattle, and the registration of relations between beef end products and cattle constituent parts, were considered important. In the case of producing canned sausage products and canned sauce products, the requirements of the registration of lot numbers consumed by production and the registration of process variables on batch level, were considered important. In the case of the pharmaceutical manufacturer with its pharmaceutical test kits, the requirements of registering pooling and segregation of material lots in warehouses and batches in production, and the registration of data on batch level in production, were considered important.

Although the enterprises described by these cases do not seem that alike, it can be noted that their requirements with respect to tracking and tracing, are alike. Similarities are found in the requirements of the enterprise situations. Because of similarities, it is possible to construct a reference data model that is valid for a class of situations and which can be instantiated and/or customised on demand. A reference data model can be constructed that is generic enough as to incorporate the important requirements found in the case studies. Generalised, three core requirements should be distinguished that need to be accommodated in the reference model:

- Support for the registration of historic relations between lots and/or batches
- Support for the registration of operations on lots and/or batches in production
- Support for the registration of associated variables and values, on operation

The induced requirements are the general design principles for the construction of the reference data model. The incorporation of these design principles will enable the model to be general enough and allow instantiation to different situations. The following question then, is how can these design principles be translated into data entity types and relationship types for the reference data model? The upcoming sections will give a more in depth look into the reference model that has been developed. Important data structures of the reference model are discussed, as to grasp a more thorough understanding of the workings of the model.

Modelling the Bill of Lots/Batches

A data model is viewed a coherent representation of objects from a part of reality (Hofstede, 1998). Data models consist of entity types and relationship types. The entity types lot and/or batch and bill of lots and/or batches, and their relationship types, are elaborated on next. The mentioned types play an important role in tracing the composition of the end product through the production process.

The production process can be viewed as a sequence of activities transforming a listing of raw materials, parts, intermediates and subassemblies into one particular end product. The materials, used to produce a certain end product, are contained in lots. Lots may contain production materials or purchased materials. A lot is considered a quantity produced together and sharing the same production costs and resultant specifications (APICS, 1998).

It is important to register which lots made a contribution to the composition of a certain end product batch. Lots consumed in production must be tracked through the production process in order to be able to determine the composition of the end product down to its constituent parts. It is therefore necessary that each parent assembly maintains traceability relations with its sub-assemblies. By registering the relations between sub-ordinate and super-ordinate material lots, a method of tracking the composition of the end item is obtained. When the entire sequence of activities required for manufacturing a certain end item adheres to this registering of relations, a multilevel bill of lots can be compiled. That bill of lots then contains the necessary data to determine, (i) the composition of an end product out of component lots and (ii), all end products having consumed a component lot of specific interest.

To understand the design of the bill of lots, some knowledge of the bill of materials is required. A bill of materials registers each relation between a sub-ordinate entity and super-ordinate entity. It comprises of a list of components required for the production of a parent item. A representation of a bill of materials is depicted in figure 4. The graphical representation of the production structure is given by the associated Gozinto Graph (Loos, 2001). From a designers view, the bill of materials represents a set of parent-component relationships whereby each relationship is an entity in itself (Scheer, 1998; Bertrand et al., 1990). The relationship is characterised by such attributes as: parent item identification, component item identification, effective start date (the date the relation is activated), effective end date (the date the relation is de-activated), quantity of component, yield/scrap factor (the ratio of usable output from a process to its input), etc.

Bill of material for M1

pos.	material	quantity
1	M2	2
2	M3	3
3	M5	1

Bill of material for M3

pos.	material	quantity
1	M4	6
2	M5	4

pos. = position
material = subordinate material (input)
quantity = required material quantity

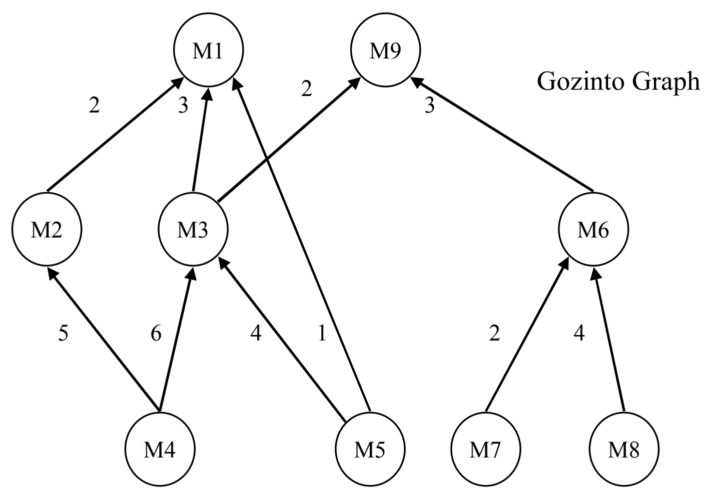


Figure 4. Bill of Materials (Loos, 2001)

The bill of lots can be designed analogous to the bill of materials. A data structure of a multilevel bill of lots is depicted in figure 5. It consists of two entity types (lot and relation) and two relationship types (explode and implode). A lot entity stores the unique identification and associated data attributes of a lot. Item identification, description, unit of measure, original quantity, remaining quantity, order type are examples of lot entity attributes. A relation entity stores the unique identification and associated data-attributes of a relation. Actual start date (the date the relation is actually activated), actual quantity of consumed material, actual yield/scrap factor, etc. are examples of relation entity attributes. For the relation entity holds: the combination of sub-ordinate and super-ordinate lot identification is unique. The relationship types of explode and implode, are used respectively to explore where-from relations in backward traceability and where-used relations in forward traceability.

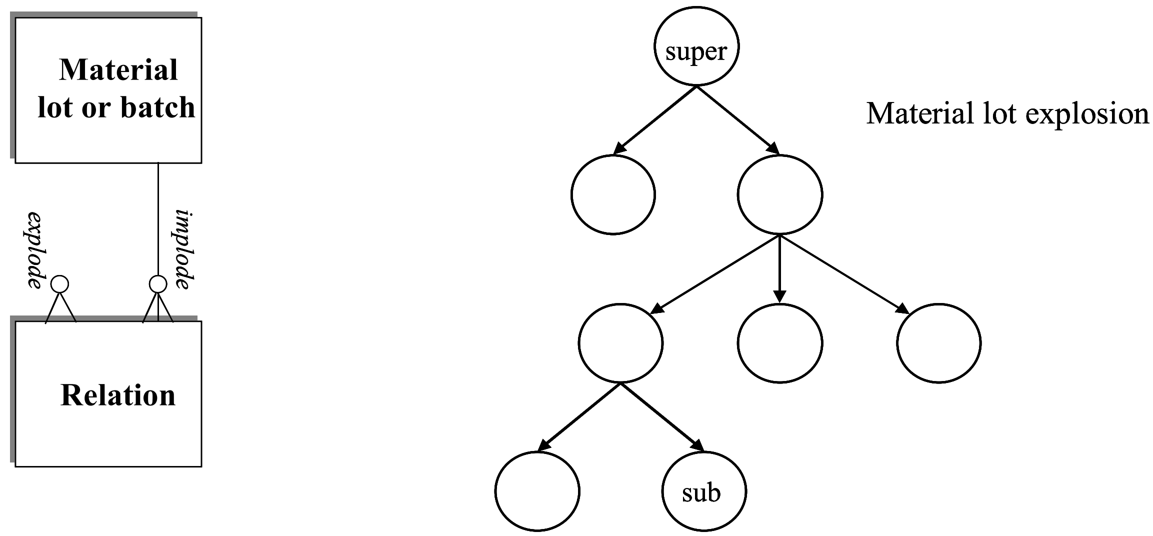


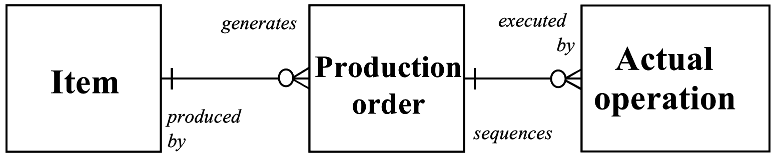
Figure 5. Multilevel Bill of Lots (Dorp van, 2001a; Dorp van, 2001b)

Different reasons can exist as to why materials are pooled or split. For example, when larger operation quantities are desired on operation and lots are considered of similar quality, warehousing may pool them. Material lots are then joined to form one bigger lot. In production, material lots and batches are mixed by capacity units, when sequenced by operations in a routing. Regardless however of the reason of pooling, traceability of material lots must be maintained. Therefore, newly created lots should be assigned unique identification and the relations created on pooling the material lots, should be recorded. Besides pooling of material lots however, organisations may also split material lots for certain reasons. Warehousing may split a material lot for example, in the situation that some part of the material has become damaged and the composition of the lot is no longer uniform. Segregation of the material then takes place and the lots split are assigned unique identification. Such lot is then split-up into two lots: a lot with damaged material and a lot with undamaged material. Considering the above situations, the application of the multilevel bill of lots is extremely important to materials handling. Fortunately, the structure of the multilevel bill of lots is capable of recording all the necessary relations to keep pooling and splitting of material lots traceable.

Modelling Actual Operations and Variables

In this section another part of the reference model is highlighted: the traceability of operations and operating variables in production. A manufacturing process is a network of manufacturing steps, which have been aggregated into operations for the purpose of manufacturing control (Bertrand et al., 1990). In manufacturing planning, items are prescribed so-called normative operations on capacity units. In production execution however, tracking and tracing requirements demand specific data on actual operations performed and not on normative operations. Hence, actual operations must be linked to the production order execution of a certain item. This is depicted in figure 6.

Furthermore, from production point of view an operation is a black box with specific properties, which are not subject to internal manipulation (Bertrand et al., 1990). The transformation of materials during an operation is performed under certain constraints with specific operating instructions. Nevertheless, deviating material input specifications and operating conditions, can be cause for deviation of the materials output specification. With the input deviation known however and the operating conditions registered, output deviation can be established within certain boundaries. Therefore, read-out of operating variables is important from viewpoint of tracking and tracing. Hence, it should become possible to link the actual values of operation variables to the actual operations executed. The reference data structure to realise this is depicted in figure 7. Further, the actual operation will be linked to the capacity unit on which the operation is executed. This functionality is represented in figure 8.



State dependent extension
(*Source*: adapted from Bertrand et al., 1990, p. 135)

Figure 6. Actual Operations Executed

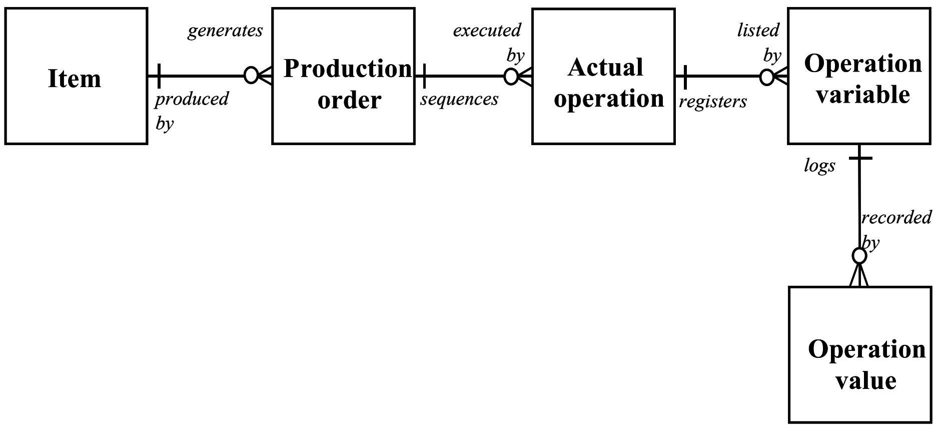


Figure 7. Operation Properties

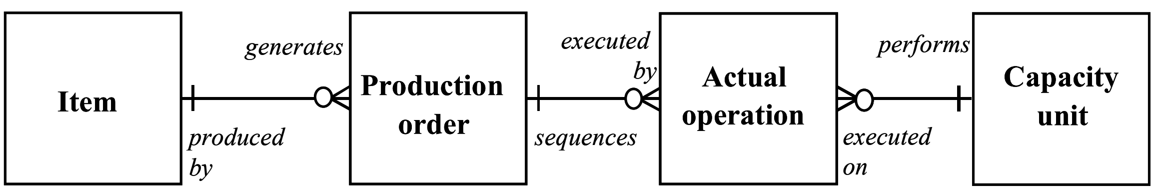


Figure 8. Registration of Capacity Units

Modelling the Integration of Bill and Operations

In general, customer-items are obtained by generating one or more manufacturing orders, each issuing a particular material lot. The final material lot is obtained through a sequence of multiple (actual) operations in manufacturing. The list of actual operations should be kept traceable in relation to the final production lot. This, however, was not included in the data models presented previously. The functionality can be included, by relating the material lot entity type to the actual operation entity type. This functionality is depicted by figure 9.

Further, relations between sub-ordinate and super-ordinate lots are formed on actual operations. In the discussion thus far however, the recording of data on lot relations and the recording of data on operations have been treated as two separate things. Such de-coupling however is not desirable as it prevents us from mapping the actual operating data on the relations recorded in the bill of lots. Operating data and relations in the multilevel bill of lots must be related on the right level. Clearly, operating data should not be registered on the level of the production order (the final production lot), as then data on operations are aggregated over all the (multilevel) relations and it will be impossible to narrow down a particular problem. Therefore, traceability relations must be stored in conjunction with the operation[1] that invoked them. This can be included in the data model by adding a material requirement relationship between the actual operation entity type and the relation entity type (figure 10).

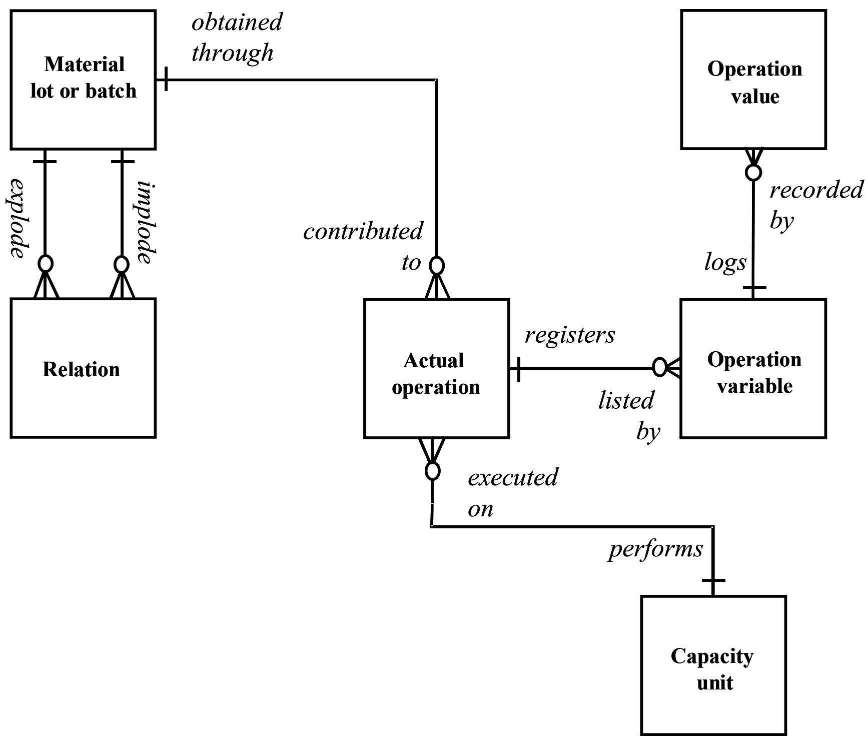


Figure 9. Actual Operations Sequenced

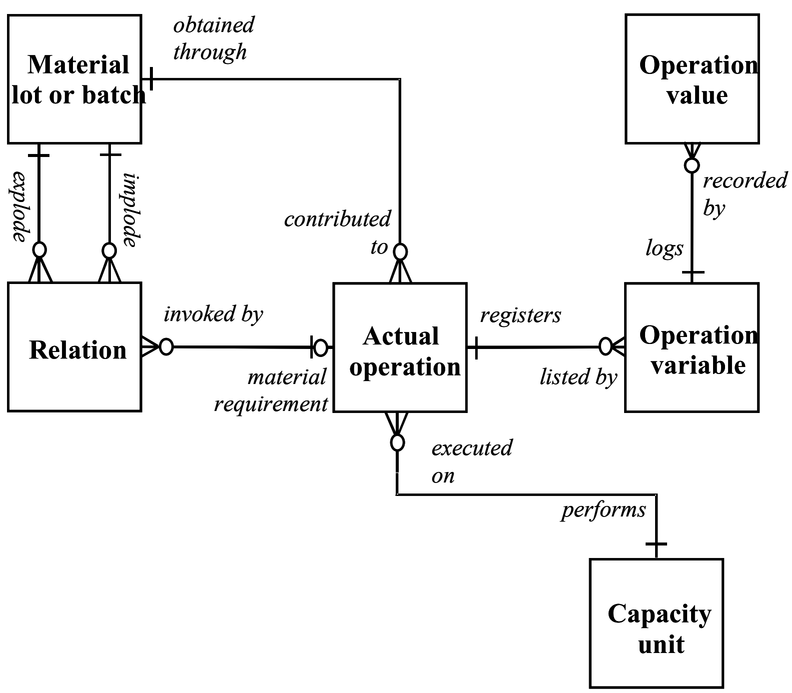


Figure 10. Material Relations and Responsible Operations

[1]Read: converging operation.

Model Overview

In this section, the model overview is presented. The comprehensive reference data model is displayed in figure 11 and represents essential functionality for tracking and tracing in manufacturing. The model states the data requirements an information system should incorporate and does not say anything about an information system's performance requirements. Therefore, the data included in the reference data model only states what data is to be processed, stored and presented by the information system.

The reference model is designed to accommodate support for the registration of historic relations between lots and/or batches, support for the registration of operations on lots and/or batches and support for the registration of associated operation variables and values. Such elements of design were identified as the core requirements and/or design principles for the model. The comprehensive model derived, includes the relevant data entity types and relationship types concerning the item produced, the production order responsible, the material lot obtained, the history on constituent material parts, the data of processing and the capacity units processed on. A brief elaboration on 'reading' the model now follows.

A requested item is produced with a production order that issues a material lot.[2] Under the production order, operations are sequenced and executed on capacity units. The operation's material consumption is maintained by relating the actual operation to the registered relations (within the bill of lots/batches). Further, operational performance is registered by the operation variable and values. Operation values are registered in relation to the operation variables, which in turn are related to the actual operation executed. Every operation executed is also related to the final production lot generated. This production lot can be exploded to trace back constituent parts. The implode relation can be used to trace forward and see whether lots have been used in other production orders (end-lots) as well.

The obtained reference model can be used to extend existing applications, which lack tracking and tracing functionality.

By now, it has become apparent that a tracking and tracing solution cannot suffice with just the registration of normative data on e.g. items and operations. What is especially required on behalf of tracking and tracing, is the registration of data on instances of items and operations. The tracking and tracing solution presented here, includes such flexibility. It has been realised by modelling different abstraction levels of the object system. The model thereto distinguishes: the instance level (e.g. Material), the object level (e.g. Item) and the meta level (e.g. Relation).

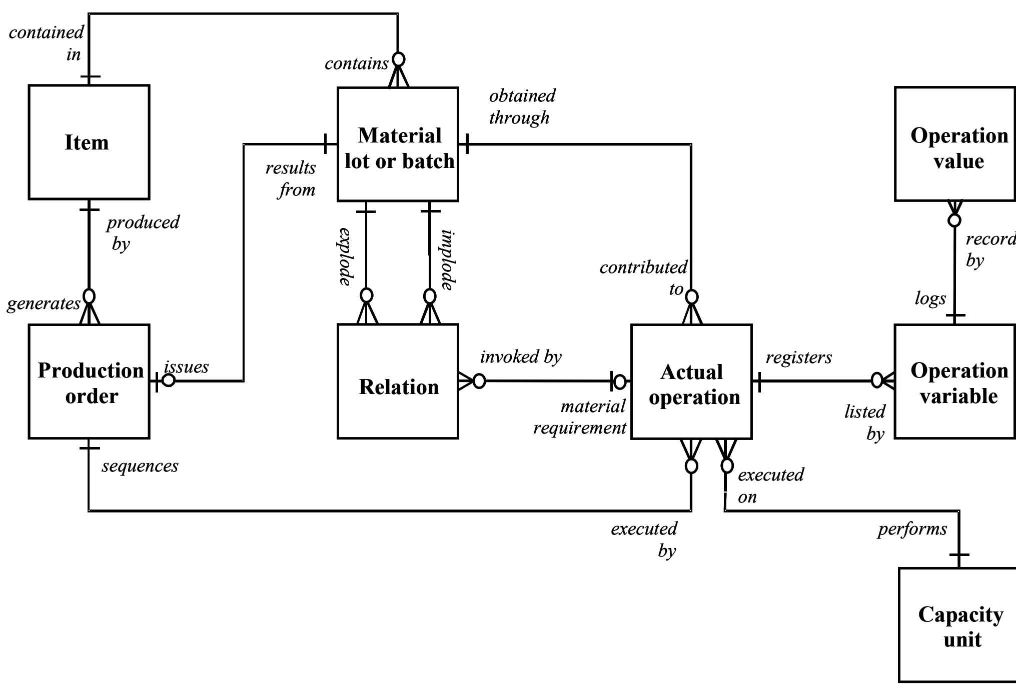


Figure 11. Comprehensive Model Overview

[2] Mind that material lots generally need not stem solely from production orders, purchase orders may for example also be the origin of demand for material (i.e., demand tracking for a material lot may include other order types as well).

Conclusions

In this paper, case study research on the induction and modelling of requirements for tracking and tracing has been described. General requirements could be formulated as a result of case study research. Three main requirements noted were: support for the registration of historic relations between lots and/or batches, support for the registration of operations on lots and/or batches in production and, support for the registration of associated operation variables and values.

The natural language requirements were successively formalised with data models. The paper elaborated on the modelling of the requirements by discussing specific entity types and relationship types. Core entity types of the reference data model: material lot or batch, (lot or batch) relation, operation, operation variable and associated value. Other (supportive) entity types distinguished: item, production order and capacity unit of execution. Particular, the inclusion of the multilevel bill of lots (or batches), must be considered important to tracking and tracing. That part of the reference model is capable of recording all the constituent parts of the final product lot or batch obtained, and in relation to operations, keeps all necessary processing data on these (constituent) parts accessible, on the right level (non-aggregated).

Concluding, the induced reference data model described in the paper, records knowledge and experience on enterprise tracking and tracing. The reference model solution is obtained from individual manufacturing situations. The model holds validity for a class of enterprises, more specific, for a class of situations (i.e. manufacture). The model can be instantiated and/or customised on demand, in accordance with situational requirements.

Future Research

The reference model has some restrictions with respect to application. One such restriction that shall be mentioned is the support for Multiple Input Multiple Output Processes (MIMOP; Jansen, 1998). While there is functional support for the registration of pooling and segregation for lots and/or batches, provided by the bill of lots and/or batches, the registration of associated *actual* operations is only intended for pooling operations (convergent production structure). Other operations have not been considered. Typical support for multiple input-output operations therefore, is not included. A recommendation for future research is, to determine what modelling solution is able to satisfy the registration of actual multiple input-output material relations, in conjunction with the associated actual multiple input-output operations. Another restriction of the reference data model that can be mentioned, is the support for cyclic operations. In cyclic production, part of the processed material is fed back into the system (Rijn van et al., 1993). The reference data model does not support this registration. Future research should therefore also determine what modelling solution is able to satisfy the registration of material relations on *actual* cyclic operations (state dependent).

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