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Data and Process Requirements for Product Recall Coordination

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Abstract. When an organisation becomes aware that one of its products may pose a safety risk to customers, it must take appropriate action as soon as possible or it can be held liable. The ability to automatically trace potentially dangerous goods through the supply chain would thus help organisations fulfil their legal obligations in a timely and effective manner. Furthermore, product recall legislation requires manufacturers to separately notify various government agencies, the health department and the public about recall incidents. This duplication of effort and paperwork can introduce errors and data inconsistencies. In this paper, we examine traceability and notification requirements in the product recall domain from two perspectives: the activities carried out during the manufacturing and recall processes and the data collected during the enactment of these processes. We then propose a workflow-based coordination framework to support these data and process requirements.

Keywords: Product Recall, Traceability, Recall Notification, Requirements Analysis, Workflow Technologies.

1 Introduction

Every organisation involved in manufacturing and/or the supply of food or consumer goods must be prepared for product recalls. In 2008 alone, there were over 1500 non-food consumer product recall notification announcements and over 3000 food and feed recall announcements in the EU [7, 8], around 1160 recall incidents in China, and 439 incidents in the US [22]. There have been a number of highly-publicised product recalls in recent years, such as Toyota recalling a number of its vehicles due to defects in accelerator pedals [31], Mattel recalling over 1.5 million toys in 2007 due to toxic lead paint [18], and the recall of many dairy products, including baby formula, due to melamine tainted milk in 2008 [30]. The impact of contaminated food and dangerous products can be devastating, potentially resulting in numerous deaths. Manufacturers of such goods may be faced with lawsuits, and can suffer from serious loss of reputation. Hence, organisations must ensure that product safety is emphasised in all phases of the production process and they must have a detailed recall plan for "inevitable product recalls"[4].

Many countries have regulatory bodies which deal with product safety matters and provide guidelines on how to conduct product recalls. For instance, the US Food and Drugs Administration (FDA) sets out recall requirements in its Regulatory Procedures Manual [32]. Health Canada and the Canadian Food Inspection Agency coordinate product and food safety recalls [13]. In China, the General Administration of Quality Supervision, Inspection, and Quarantine oversees the safety of all locally-made products [20]. In Australia, product recalls are governed by the Australian Competition and Consumer Commission [3].

Manufacturers must therefore ensure that their products comply with national product safety measures and recall process standards. Typically, such guidelines are presented merely as checklists of actions to be performed. Here we

develop *a formal workflow model for coordinating a generic product recall process and for supporting efficient communication with all stakeholders.* Such a process model can be used for carrying out trial recalls and as a first step toward fully automating the recall process. This will enable organisations to perform recalls efficiently and to effectively monitor their compliance with relevant legislation.

Two kinds of traceability are important for product recalls. *Forward traceability* is concerned with tracing end products that may contain ingredients from a particular supplier through the production process and the delivery network. For example, in January 2009, the Kellogg company issued an industry-wide product recall on many of its products after one of their suppliers indicated that the peanut paste they supplied was potentially contaminated with salmonella [17]. This is also referred to as 'tracking'. *Backward traceability* is concerned with the ability to trace the supplier and the production process used for a particular product given its characteristics. For example, in July 2009, a number of passengers on Virgin Blue flights became ill after eating chicken wraps contaminated with listeria bacteria [21]. The source of the contamination was eventually traced back to a processing plant in Wollongong. This is also referred to as 'tracing'.

Regardless of whether an organisation needs to conduct tracking or tracing, it is important that appropriate data sets (e.g., supplier and order details, production logs and delivery records) and the relationships between these data sets are kept up to date for fast retrieval. Currently such data sets are often stored in different manual and automated filing systems with no easy way of correlating information between them. In particular, data requirements for traceability are rarely carefully thought out and planned in advance. The data gathering stage can be an ad-hoc activity in which an organisation has to gather relevant details as quickly as possible under enormous pressure. A crucial part of planning a traceability system involves "carefully researching and agreeing on what data is needed, how it will be entered, and how to provide the output" [26]. In this paper, we identify *generic data requirements for traceability and explicitly capture the interrelationship between these data sets.*

Many parties need to be notified during the recall process including suppliers, consumers, regulatory authorities, delivery companies, retailers, and health officials. Each of them has their own information requirements about a recall incident. Currently, it is time consuming for an organisation to prepare separate recall notification documents tailored toward each party. It is also easy to introduce data entry errors during the process. Therefore, we aim to *determine the common data requirements for notification and to identify opportunities to automate the notification process as much as possible.*

The *research approach* we undertook to carry out a detailed requirements analysis for traceability and notification requirements in the product recall domain is as follows. We carried out a detailed literature review on how product recalls are performed in various countries including Australia, the United States, the United Kingdom and the European Union. The recall cases that we collected from these different countries and in different domains inspired the five distinct product recall scenarios discussed in Section 2. In addition, we consulted a num-

ber of food and product recall standards/guidelines including specific guidelines for different product categories e.g., Food, Motor Vehicles, Medical Appliances, etc. The findings from these research activities formed the basis of our technical proposal discussed in Section 3. In Section 4, we then demonstrate how a workflow system can play a significant coordination role in carrying out product recalls.

2 Product Recall Scenarios

In this section, we describe five distinct recall processes for different products: bread, frozen food, automobiles, toys, and artificial heart pumps. Each recall scenario is based on an actual incident from the past few years[3]. A common characteristic among these diverse products is that they are all produced via a component manufacturing process. However, their lifecycles differ in the number of suppliers involved, the nature of the manufacturing process, the shelf-life of the products, and the legal obligations for their traceability.

A generic manufacturing process consists of three main processes: (1) a *materials intake process* concerned with purchasing and warehousing supplies (e.g., raw ingredients, component parts), (2) a *production process* concerned with manufacturing finished products from these supplies using workers and machinery, and (3) a *delivery process* concerned with packaging the finished products and storing them in warehouses and/or shipping them to retailers using a number of distributors. To keep track of products for recall and other purposes, organisations use various product identification techniques including RFID tags, bar codes, batch numbers, lot numbers, serial numbers, etc. Furthermore, it is necessary to keep track of the equipment and workers involved during production and delivery, which is usually done via timesheets, log books etc.

2.1 Product Recall Scenario — Bread making

The basic ingredients for bread making include grain, water, and yeast. Sacks of flour and other ingredients are stored in warehouses. The baking process starts with mixing and kneading the dough in an industrial mixer. The dough is then fermented and loaded into a divider that cuts it into pre-determined weights. A molding machine shapes the dough into balls and drops them onto a conveyor belt enclosed in a "prover". When the dough balls emerge, they are conveyed to a second molding machine which shapes them into loaves and drops them into pans. The pans travel to another prover before entering a tunnel oven. When the bread is baked, it is then sliced and passed to a wrapping machine. The bread loaves are then packed onto pallets and delivered to stores.

From a recall perspective, the interesting characteristics of this process are as follows. The fact that a loaf of bread per se is not uniquely identifiable poses problems when a recall becomes necessary, so the best-before and manufacturing

[3] The generic process descriptions are based on those in `www.madehow.com`.

dates must be used as surrogate ways to identify them. There is also no way to separately identify the ingredients once they are combined in the finished product. As a low-cost, high-volume commodity, bread has an extensive distribution network involving many small businesses who directly use or on-sell loaves. To enable forward tracing, it is therefore necessary to keep accurate records of the raw materials used during production. For instance, workers must make records of which sacks of flour, identified by lot number, were used on a certain day. In addition, we need to also keep track of the workers and equipment involved in the baking process.

Consider a scenario where customers report finding foreign objects in bread loaves. The investigation finds that a disgruntled employee, say 'John', has been deliberately tampering with the products. In this case, the organisation needs to find answers to the following questions (from various data sources) quickly.

- What was John's work schedule in the last few weeks (employee records)?
- Which batches were worked on by John on those days (production data)?
- What are the identifying features of suspect products (product data)?
- Where are the potentially contaminated batches now (distribution data)?

2.2 Product Recall Scenario — Frozen Food

The process starts by preparing the raw food ingredients (e.g., pasta, meat, vegetables) first. All these ingredients are then cooked and placed into trays before the trays are frozen quickly (the temperature can get as low as -59℃). The frozen food is then put into cardboard cases and the batch numbers and best-before dates are printed on the packaging. These cases are then loaded into pallets and placed in a refrigerated storage facility. They are then transported in refrigerated trucks to retailers. The food will remain in near perfect condition if it is kept at -18℃ during shipping and storage.

From a recall perspective, food safety is directly linked to the proper handling and preparation of food during production as well as transportation. In this case, it is important to keep track of temperatures inside the storage facilities and in refrigerated trucks. As the shelf-life of frozen food can be up to a year, production schedule data needs to be kept for at least that long.

Consider a scenario where customers report getting sick after consuming the product. The manufacturer needs to find out whether there are some production lines for which temperatures inside the freezer and the refrigerated truck were not low enough (e.g., higher than -30℃ in the freezers or higher than -10℃ in the trucks). Answers to the following questions are required quickly.

- Were there batches in freezers with a high temperature (production data)?
- Were there batches in trucks with a high temperature (distribution data)?
- What are the identifying features of the suspect products (product data)?
- Where are these batches/lot numbers now (distribution data)?

2.3 Product Recall Scenario — Motor Vehicles

An automobile assembly plant uses components from more than 4000 outside suppliers, including company-owned parts suppliers. Car frames are placed on an assembly line and moved to assembly areas where various components are installed. For heavy component parts, articulated robots perform the lift-and-carry operations while assemblers bolt pieces in place. The body is built on a separate assembly line. The vehicle is then painted and cured in baking ovens. After the internal components are installed, the vehicle is inspected. When the vehicle passes final audit, it is driven to a staging lot to await shipment. A Vehicle Identification Number (VIN) is assigned at the start of the production line and a monitoring unit keeps track of a vehicle's progress along the assembly line.

From a recall perspective, even though the number of suppliers is huge, they are well-known and the parts well-labelled. As a vehicle goes through so many different steps during assembly, accurate recording of the manufacturing sequence is essential. There is collaborative work between workers and robots that should be recorded as well. The VIN number provides a unique identifier for the finished product. Sometimes, the buyer's information, in addition to the dealer's information, can be found for a vehicle at the time of recall.

Consider a scenario where mechanical problems with one of the robot arms, R1, are detected during its six-monthly inspection, as a result, it is possible that the welds produced by this robot could fail. The issues in this case are as follows.

- Which VINs were worked on by R1 in the past six months (production data)?
- Where are these cars now (distribution data)?
- Are there any customer records for these cars (customer data)?

2.4 Product Recall Scenario — Toys

The toy design process involves both the toy and its packaging. Toy design is followed by the development of a prototype. Patterns for the master mold for the toy are created, after which patterns for the various parts of the toy are made. These molds and patterns are used for creating the finished parts for the toys. Patterns for each individual piece are sent out for assembly line production to overseas manufacturers. These manufacturers create the parts, assemble the toys, paint them and prepare finishing details. In the meantime, the packaging is designed and mass-produced and sent to the toy production facility. The packaged toys are then put into cases and sent to distributors.

From the recall perspective, it is notable that the toy manufacturer relies on third-party overseas manufacturers to produce the toys according to their specification. Toy manufacturers need to enforce strict quality control measures as toys are frequently recalled due to choking hazards, toxic materials, etc. Even though the number of overseas manufacturers that the toy manufacturer works with can be limited, the distribution networks for toys are typically very large. The toy manufacturer needs to keep track of product numbers and model numbers as well as production dates and the manufacturer involved.

Consider a scenario where a number of toys sold by the manufacturer are found to contain excessive levels of lead in their paint. The company has identified that one of their overseas manufacturers, M1, may have used lead-based paint on the toys. The company must now answer the following questions quickly.

- Which toys were produced by manufacturer M1 (supplier records)?
- Which batches used paint that could contain lead (production data)?
- Are there other toys produced by the same manufacturer (supplier records)?
- Where are those toys now (distribution data)?

2.5 Product Recall Scenario — Heart Pumps

An artificial heart is made out of metal, plastic, ceramic, and animal parts. Most components are custom made by third party manufacturers. Each heart pump consists of up to 50 components put together using special adhesives. Several assembly operations happen in parallel, including the assembly of the motor housing and components, the assembly of the percutaneous tube and the attachment of the pusher plates to the polyurethane diaphragm. The final assembly of the complete system occurs after careful inspection. Each device is sterilized and sealed in a plastic tray, packaged in a custom suitcase, and sent to distributors.

From a recall perspective, this process involves a small number of suppliers with well-labelled components. The assembly process is straightforward with strict quality control measures. Every component, including adhesives, used in the process is controlled by lot and serial numbers so that it can be traced.

Consider a scenario where a component from a particular supplier, S1, is found to be defective during testing and the serial numbers of defective components have been provided by the supplier. The company must now determine which heart pumps to recall, so it needs to answer the following questions.

- Which heart pumps, identified by serial numbers, used defective components from supplier S1 (production data)?
- Where are those heart pumps now (distribution data)?

3 Product Recall Coordination

The case studies in the previous section show that there are a wide variety of recall scenarios, involving different data recording, traceability and notification requirements. To produce a generic process model for product recalls we reviewed recall standards from Australia, the United States, the United Kingdom and the European Union. We also consulted a number of food and non-food product recall standards and associated guidelines. Clearly, effective and efficient tracing of suspect products is essential for a successful recall. It requires that information from different sources, including Enterprise Resource Planning systems, Human Resources systems, logistics systems and manual on-site records, is gathered and correlated to get an accurate picture of the recall's scope. We also noted high overheads associated with satisfying regulatory bodies' documentation and notification requirements.

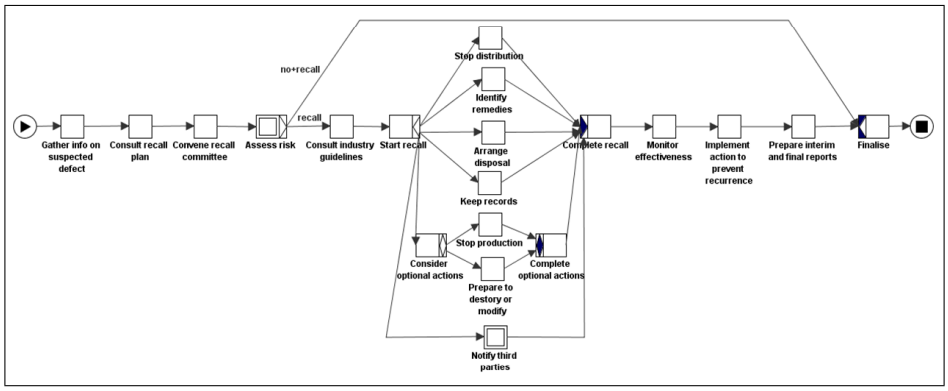

Fig. 1. A generic product recall process

3.1 A Generic Product Recall Process

In this section, we present a generic product recall process using the YAWL notation [1] as shown in (Fig. 1). The model is developed based on product and food recall guidelines in Australia [3, 10]. It was also validated against guidelines from the US and the EU. The process describes the main activities undertaken by a recall sponsor, typically the manufacturer of a suspect product. Recall incidents may be triggered by consumer complaints, supplier notifications, failed quality assurance tests, etc. It is also possible that there are extortion threats made against a company, such as those faced by Arnotts in 1997 [24]. In each case, the manufacturer is responsible for investigating the problem thoroughly and carrying out a comprehensive risk analysis (c.f., the *assess risk* subprocess in Fig. 1).

A decision can then be made as to whether the product should be recalled or not. If a decision is made to recall a product, the manufacturer must consult and follow relevant industry guidelines. The manufacturer also takes appropriate actions to stop the distribution of its products, identify remedies, arrange for storage and disposal of the contaminated products and keep records to evaluate the recall's effectiveness. Depending on the type of product and the defect responsible for the recall, the actions taken by the manufacturer could also include halting production of the product and destroying potentially contaminated products.

In addition, the manufacturer must notify third parties about the recall. It is also important that the effectiveness of the recall process is closely monitored. The manufacturer can then implement necessary changes to prevent a recurrence of such problems. The regulatory authorities can also request evidence of the recall's effectiveness from the manufacturer, so the manufacturer is obliged to keep appropriate records about the recall incident. Required reports are then prepared and sent to interested parties.

The *assess risk* subprocess (Fig. 2) describes the main steps involved in carrying out a comprehensive risk assessment. The outcomes of this process are to

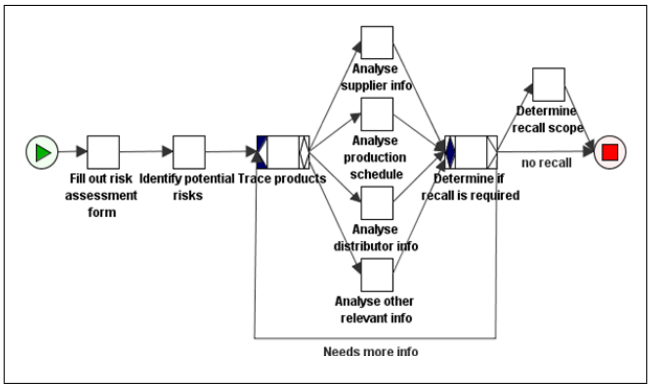

Fig. 2. The risk assessment subprocess

decide whether to recall and to determine the appropriate recall scope. It is very important to get the scope right for a recall as too narrow a scope could mean that unsafe products are still left in circulation and too wide a scope could add millions of dollars in lost revenue. To make the recall scope decision, it is essential that adequate information is provided to the decision maker. In our model, these decisions are modelled as two manual tasks (*determine if recall is required* and *determine recall scope*). The information requirements for these decisions are provided by the four preceding data analysis tasks. The process model depicts the main data sources (supplier information, production schedule, and distributor information and other relevant information, e.g., quality assurance test results).

The *notify third parties* subprocess (Fig. 3) shows the various stakeholder notifications that must be produced in a timely manner during a recall. Some regulatory bodies prescribe a specific form that must be used for recall notifications, while others leave this to the manufacturer. Different means of contacting the various parties are also allowed depending on the urgency of the situation. From our investigations, we noted that the majority of the information required in these forms is standard (e.g., the description of the product being recalled, the reason for the recall, the instructions on how to remedy the problem) while some other extra information could be required for particular cases (e.g., contact details for distributors, other identification features specific to the supply chain, bank account details for recovering recall expenses, etc.). Despite the large amount of standard data required for notifications, in practice organisations still fill in these forms manually, which is both inefficient and error-prone.

3.2 Data Requirements for Product Traceability

From this understanding of the recall process and associated standards we identified the data requirements needed to trace a product from its origin, through the production process, and finally to the consumer. To achieve end-to-end traceability, it is essential that adequate data sets are kept for each product and that,

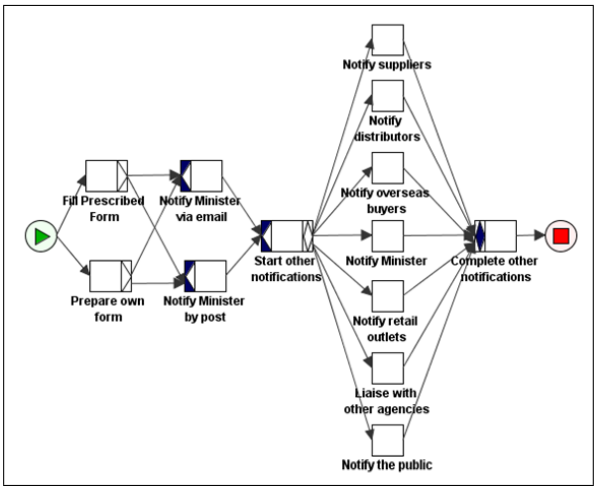

Fig. 3. The third-party notification subprocess

most importantly, the relationships between these data sets are maintained. The Object-Role Model [12] in Fig. 4 depicts the main data attributes that must be captured to enable end-to-end product traceability.

The main categories of data are as follows:

1. Materials Intake data associated with the product's constituents (e.g., details of raw materials obtained from suppliers and their storage locations);
2. Production data associated with the production process. We explicitly model the fact that a particular constituent is an input to a particular activity, as well as the details of workers and equipment employed during production;
3. Final Product data associated with the product itself (e.g., serial numbers, batch numbers, and best-before dates); and
4. Delivery data associated with the storage and delivery of the product, including lot numbers, warehouse locations, traders and customers.

Note in our model that the attributes of 'products' and 'constituents' overlap considerably, which reflects the view that a constituent of a composite product can be viewed as a product in its own right. There are also some limitations of the model that may require its extension in certain recall scenarios. For instance, no provision has been made for the same product being labelled differently by different companies in the supply chain. Similarly, we have not attempted to introduce features to allow for engineering change management as the supply chain evolves over time. Conceivably features for both of these situations could be added to the model, but have been omitted here for brevity.

For those readers who are not familiar with the ORM notation, we now briefly discuss the ORM 2 notation used in our paper. An ORM model captures relationships between entities. An entity type in the model is depicted as a round-corner rectangle (e.g., Constituent, Supplier). An entity type has an identifier

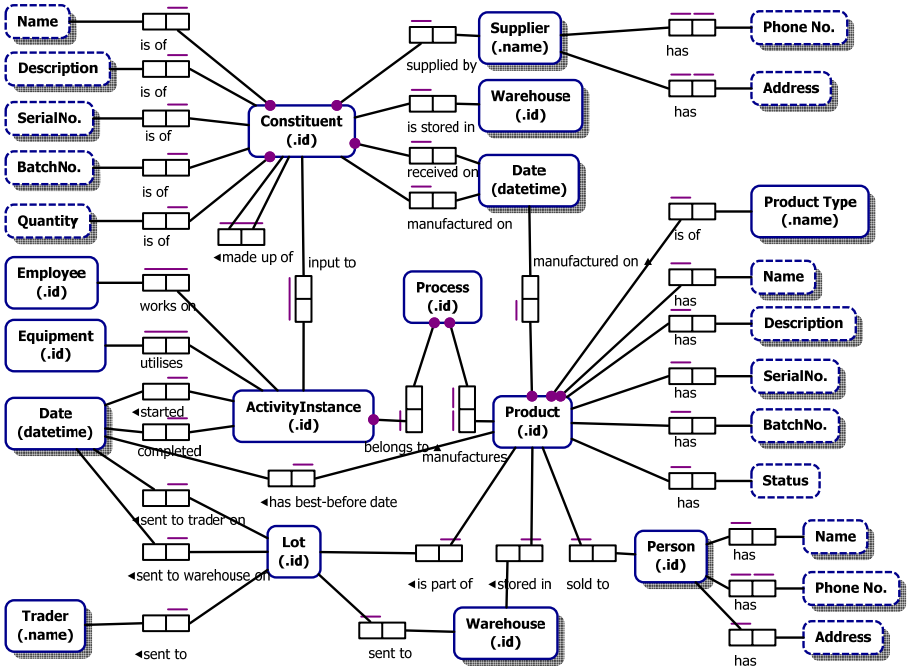

Fig. 4. Data model for product traceability

label type (e.g., a constituent id or a supplier name). An entity type can have relationships with one or more entity types (e.g., "supplied by" is a binary fact type between a constituent and a supplier and it is modelled using a fact type with two roles connected to the two entities involved). A bar above a fact type represents a uniqueness constraint that applies to that fact type (e.g., one to one, one to many, many to many for binary fact types). A black dot attached to the connector between an entity and a role indicates whether this role is mandatory for a particular entity (e.g., every constituent must have a supplier who supplies the product). An entity type can be associated with one or more label types which are depicted as a rectangle with dash lines (e.g., SerialNo., BatchNo.).

3.3 Data Requirements for Recall Notification

The recall standards require stakeholders to be notified about recall incidents in specific ways, e.g., direct communication, published recall notices, etc. We consolidated these needs to identify general data requirements for recall notification. These are primarily concerned with ways of describing suspect products (e.g., unambiguous product descriptions, packaging information and photos).

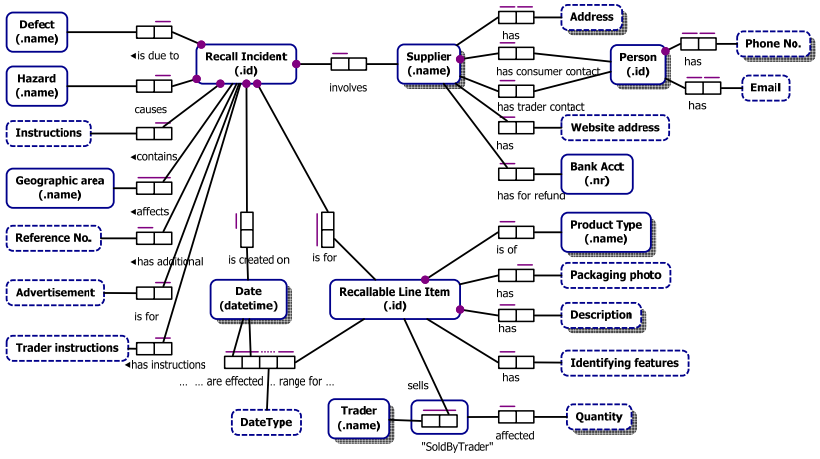

Fig. 5. Data model for recall notification

The Object-Role Model in Fig. 5 depicts the main data attributes that are required in notification forms. The main categories of data are as follows:

1. Recall incident data about the reason for the recall and the instructions on what to do with suspect products;
2. Supplier data associated with the supplier of the recalled product including their contact details;
3. Identification data associated with the product type generally and recalled items specifically, including photos of the packaging where applicable; and
4. Trader data associated with traders who sell the product.

The next section describes how these data and process requirements can be supported using a workflow-based coordination framework.

4 An Architecture for Automated Product Recall Coordination

We propose the use of workflow technologies to coordinate product recalls in an efficient manner(see Fig. 6), although conceivably the same concepts could be implemented within an organisation's existing processes and software tools. The important consideration here is to capture the required data through the coordination of manual and automated activities carried out by different manufacturing systems. Workflow systems typically capture event logs (e.g., activities, timestamps and resources) as well as other data attributes used during process enactment. For recall purposes, workflow systems can thus record data attributes

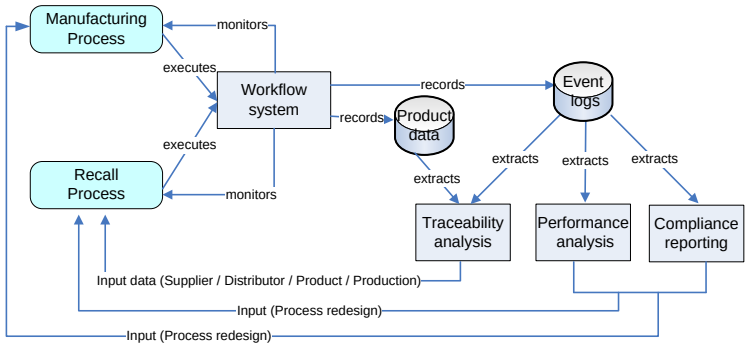

Fig. 6. A workflow-based coordination framework for product recalls

required for traceability and recall notification as the manufacturing workflow is being enacted. This approach enables ready access to relevant data when a recall incident occurs.

The product recall workflow is enacted when a recall incident occurs and plays a coordinating role during the incident and is also useful for reporting purposes. The recall workflow makes use of the traceability data already captured to decide on an appropriate recall scope and to populate the data required for third-party notifications. Using the data from event logs and product logs, we can carry out a thorough traceability analysis that supports both forward and backward traceability of products, undertake performance analysis of both the manufacturing process and the recall process, and finally ensure that the undertaking of a particular recall incident is in compliance with relevant legislations. The insights gained from such analyses can then be used for improving both manufacturing and product recall processes. Next, we illustrate our proposed approach using the-state-of-the-art open-source YAWL workflow management system whereby the manufacturing process and the recall process (together with associated data collections) are modelled as executable YAWL workflows.

5 Illustration

We now demonstrate the practicality of the proposed approach using the YAWL open-source workflow environment [1] and the process mining framework ProM [2] (See Fig. 7). The YAWL environment is chosen as it is a modern business process automation framework with explicit support for the modelling of data and resources used in a process and logging of data associated with them. ProM is a sophisticated process and data mining software tool that can be used to perform various analyses on these logs. The combined use of YAWL and ProM tools demonstrates the coordination role that can be played by the IT/Workflow systems in the product recall domain. To this end, the bakery process was captured as an executable YAWL workflow to illustrate how the product recall data requirements can be captured. The generic recall process is enacted as a YAWL

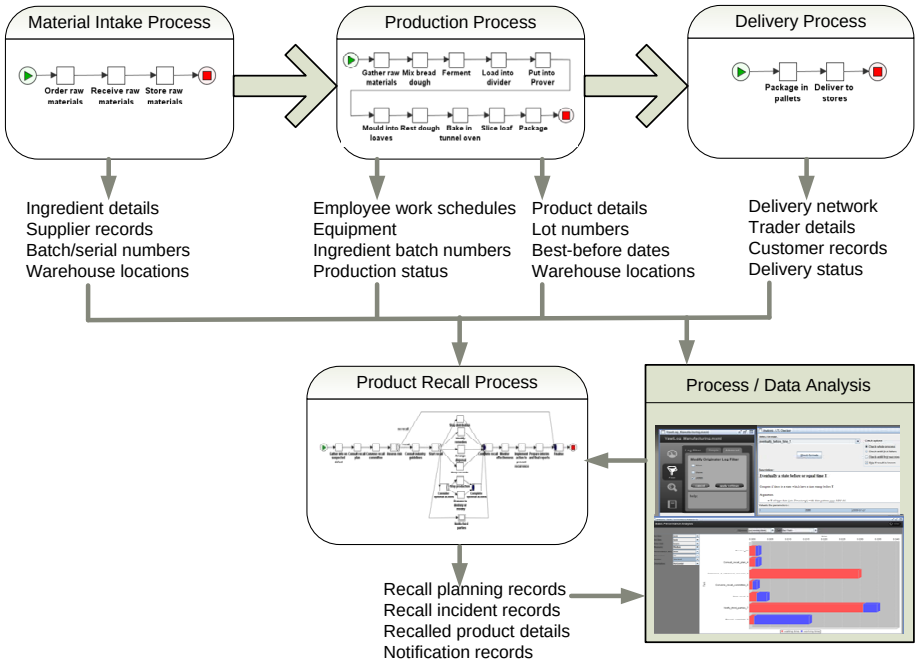

Fig. 7. A product recall demonstration using the YAWL environment and the ProM framework

workflow to illustrate how a product recall can make use of automatically logged data.

5.1 Capturing Recall Data

Fig. 8 describes a simplified commercial bread making process based on the process description given in Section 2.1. The process constructs have been intentionally kept simple as the focus here is on the data requirements. XML data types were used to capture the data requirements of the process based on the traceability ORM model given in Section 3. The process was then run a number of times within the YAWL engine with mock data. The engine logged the production schedule (i.e., activities, event timestamps and resources used as default) and other data attributes that are associated with the process. These logs were then stored in a database and retrieved later for analysis. Listing 1 shows the XML data type definition of a product and listing 2 shows an excerpt of the log that can be retrieved from the workflow system. Please note that our primary goal here is to have ready-access to the product and production data for recall purposes. It is perfectly OK for an organisation to use a different form of record keeping as long as the resulting product and event logs are available for analysis.

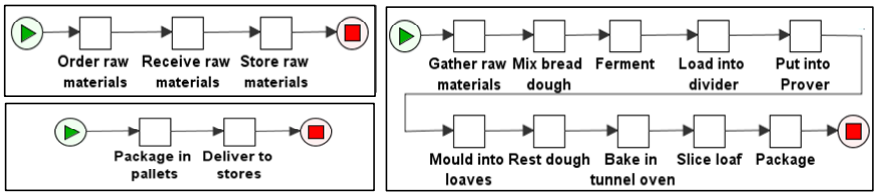

Fig. 8. Bakery - Materials Intake subprocess and Delivery subprocess (left) and Production subprocess (right)

```
<xs:complexType name="Constituent">
   <xs:sequence>
      <xs:element name="ID" type="xs:string" />
      <xs:element name="Name" type="xs:string" />
      <xs:element name="Supplier" type="Company" />
      <xs:element name="BatchNo" type="xs:string" />
      <xs:element name="ManufacturedDate" type="xs:date" />
      <xs:element name="ReceivedDate" type="xs:date" />
      <xs:element name="WarehouseLocation" type="xs:string" />
      <xs:element name="Quantity" type="xs:string" />
   </xs:sequence>
</xs:complexType>
```

Listing 1.1. An excerpt from XML datatype definitions in the Bakery YAWL model

```
<event>
      <date key="time:timestamp" value="2010-07-19T11:04:07.957+1000"/>
      <string key="concept:name" value="Order_raw_materials"/>
      <string key="lifecycle:transition" value="unknown"/>
      <string key="Constituent/ID" value="010"/>
      <string key="Constituent/Name" value="Flour"/>
      <string key="Constituent/Supplier/ID" value="S1"/>
      <string key="Constituent/Supplier/Name" value="Supplier_A"/>
      <string key="Constituent/Supplier/Address" value="123_Street"/>
      <string key="Constituent/Supplier/ContactNo" value="12112211"/>
      <string key="Constituent/Supplier/Email" value="a@suppliera.com"/>
      <string key="Constituent/BatchNo" value="11211"/>
      <date key="Constituent/ManufacturedDate" value="2010-07-06T00:00:00"/>
      <date key="Constituent/ReceivedDate" value="2010-07-22T00:00:00"/>
      <string key="Constituent/WarehouseLocation" value="W010"/>
      <string key="Constituent/Quantity" value="100kg"/>
</event>
```

Listing 1.2. An excerpt from an XML log generated from a running instance of the Bakery Material Intake process

5.2 Handling a Potential Product Recall Incident

When a potential product recall incident occurs, an organisation must initiate an investigation into this incident and start off the recall process. By using an automated solution for product recall, an organisation can respond to these incidents in an effective and efficient manner. For illustrative purposes, we use the generic recall process depicted as a YAWL process in Fig. 1 to simulate a recall incident using the bakery scenario with the disgruntled employee described in Section 2.1. In this recall workflow, we capture the traceability requirements and the notification requirements as XML data attributes. Various activities within the *assess risk* subprocess makes use of the log data already captured from the bakery process. To identify an appropriate recall scope, the bakery should review its production records for the last two weeks, focusing on the batches

that 'John' work on. The locations of these bakery products with affected batch numbers can then be tracked down in the warehouse, and the products involved can subsequently be removed from the warehouse. The products which have been sent to stores are then identified through the delivery records. Therefore, the key data sets of interest include: (1) Production records: production dates, product id, product batch numbers for the products that 'John' worked on; (2) Product records: product details, warehouse locations; and (3) Delivery records: delivery dates, trader details, quantity shipped. We used ProM to carry out the traceability analysis using the information contained in logs from the production process and the delivery process. During the notification process, the data gathered during the *Assess Risk* subprocess is used to automatically pre-fill the notification forms for various stakeholders. As well as routine data about the manufacturer (company name, contact details, etc) and the product generally (name, description, etc), specific data about the suspect items (manufacturing dates, best-before dates, batch numbers, etc) can be extracted from the logs.

5.3 Recall Data Analysis Using a Process Mining Tool

Once basic production and delivery data is captured by the workflow system, we can then use a process mining tool such as ProM [2] to extract and present the information typically needed during a product recall[4].

- **Traceability Analysis:** For backward and forward traceability purposes, we can use existing process mining technologies such as those provided by ProM to analyse data for recall scenarios provided in Section 2. For instance, for the product tampering example by an employee in a bakery, the logs are filtered by time (e.g., two weeks) and then by the employee who worked on the product using *the originator log filter* (See Fig. 9). Similarly, for the contaminated frozen food scenario, we can filter the production and distribution logs based on a certain temperature value using *the attributes value filter*. We can also use *the basic log statistics* feature to identify the temperature range logged during the frozen food production process. For the robot arm welding problem in a motor vehicle manufacturing plant, the logs can be filtered based on the equipment id using *the attributes value filter*.
- **Performance Analysis:** There are a number of performance analysis features in process mining tools such as ProM that can be used to monitor the effectiveness of a recall. For example, the *log summary* feature can provide an overview of all the recall incidents conducted by an organisation. The *log summary and performance analysis features* in ProM also provide insight into the timing of the recall and the corresponding actions taken (see Fig. 10).
- **Compliance Reporting:** Using *the process discovery feature* available in ProM and the detailed log data from a recall process, it is possible to ensure

[4] Some screenshots are from ProM 5.2 and others are from ProM 6. At the time this paper was written, ProM 6 was under development and some of the data filters were currently only available in ProM 5.2.

Fig. 9. Examples of product recall data traceability analysis using ProM

that a recall process conducted by a particular organisation is compliant with the legislative requirements imposed by a particular country. Similarly, we can check to see if the sequence of execution in the logs conforms to the prescribed recall process using the log replayer (see Fig. 10).

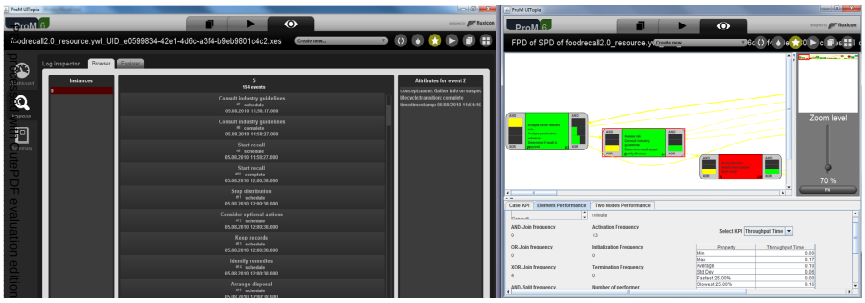

Fig. 10. Examples of performance analysis and compliance reporting using ProM

6 Related Work

Much research has been done on product traceability. Regattieri et al. presented a general framework for a food traceability system and illustrated how it can be used together with RFID tags [23]. However, the framework described is very abstract and the company must have full control over the process. Ruiz-Garcia et al. also proposed a traceability system for agricultural production and fruit transport using batch codes and a web services framework [25]. Setboonsarng et al. discussed food safety requirements in Japan and the use of ICT technologies

via two case studies [26]. Sugahara proposed the use of RFID tags and mobile technology for traceability in Japan's agricultural industry [29]. Kärkkäinen et al. proposed an approach for efficient tracking whereby the focus is on gathering and management of current locations of products [15]. Another technique to manage a product through various stages of its lifecycle and across different supply chain partners is to make use of globally unique product identifiers (GUPI) [9]. Some proposals for GUPI include the use of ID@URI [9, 16] and the use of Electronic Product Codes (EPC) [27, 5, 6]. Our framework can be used with any type of applicable product identification techniques. It is envisioned that making use of unique identifier schemes such as RFID, ID@URI,EPC etc. will reduce the effort required for tracing products if all ERP/workflow systems used in the companies throughout the supply chain utilise them.

Some researchers have proposed the use of reverse distribution networks to recall defective products within a logistics framework [19, 14]. Their research proposes the use of a central database for information storage. The workflow process perspective of product recalls has been largely unexplored. Also a central database might not be feasible when dealing with a large number of players within a supply chain. We instead exploit the coordination capabilities of workflow systems to link data stored in different systems.

The introduction of recall notification systems in the European Union, the United States, Canada and China highlighted the need for automating recall notifications. For countries within the European Union, there is the RAPEX system for non-food consumer products and the RASFF system for food and feed [7, 8]. After the lead paint scandal in 2007, the Chinese government put in recall systems for unsafe food products and toys [20]. The workflow requirements presented in this paper could be used to coordinate these stand-alone recall notification systems with the remainder of the overall recall process.

There are also commercial tools for managing recalls in the manufacturing industry. They are primarily intended for products that are still within the confines of the factory or warehouse [11]. They allow an item's first port of call to be identified, but it is expected that each of these distribution points will then be contacted individually in order to determine what has happened to the item in question [28]. Once again, our workflow model offers a way of linking these systems into the end-to-end recall process.

7 Conclusion

Conducting a product recall is a complex process involving many stakeholders. It is both time-constrained and safety-critical, and is subject to government regulation. A successful product recall requires coordination of many tools and processes for tracing products, generating various notifications and demonstrating compliance with regulations. Our requirements analysis has defined the data that must be collected and the workflow processes required to coordinate a complete product recall in a manner consistent with industry standards. We have also shown how a state-of-the-art workflow management system could be used

to make product recalls more efficient and effective, by coordinating existing manufacturing tools and processes. In summary, the contributions of the paper are threefold: (1) a generic model of a product recall process, (2) detailed data requirement specifications for traceability and notification during product recalls (in the form of ORM models) and (3) a framework to demonstrate how a workflow system, or equivalent process control and monitoring technologies, can play a coordination role for product recall.

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