Fault Detection and Diagnosis in Manufacturing and Inventory Management regarding Customs Compliance

A Case Study for Automated Auditing

Abstract. Companies operating in international markets are faced with a multitude of complex rules and regulations that must be complied with in order to trade successfully. A general phenomenon among multinational manufacturing companies is that, when they are conducting businesses across the borders, their internal information system sometimes fails to interface well with the information system or platform built specially for customs compliance. This leads to missing inventory or components and results in other types of problems, such as delay of goods delivery or incorrect amount of duties. One of the main difficulties in fully integrating the two information systems arises from the highly flexible and volatile nature of manufacturing processes, which would need a highly customizable and adaptive information system. However, there is a lack of systematic method to integrate information systems within a flexible multinational manufacturing process. Moreover, improper operations that exist in manufacturing and inventory management could hamper normal business processes.

Therefore, in order to have well integrated systems as well as timely detection and diagnosis of improper operations for automated auditing, data analysis tools are needed. This research aims to explore the application of data analytics techniques in the supply chain field, specifically in process related customs warehouse, by tracing the information flow while reconstructing the material flow for manufacturing to update the information systems.

Keywords: Auditing, Business process, Compliance, Information systems

1 Introduction

International companies are experiencing problems of adopting information systems to be compliant with customs during the process of custom clearance, due to the complex nature of the supply chain management across the border [1]. Multinational companies usually have complex supply chains that some parts are purchased in one region but are assembled or manufactured in another region, and eventually shipped and sold to other regions. Companies are compelled to comply with international trade regulations while moving goods quickly and cost effectively. In addition, there is no such specific and tailor made information system that integrates seamlessly with existing operational processes and Enterprise Resource Planning (ERP) environments, and at the same time covers key aspects of customs and trade compliance and communication requirements.

Consider ABC, a major Dutch company manufacturing electronic equipment, adopted two information systems to support manufacturing and inventory management: an ERP system and a Customs Management System called SaF. ABC regularly implements stock reconciliation procedures between information systems , i.e. counting and evaluating stock-in-trade. However, ABC discovered large differences underlying ERP and SaF from stock reconciliation in 2014. Further analysis of the root causes of these differences has shown in ABC's internal control report as three main reasons: Deviation from the standard operating procedure by employees as agreed in the workflow instructions; Misuse of the movement types in ERP by which items are incorrectly assigned in the returning stock; Constraints in the ERP system, i.e. infeasibility to customize the information system for every new product as well as the flexible manufacturing process.

These problems are common in the supply chain field. The expected outcome of our research is to detect these deviations and misusage automatically and reduce the inherent constraints in the operating information systems, potentially in the meantime discover the corresponding value increase in financial flows. In order to achieve these contributions, the main research question is:

How can differences and incorrect inventory in ERP and customs management systems be discovered, and root causes of these differences be diagnosed automatically?

This main objective leads to the following research steps:

Step 1: apply appropriate mining techniques to identify the 'normal' processes adopted for manufacturing and production line configuration from ABC's historical logging data; specifically, apply process discovery techniques to discover how manufacturing and inventory management is performed and which components are typically used to assemble a product.

Step 2: apply conformance checking methods to the processes being audited and/or output of the customs checking software to detect deviations from normal behavior.

Step 3: define appropriate metrics to assess compliance in international supply chains, combining impact analysis of different types of faults.

Step 4: develop fault mitigation methods and mechanisms based on the identified root causes, then validate with pilot studies. This will include expert interviews and other case analysis.

2 Current Practice

According to standard ERP operations, goods movements as material flow should be recorded in terms of movement types (e.g. 3-digit number) as information flow. For example, 101 stands for 'Goods receipt for purchase order', 261 stands for 'Goods issue for a production order', and 262 means 'reversal movement type of 261', i.e. cancellation of the production order. In practice, some records are input manually into information systems at working sites, specifically when the production work orders are being implemented. In this circumstance manual mistakes/faults could happen.

The overview of IT systems of ABC is shown in Fig. 1. The logistical and financial records are registered in an ERP system provided by SAP. The monthly declarations for Customs are made using Automated Periodic Reporting (GPA). GPA cannot directly be created from SAP, due to the fact that SAP doesn't maintain the customs status of the goods. Therefore ABC decided to adopt SaF. For this matter the relevant data are processed from SAP to SaF. Based on SAP movement types (transaction code), SaF is able to recognize the customs transaction code, using a correlation table. With the help of this table SaF is able to recognize inbound, production, outbound, surplus of goods, etc.

The parts that are necessary for the production of the machinery are purchased, both inside and outside the EU. The non-EU parts are always stored in the customs warehouse. The components are released on request from the customs warehouse to the subsidiaries in the EU or other parts of the world, or used in the production process in the Netherlands. At the start of the production the parts are placed under Inward Processing Suspension system (IPS). Immediately after the completion of the production the IPS is finished. The final products get stored in the customs warehouse in the Netherlands and after that they get shipped all over the world.

Take the business process regarding goods movement in Bonded Warehouse as an example. A bonded warehouse is a physical warehouse where goods are stored or undergo manufacturing operations with customs supervision; i.e. goods are in the country, but have not been formally imported, hence are exempted from payment of import duties. These goods are called bonded goods. They should be placed in bonded zone of the warehouse, unless extracted for production, re-export or recycle.

Upon receiving goods from suppliers, SaF recognizes whether the goods are free or bonded and process them differently. In particular, only the data from customs goods are used by SaF for the GPA. SaF has a number of pre-programmed controls that are performed upon receipt of datasets to verify the quality of data. Failing to meet quality requirements the data will not be accepted by SaF and stored in the so called error-portal. In this case, data has to be adjusted in SAP and processed again by SaF.

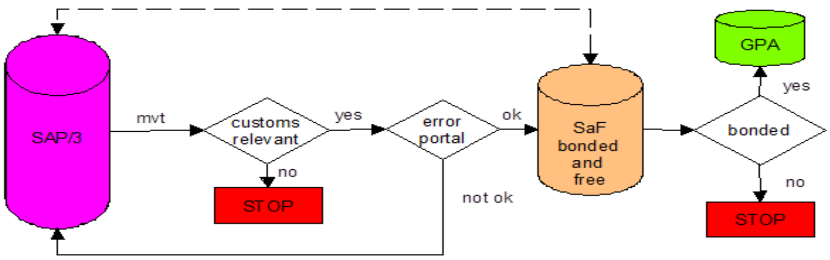

Fig. 1. Overview of customs related IT systems of ABC (figure from Dutch customs)

3 Research Design of an Audit Framework

Process mining is a promising means to systematically analyse data recorded by a business's ERP system [2]. It gives auditors a new and more comprehensive way of conducting those tests of detail and of understanding the state of the control environment than the procedures that they rely on today. Process mining’s goal is to extract knowledge from event logs. Event logs (also referred to as transaction logs or audit trail) are extracted from the contemporary information systems [3]. Event logs contain large amount of data that can help companies to monitor and audit their business processes. In order to create an event log two important preparatory steps are necessary: the identification of activities and the selection of a process instance [2].

A sequence of activities always corresponds a sequence of events recorded in information systems. Event logs are needed to assess the compliance of the actual behavior with the prescribed behavior. Moreover, as a process model is not available, event logs are used to discover it.

Our adapted audit framework and steps are depicted in Fig. 2. After data analysis of movement types and event logs, Step 1 artefact discovery should result in the main artifacts used in this research, namely business process model, sequences of movement types and production configuration. Although the sequences of movement types could be potentially the more interesting artifact, its definition depends on the process model. Applying techniques of conformance checking as Step 2, deviations/faults will be detected. With respect to different types of fault scenarios, Step 3 impact analysis will facilitate proposing fault mitigation methods as Step 4. These methods improve the process model, and assist deploying internal controls in artefacts or processes.

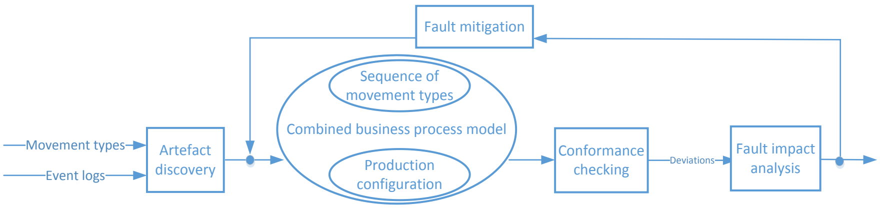

Fig. 2. Adapted audit framework

3.1 Acquiring Appropriate Data and Artefact/Process Discovery

Process discovery takes an event log and produces a model without using any other priori information. After extracting a portion of data at ABC manufacturing and inventory operations, experiment with process mining software (e.g. ProM), according to the selected process instance, which is a specific occurrence or execution of a business process. After data analysis of movement types and event logs, the combined process model should be derived as Fig. 3 illustrates.

Sometimes more detailed data within one activity is needed to do the analysis. For example, the multi-instance marker (three vertical lines) in ‘inward processing’ of Fig. 3 indicates several activity instances are needed in parallel. This means that the activity is performed many times with different datasets. For example, when engineers receive different components from other employees during manufacturing, they will need to evaluate them many times, each time with different data. Therefore, in the multi-instance loop collapsed sub-process of ‘inward processing’, there could be sub-manufacturing processes composed of multiple production configurations.

Fig. 4 gives a simple example of production configuration. Components A, B, C are assembled to become one piece of D. The value increases to 5000 euros instead of just adding the value of raw materials. Then with E joining, the product becomes F instead. The manufacturing of the final product also needs components G from other countries with different price. Eventually one piece (1PC) of machine is produced.

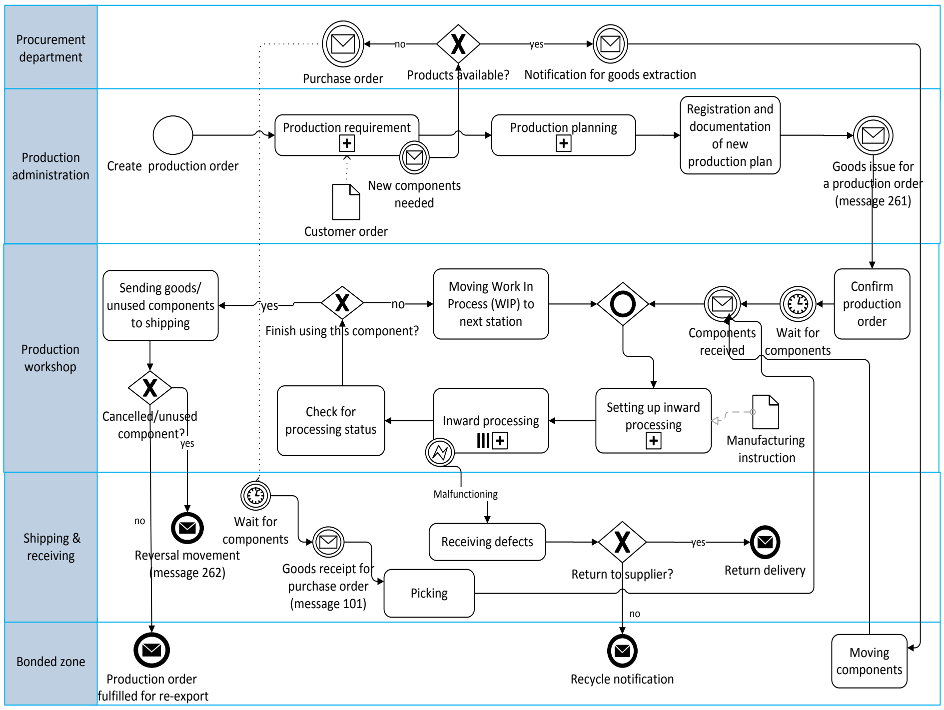

Fig. 3. Business process model for production in bonded warehouse using BPMN

The general goal is to extract Bill of Materials (BOM) of each production process and discover the corresponding value increase in financial flows. The complications could be returning some unused components e.g. C' back to inventory from production process in Fig. 4, or some intermediate parts are sold to other countries. All these goods movements are recorded in the ERP system and the related financial flow as well. Note that for each production process there could be value increase of the intermediate products. With advanced technology enhanced human labor, the value increase could be tremendous as a sudden value jump in financial flows.

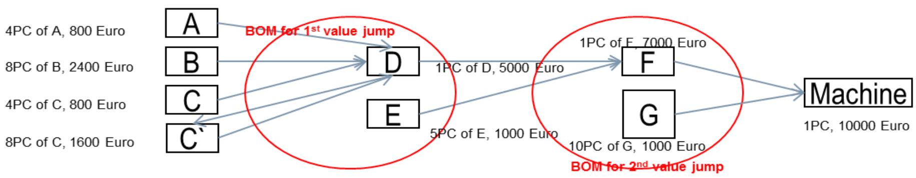

Fig. 4. An illustrative example of production configuration

3.2 Conformance Checking

Conformance checking is also referred as conformance analysis, aims at the detection of inconsistencies between a process model and its corresponding execution log [4]. Logs represent observed execution sequences of activities from the normative process model. In the desirable case, logs completely comply with the behavior defined by the process model and are called valid execution sequences. In practice, observed execution sequences often deviate from predefined behavior. This may be the case when the execution order is not explicitly enforced by the information system that records the logs. It is also possible that people deliberately work around the system.

By comparing deviant process flow from normal process flow, we can discover different types of fault. The normal sequence of activities regarding goods movements should follow a certain pattern represented by a sequence of movement types. Even though some movement codes (such as code 101 and 261) can be followed by multiple movement choices, the movement sequence should follow certain rules in information systems. For example, message 261 initiates a "Goods issue for a production order". When some components are cancelled, the process should always be ended by message 262 even though there would be sophisticated manufacturing processes after "production order". By the end of the production phase any remaining unused components are returned to the inventory and a 262 against this order should be posted.

There could be abnormal sequences. When components are sent to shipping & receiving after cancellation in production workshop as Fig. 3 shows, some employees confuse the use of code 262 and 101, or they couldn't distinguish whether these components are received for cancellation reversal or purchase order. Instead of typing correct code 262 as a reversal movement into systems to close the production order, they use 101 to receive goods instead. This fault may cause unnecessary duty repeatedly levied on the same goods, because code 101 acts as an intermediate message may continue another duty levy process to production again automatically. In this case, the movement history of these wrongly recorded goods will contain code sequence "…-261-101-261-…", which is different from the normal possibilities.

3.3 Impact Analysis of Faults

The severity of deviations/faults depends on the application domain and context information. We will analyze different categories of severity as well as impact metrics. In principal, impact analysis should be carried out as follows.

First, define baseline and alternative scenarios. In any case evaluating a single fault or several faults, measuring the incremental net changes associated with each fault is needed. To do this, it is necessary to define the "baseline" scenario, and measure any net changes against what would have occurred in the absence of the change.

Second, identify area or objective boundaries. For example, the geographic boundary of this research is currently limited using EU regulations. Generalizations depends on data availability and the parameters of the case studies.

Third, select main indicators and secondary indicators. Secondary indicators can be used to measure the other impacts of each fault. In many cases, secondary effects may be addressed qualitatively, but they add depth to the analysis nevertheless.

Last, calculate direct, indirect and induced impacts. For example, a quantitative measure of effects can be developed by estimating the incremental cost generated by each fault. There are other methods to estimate these impacts in different disciplines.

3.4 Developing Fault Mitigation Methods and Validation with Pilot Study

After developing impact-based quantification of fault, we will find appropriate mitigation methods from root causes of different types of faults, to improve the process model and internal controls as well. The study should extract insights about supply chain processes from the data and process models, and expected to be validated and piloted in real-life situations with exporting or importing scenarios.

Through tracing these abnormal movement sequence patterns, a large number of faults can be distinguished. Ideally the results of these research steps should be applied in ERP and customs management systems as an active fault detection module. Once the system detects abnormal code input, it can generate alerts and a composite recommendations of internal controls immediately and directly to the relevant managers. If these fault can be found in the early period, it is more likely and much easier to timely correct them in order to eliminate or minimize their negative impacts.

4 Contributions

Our case-based research could be generalized to a broader level for automated auditing based on data analytics using process mining. The framework contributes to:

1. identifying different types of fault scenarios related to trade and customs;
2. checking whether processes are in place and functioning well;
3. recommendations of internal controls depending on different types of faults;
4. automation in of audit by updating business rule set of fault mitigation, etc.

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