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Regulatory Supervision with Computational Audit in International Supply Chains

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ABSTRACT

Nowadays, as international trade with cross-border logistics increases, the administrative burden of regulatory authorities has been dramatically raised. In order to reduce repetitive and redundant supervisory controls and promote automatic administration procedures, electronic data interchange (EDI) [1] and other forms of information sharing are introduced and implemented. Compliance monitoring ensures data quality for information exchange and audit purpose. However, failure to be compliant with various regulations is still a general phenomenon globally among stakeholders in supply chains, leading to more problems such as delay of goods delivery, missing inventory, and security issues. To address these problems, traditional physical auditing methods are widely used but turned out to be time-consuming and costly, especially when multiple stakeholders are involved. Since there is limited empirical research on compliance monitoring for regulatory supervision in international supply chains, we propose a compliance monitoring framework that can be applied with data sharing and analytics. The framework implementation is validated by an extensive case study on customs supervision in the Netherlands using process mining techniques. Practically, both public and private sectors will benefit from our descriptive and prescriptive analytics for audit purposes. Theoretically, our control strategies developed at the operational level facilitates mitigation of risks at root causes.

CCS CONCEPTS

• **Applied computing → Computers in other domains → Computing in government** → E-government

[1] EDI can be defined as the transfer of structured data, by agreed message standards

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KEYWORDS

Audit, Compliance, Process mining, Regulatory supervision, Supply chains

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1 INTRODUCTION

The importance and complex nature of international trade place an increasing demand for multidisciplinary and interdisciplinary knowledge of private sectors, their service providers and governmental agencies in areas such as international logistics, international tax and excise control, etc. In a trusted trade lane, where controlled goods flows are accompanied by reliable business data, regulatory authorities can assess whether further facilitation or enforcement is possible. Before this can be effectuated, the quality level of compliance has to be made visible, both shown and proven to the supervising authorities. In 2014, Customs Administration of the Netherlands introduced the "Enforcement vision". The purpose is to combine the enforcement of the fiscal integrity and security of EU-border goods movements and meanwhile contribute to the economic competitiveness of the Netherlands and the EU by facilitating businesses. This is brought into practice by applying a layered enforcement approach: risk assessment of incoming and outgoing goods is enhanced with information reliability of the underlying businesses.

Businesses are links in international supply chains. From the government's perspective, the focus is not only on the physical goods, but also on the kind of businesses behind the imports and exports, which highly depends on reliability of data. The regulator must regularly assess the adequacy of the design of the control measures, their implementation and operating effectiveness [1]. Such assessments are normally performed by IT auditors. Currently, most IT-audit practices are seen as results of professional judgment. In case a system of controls can be formally specified, testing the adequacy of the design can be seen as formal verification. Whether the system of controls satisfy a set of properties which together ensure reliability is still a concern.

Information Systems (IS) solutions provide some features for tracking origin and destination attributes of items in their data files to improve compliance and reliability. There are many standardized information systems to enhance visibility, digitize documentations and automate declaration processes for supply chain management [2]. However, the problem of compatibility and integration of systems and processes are still prominent [3]. Although IS controls can increase efficiency and visibility in operational processes, many compliance management systems (e.g. automated reporting systems for lodging import/export declarations to customs) aren't integrated well with other key enterprise systems. Currently, there is an immense gap globally between enterprise systems and compliance management systems, triggering massive manual efforts for controls, increasing redundancy and errors, e.g. inaccuracy of goods descriptions, wrong claim of duties, etc.

When correct and standardized information exchange is not achieved, conflicts between regulatory changes of public sectors and business strategies of private sectors may cause unexpected cost, delay or even fraud. In order to avoid inefficiency and higher transportation costs in global trade, the faster an organization files the data, the quicker the product will ship. On the other hand, the consequences of not complying with regulations can be problematic, which lead to penalties and delivery delays. Activities at the operational level are the potential sources of both the introduction and propagation of errors [4]. Control strategies developed at the operational level should be able to mitigate the risks at the root causes by eliminating the sources of the introduction and propagation of errors.

In this paper, we propose a systematic compliance monitoring framework for regulatory supervision in supply chains by analyzing operational processes focusing on import process and manufacturing activities. Process mining with mock data hypothetically demonstrates the proposed framework. Empirically, we present an extensive case study as validation, which could help organizations locate the deployment of IS controls both internally for private sectors and externally for regulatory authorities.

2 THEORETICAL FOUNDATIONS AND RESEARCH METHODOLOGY

2.1 Compliance Monitoring and Regulatory Supervision

In supply chain domain, stakeholders from manufacturer, exporter, forwarder, customs agent, third-party logistics (3PL) provider, carrier, importer to governmental agencies are involved and play different roles. There are plenty of regulatory sources, such as laws, standards and rules, to monitor and standardize stakeholders' behaviors. Compliance monitoring ensures data quality for information exchange and audit purpose [5]. The objectives are ensuring correctness, continuity of business and administration, and creating reputation [6]. Specifically for regulatory supervision in supply chains, compliance monitoring also deals with pre/post-shipment inspections, control of product packaging and labelling, and import/export requirements by using relevant data, etc.

To reduce compliance problems, organizations need to establish the reliability of compliance reports. Such reports are generated by executions in information systems, therefore, reliability depends on the internal controls built into business processes and information systems [7]. In international trade, if consistent and informative import and export documentations could be generated, then trade and license requirements would be much easier to comply with. Thus, compliance monitoring is a fundamental requirement for regulatory supervision in international supply chains.

In practice, this often means that the regulator delegates supervision tasks to the private sector by a form of *self-regulation* [8]. Normally the regulator would set the norm, define performance indicators, test the norm, and take corrective actions in case of deviations. However, private sectors can in same cases perform these tasks themselves. In that case, the regulator only performs a form of meta-supervision. It means that the regulator has a choice on how to respond to desired or undesired behaviors, i.e. *responsive regulation* [9]. The regulatory response (e.g. education, feedback, warning, penalty) is based on the specific compliance behavior of the party being regulated. According to the famous regulatory pyramid [9], an incidental violation may lead to a warning, but does not immediately lead to a penalty. Repeated violations, however, do lead to sanctions. In general, regulators are expected to control and reduce risks for society [10]. Therefore, another element that can be taken into account when determining the regulatory response is the risk for society caused by deviant behaviors, i.e. *risk-based regulation* [11, 12]. The way in which private sectors collaborate in a supply chain and set up their logistics operations, security measures and information systems affects the risks for society. Therefore, a systematic approach for regulatory supervision is needed, taking the entire system into account including in particular the internal control measures [13].

2.2 Computational Auditing

Auditors are expected to provide "reasonable assurance that the reports are free from material misstatements" [14]. Since regulatory authorities cannot be present all the time and must rely on accounts from the party being audited, monitoring assurance over the current state of operations is needed. Researchers have proposed approaches like online auditing [15, 16], continuous control monitoring [17] and continuous auditing [18, 19], etc. The purpose of these techniques is to provide assurance over continuous data streams, i.e. continuous assurance [20].

There are two kinds of information architectures for a continuous auditing system: Embedded Audit Module (EAM) and Monitoring Control layer (MCL) [19]. EAM uses enterprise resource planning (ERP) systems to run analytic procedures. This has the disadvantage that the organization could manipulate source codes. So most reported implementations use MCL with a separate server for control monitoring [19]. Security measures should ensure confidentiality, integrity and availability (24/7) of the data streams. This triggers other questions, e.g. which party should host the server: the company, an external auditor, the regulator, or a trusted party in the role of intermediary [21].

2.3 Data Analytics and Process Mining

Process mining is a new and highly promising means of systematically analyzing data recorded by a business's ERP system [22]. Process mining gives auditors a new and more comprehensive way of conducting tests on details and understanding the state of the control environment than the procedures that they rely on today. The general research of process mining includes process discovery, conformance checking, performance analysis, process prediction and process improvement [23].

Information systems capture activities happening in the "real world". To perform process mining on data, the digital traces captured in the information systems must be extracted and transformed into *event logs*. Assume the existence of an event log where each event refers to a *case*, an *activity*, and a point in time, i.e. timestamp [24], an *event log* can be seen as a collection of *cases*. A *case* can be seen as a *trace*/sequence of *events*.

2.3.1 Process discovery. The Fuzzy miner is one of the younger process discovery algorithms and was developed by Christian W. Günther in 2007. It is the first algorithm to directly address the problems of large numbers of activities and highly unstructured behavior. In order to discover and visualize process models in an interactive manner, this research uses the Fuzzy miner with significance/correlation metrics to interactively simplify the *process model* at desired level of abstraction.

2.3.2 Process model. A *process model* represents the *activities* and processes of an organization to achieve its goals. It can be derived from the activities and control-flow of the process i.e. the ideal execution of process, not based on factual data about it. To ensure the understanding of stakeholders with different skill levels, several notations have been proposed for process modelling: informal (e.g. natural language) for general public; semi-formal (e.g. BPMN) which requires some training; formal (e.g. Petri net) which allows advanced analysis. Being widely used in industry, Business Process Model and Notation (BPMN) provides a common language to meet user requirements for improving processes and the IT specification for system connections, business rules and data architecture [25]. In this research, we adopt both BPMN and Petri net as graphical representations for the specification of processes.

2.3.3 Conformance checking. Conformance checking provides auditors a more extensive way of understanding the state of the control environment than the procedures on which organization rely nowadays to detect inconsistencies [26]. To check the conformance of a recorded sequence of *event logs* with the *process model*, we use the algorithm of *alignments* [27]. Alignments provide a robust approach to conformance checking by allowing the detection and analysis of nonconformity between the observed and prescribed behavior. In particular, alignments are able to pinpoint deviations that have caused nonconformity. The prescribed behavior is modeled as Petri net, which provides a formal semantics that can be exploited for automated analysis. A Petri net is a tuple (P, T, F, m_i, m_f) where P is a set of places, T is a set of transitions representing transaction codes, $F \subseteq (P \times T) \cup (T \times P)$ is the flow relation connecting places and transitions, m_i is the initial marking and m_f is the final marking.

3 COMPLIANCE MONITORING FRAMEWORK FOR REGULATORY SUPERVISION

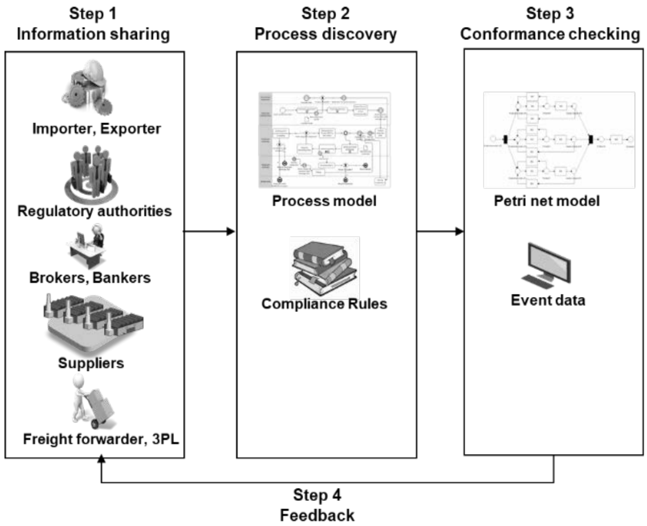

Figure 1: A compliance monitoring framework in international supply chains.

Governments need to reduce administrative burden and are slowly replacing the traditional command-and-control model with cooperative compliance programs [28]. In this research, we propose a framework to assist regulatory authorities supervising and facilitating international supply chains. An overview of the framework is presented in Fig. 1, which consists of four main steps to be elaborated in the following subsections. Sharing compliance related data among stakeholders is the first step as well as a precondition for compliance monitoring. Process discovery (step 2) aims to elicit the main artifacts used for the analysis, namely process model and compliance rules. The process model encodes all the sequences of activities that are allowed by the organization's information systems and most importantly, compliance rules. The process model in Petri net is then used in combination with conformance checking techniques (step 3) to analyze event logs for detecting possible deviations. The identified deviations are then analyzed together with the stakeholders involved to form a feedback loop (step 4).

3.1 Data Sharing in Information Flow

To detect nonconformity for regulatory supervision, the first step is to analyze the relationship of information flow in data & document layer and organizational layer [29]. Table 1 provides the explanations for the acronyms used in data & document layer for analyzing information flow.

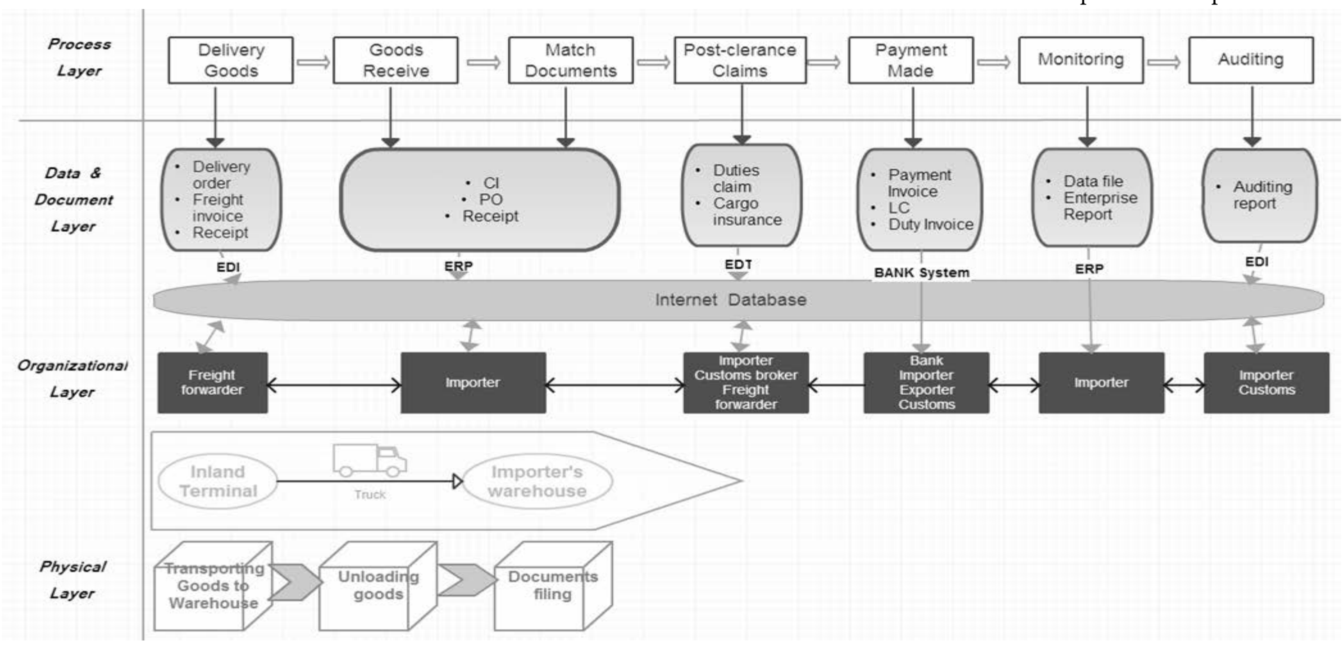

Figure 2: Data sharing among organizations during import.

Table 1: Definitions of Acronyms in Data & Document Layer

Acronym	Terminology	Explanation
CI	Commercial Invoice	Contains traders, goods, payment information
EDI	Electronic Data Interchange	Electronic interchange of information using a standardized format
LC	Letter of Credit	States importer's bank guarantee that export will receive payment
PO	Purchase Order	Official offer issued by buyer to a seller

We present a generic import process in combination of the data pipeline model [29] and the illustration of global supply chains [30] in Fig. 2. Unlike their import process model which only gives a long flowchart to describe events happening, we emphasize activities closely related to compliance requirements and omit irrelevant activities, e.g. payment issues. In addition, more layers have been added and data pipeline has been used to illustrate information flow. Export process is less complicated and can be analyzed in a similar way. In Fig. 2, goods are picked up by the freight forwarder to delivery and received by importer. The forwarder/broker provides freight invoice and goods receipt to both the importer and exporter. The importer reconciles the list of invoices, containers, POs, goods receipts, etc. Then the importer files any post-clearance claims, e.g. duty overpayment, cargo insurance, etc. Payment to the exporter and duties to customs due by the importer will be approved by banks. Meanwhile, importers scan barcodes of packages and store goods into their own warehouses. For the importer and exporter themselves, monitoring and self-assessment are necessary, which help them evaluate the effectiveness of internal controls and identify process gaps that increase risks. Customs also conduct audits to make sure the validity of their certificates and compliance to regulations.

3.2 Process Discovery

In order to detect and respond to various forms of possible disruptions in global supply chains, stakeholders need to distinguish explicit compliance rules which are published and continuously available from implicit rules when exchanging information. Here are some explicit compliance rules in international trade. Goods are typically stored in a customs warehouse during and after import process. A customs warehouse is a physical warehouse where goods are stored or undergo manufacturing operations with customs supervision. It is under supervision with specially appointed licenses, e.g. postponed payment of duties on the imported goods. The maintenance of necessary licenses requires periodical audits from Customs officers. Goods can either be released on request from the warehouse to the subsidiaries in the country or other parts of the world, or used in the customs warehouse for further production which is more complicated for regulatory supervision. For instance, according to regulations of European Union (EU), at the start of the production, the needed components are placed under the Inward Processing (IWP) Suspension system which allows the duties to be suspended. If the final product's destination is a non-EU country after processing in the customs warehouse, no duties will be levied when the origin is also a non-EU country.

Fig. 3 shows the process model of material flow typically performed in a customs warehouse using BPMN notation. The messages recorded in ERP need to be sent to regulatory authorities for process mining with related information. The process starts with the message of goods receipt on PO, followed by the creation of a work order based on bill of materials (BOM). After receiving materials needed for production, inward processing starts. The multi-instance marker (three vertical lines) in "inward processing" (IWP) indicates that several activity instances might be executed in parallel. Intuitively, it represents (collapsed) sub-manufacturing processes which can be repeated for multiple materials. Work orders and goods receipts can be cancelled due to different reasons during the production process. Unused materials or tools that are not needed will be reversed back in stock. Malfunctioning materials are returned to the supplier or a request for repair is created.

In particular, classes of goods movements are distinguished using a three-digit message which is called *movement type* in

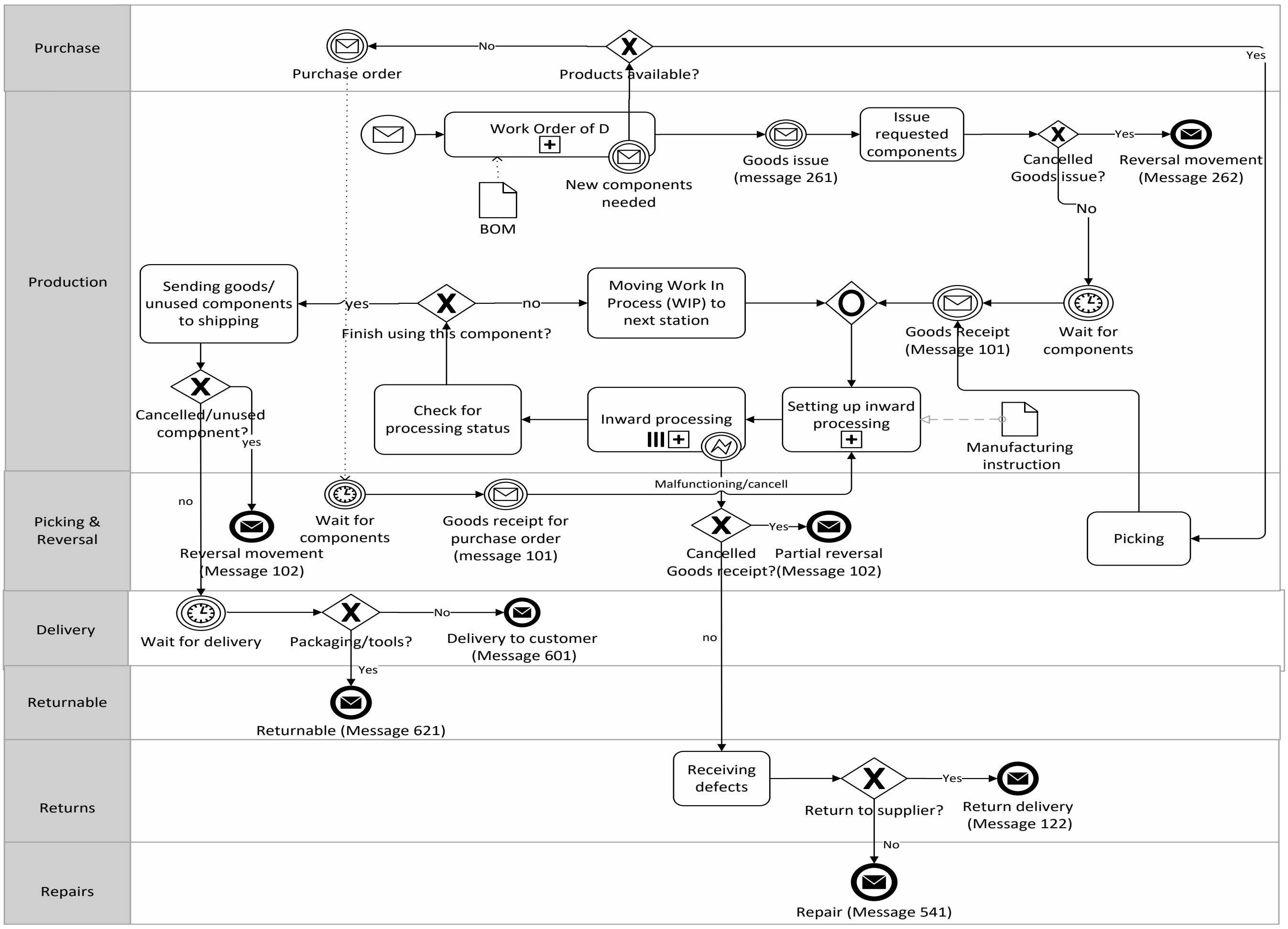

Figure 3: BPMN model of material flow in the warehouse

A work order defines which material is to be processed, at which location, at what time and how much work is required. As soon as the work order and other requests are generated, the order is passed on to the employees for goods issue; the order-relevant data is also added to ensure complete order processing. ERP. Each type of material movement is given a unique movement type, i.e., only one movement type is allowed per transaction. Movement types are used to control adjustment of inventory and for financial purposes as well.

3.3 Conformance Checking with Event Data

Suppose ongoing event data is received by regulatory authorities as Fig. 3 requires. Ideally, the material flow complies with the behavior as pre-scribed in the process model. However, reality can diverge from the prescribed behavior. This may be the case when an execution order is not explicitly enforced by the information system. It is also possible that people deliberately work around the system. Deviations from the prescribed behavior can have significant consequences with respect to compliance. Thus, it is desirable for organizations to identify such deviations as early as possible to be able to take necessary measures.

To simulate conformance checking with event data, the dataset of PurchasingExample.csv downloaded from http://fluxicon.com/academic/material/ is analyzed through the software ProM 6.7 with some activities adjusted to our research purposes. ProM is an extensible framework that supports a wide variety of process mining techniques in the form of plug-ins. Among 9119 events 608 cases with 21 activities were recorded in the dataset, from the activity of "creating production order (work order)" to "paying invoice" including duties to the customs.

Consider the Petri net model in Fig. 4 corresponds to part of the BPMN model in Fig. 3. The dataset records the instance of work order and can be used for conformance checking with respect to the Petri net model. The alignment shows that there are some deviations from the prescribed process. The visualization in Fig. 5 highlights the activity often skipped. Ten cases skip the mandatory "goods issue for production order" activity out of 413 cases indicated by red alert. The reason might be an employee has omitted to record goods issue in the system. Therefore, the inventory stays the same in the system, but should be subtracted by corresponding items. Depending on the customs status of the omitted goods and their destinations, this discrepancy in the inventory would result in different scenarios affecting not only duty payment but probably security issues.

3.4 Feedback Loop

Through tracing these abnormal movement sequence patterns, a large number of errors can be distinguished at executional level. Such inconsistencies can have negative impacts financially and physically, therefore appropriate mitigation methods are necessary for the feedback loop. For instance, the methods could be changing the IT infrastructure or revising internal controls built into information systems. Ideally these steps should be applied in ERP and compliance management systems as an active fault detection module. Once the system detects abnormal code input, it can generate alerts and a composite recommendation of controls immediately and directly to the relevant stakeholders. If these deviations 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 CASE STUDY ON CUSTOMS SUPERVISION

4.1 Data Collection with Information Sharing

As a government authority, Customs Administration of the Netherlands design, develop and enforce Customs laws on behalf of the government. ABC (anonymized from a world leading manufacturer in electronic equipment) employs several information systems to support supply chain management and ultimately the generation of declarations to regulatory authorities. 3PL is not only in charge of the goods transportation but also takes care of the goods for storage in customs warehouse. It is required for 3PL to provide all the relevant goods documents when passing the border, moving into customs warehouse and leaving customs warehouse, including invoices which are generally used as master data.

Firstly, desk research is used to study customs regulations, software user guides and internal control reports from ABC and 3PL. Secondly, we analysed ABC's 88538 records of monthly

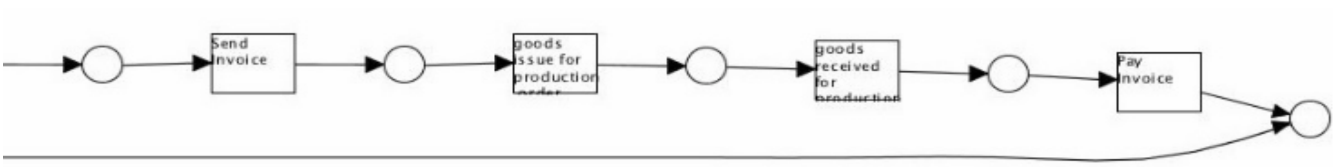

Figure 4: Partial screenshot of the Petri net model.

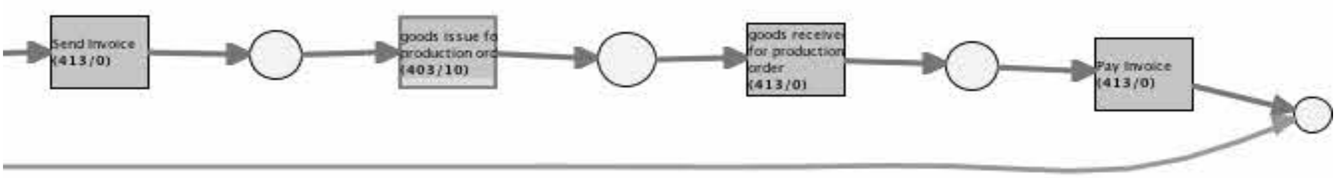

Figure 5: Partial screenshot of the conformance results.

declarations to customs in 2012 and 41706 signals from compliance management system. In addition, data of two production work orders in 2016 is used for conformance checking. Lastly, several interviews and onsite visits are performed from May 2015 to May 2017. Therefore, this research is validated by ABC, Customs Administration of the Netherlands, 3PL and their information system providers.

4.2 Problem Investigation

Table 2: Statistical Results of Declaration Signals in 2012

Transaction code	Descriptions	Information block	Total
011000	Entry of non EU goods into the customs warehouse	B	2
		B3	1
		E1	1
		E23	592
100100	Outbound entrepot - T1 transit	J	71
		J4	418
		K13	2
100900	Goods from customs warehouse brought into free circulation of EU	E1	1
		E23	594
		E28	9367
		E29	9252
		E35	4
		H7	1929
100904	Outbound entrepot - import declaration	E23	6
		E28	22
		E29	28
		H7	149
101100	Goods brought under Inward Processing	E23	63
		E28	9592
		E29	9601
111000	Goods from Inward Processing brought into warehouse	E46	11
Total			41706

Every mutation in or out or otherwise affecting the inventory in the customs warehouse results in an information line in automated periodical declarations. An information line is identified through a transaction code and grouped into information blocks. Transaction code is a characterization of a business event, i.e. movement of goods or a customs-technical operation with respect to the goods. With categorization and summation on 88538 records of the monthly declaration data in 2012, transaction codes 100900 and 101100 signal most as Table 2 shows. It means most errors happen during transfer and relocation of goods before and after IWP suspension system under customs control. As we discussed in section 3.2, IWP allows imported raw materials or semi-manufactured goods to be processed for re-export without a requirement that the manufacturers have to pay customs duty and VAT on the goods being used.

However, the signals with related checks cannot pinpoint deviations that have caused nonconformity. For example, the related check for the block E29 that signalled most is "Does not need to be filled in case of entry under the customs warehouse procedure, unless E45 is filled with J for customs warehouse, type D (transactions)". Therefore, process mining tools are needed for further investigation.

4.3 Process Discovery

The declaration data of ABC in 2012 is very complex with 88538 events and 11487 process instances. The plug-in Fuzzy Miner in ProM gives outputs on transaction codes as Fig. 6 shows using default settings. Yellow square nodes represent event classes, their significance (maximal value is 1.0) is provided below the event class name in each node. Links, or arcs, drawn between nodes are decorated with the significance and correlation represented by each relation.

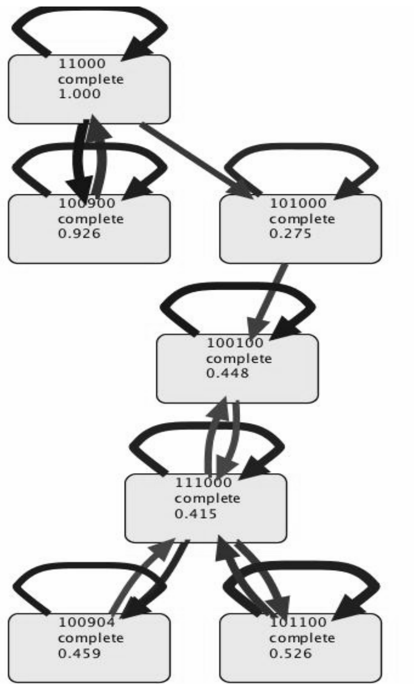

Figure 6: Fuzzy model outputs of declarations in 2012.

We can see that many back-and-forth exist with respect to the sequence of transaction codes. The simple case is to reverse transaction only once, however, the reversal transaction can also be reversed according to Fig. 6. Suppose that is called the second reversal, even the reversed reversal transaction can be reversed as the third reversal. Therefore, the consequence of a single misused transaction will not only affect this single material, but into the chain through the trace. With more reversals in the chain the probability of errors increases. Therefore, multiple reversals may result in propagation of errors.

4.4 Conformance Checking on Goods Movement

To understand these reversed transactions and pinpoint deviations that have caused signals, conformance checking is needed on materials flow under IWP suspension, i.e. goods movement during production recorded by ABC's ERP system. Fig. 7 presents the process model of goods movement during production in the form of Petri net. The normal sequence of movement types should follow certain patterns denoted by black arrows. These patterns start with a work order and with movement type 261 in ERP (meaning "Goods issue for a work order") followed by parallel movements and loops. In particular, the transitions in the process model correspond to movement types in material flow. When some goods issued are cancelled, the production process regarding these related materials should always be reversed back in stock by a reversed transaction, i.e. issue movement type+1. The production of a certain product can require various subcomponents. Assume that product D consists of three subcomponents, namely E, F and G as Fig. 7 shows. To differentiate movement types involving different components, we label transitions in the process model with both the *movement type* and the *material type*. Accordingly, label "261E" denotes a movement type 261 for material E.

is not allowed according to Petri net, i.e. a move in log. The third column in γ_1 shows that a movement type should have occurred in the trace according to the Petri net model, but it is absent in the trace, i.e. a move in model. Note that γ_1 and γ_2 provide possible explanation of what could have happened.

We analyzed two production work orders 9910 and 9900 (number anonymized) in 2016 from ABC. The resulting product of 9910 is issued to production in 9900. We found that 305 material types were issued to production in 9910. Three of them were reversed back to inventory, however, the storage locations were different from their corresponding 261 movements. The storage locations are related to specific zones under different customs licenses in the warehouse. If an error happens in storage, then a mistake can happen for declarations. For example, the material AM ISOLATOR with item value 14742,53€ was issued to production twice and reversed back once. Suppose the two materials are from different origins for classification for duty payment, it is possible that the wrong material was reversed with 262. Therefore, instead of producing correct declarations, misplacement error regarding compliance status of goods happens with goods mixed in the warehouse.

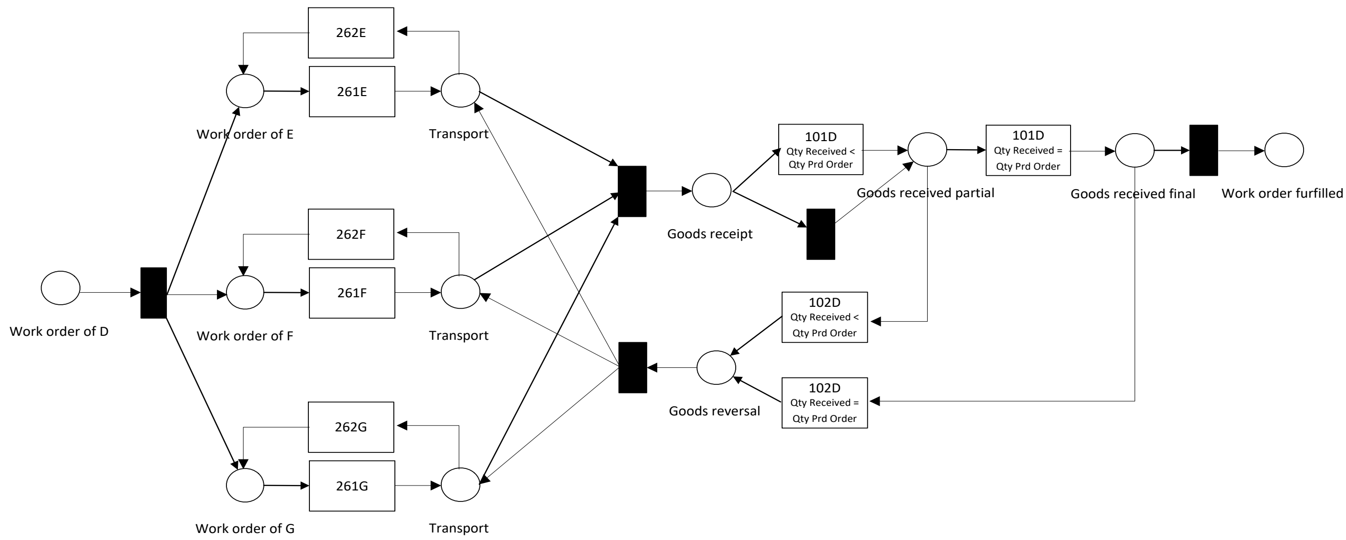

Figure 7: Goods movement during production in Petri net.

The instance of work order D can be represented by trace $\sigma_L =< 261E, 262E, 261E, 262E, 101E, 101D >$. Here are two alignments between this trace and the Petri net model in Fig. 7:

$$\gamma_1 = \frac{|261E|262E|261E|262E| \quad \gg \quad |101E|101D|}{|261E|262E|261E|262E|261E|101E|101D|};$$

$$\gamma_2 = \frac{|261E|262E|261E|\ 262E|101E|101D|}{|261E|262E|261E| \quad \gg \quad |101E|101D|}.$$

The top row of the alignments shows the sequence of movement types in the log and the bottom row shows the sequence in the Petri net model. Deviations are shown by columns that contain symbol ≫. For example, the second column in γ_2 shows that a movement type occurs in the trace although it

In addition, there are lots of reversal movements 262 without corresponding goods issue to production 261 in 9900. These deviations are not allowed in the Petri net model of Fig. 7. The effects of these deviations on inventory management and customs compliance can be significant. Since duties payable are automatically calculated based on quantities of taxable goods in declarations generated, the inventory differences of taxable goods will lead to errors in the computation of customs duties to be paid by ABC. Suppose an employee has omitted recording movement type 261 for goods issue of E in ERP. The inventory of E would stay the same in ERP but should be subtracted by corresponding items according to the Petri net. Depending on the customs status of the goods received after production, this discrepancy in the inventory can affect the duties due by a company for the product.

4.5 Feedback and Recommendations

To reduce potential error propagations, reversals must be exactly the same on quantity and value as previous transactions. However, current ERP systems do not have strict controls on this issue as reversals in information systems can have different reasons such as correction plus in inventory, transport material of a module into the cleanroom and internal orders, etc. Therefore, material reversing entries to the inventory account should be monitored with specific emphasis.

Further analysis of the root causes of inventory differences can be categorized as three main reasons: Deviation by employees from the standard operating procedure as agreed in the workflow instructions; Misusage 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.

The feasible control method is to enrich data requirements in ERP. A production work order should not only define which material is to be processed, at which location, at what time and how much work is required. It also defines which resources are to be used and how the order costs are to be settled, especially regarding compliance status. In the ABC case the compliance status refers to customs status of each material items. As soon as a planned order or other request is generated from material requirements planning, the information is passed on to shop floor control. The order-relevant data including compliance status should also be added to ensure complete order processing.

The alternative solution is to place Internet of Things (IoT) devices or RFID sensors at each transition in Fig. 7. Sensors in the transitions can then have resource class assignments. A built-in resource editor in Workflow Petri Net Designer (WoPed) allows for each process the definition of a resource model, i. e. roles, groups, and objects. WoPeD is an open-source software developed to provide an easy-to-use software for modelling, simulating and analyzing processes described by Petri net class. Based upon the capacity requirement per transition, we can calculate the capacity requirement of each resource class.

5 CONCLUSIONS

In this research, the framework of compliance monitoring defines regulatory supervision with computational audit in international supply chains on a more detailed level, providing some insights to improve compliance management. It shows relations between organization functions with compliance management capabilities and responsibilities. This results in a theoretical framework to control compliance risks, as well as guide cooperation and collaboration among governmental authorities and private sectors.

Table 3 compares our framework with traditional regulatory supervision approaches. We can see that despite the reliance on accuracy of models, our compliance monitoring approach is more scientifically rigorous. The case study results demonstrate that our approach is also applicable for complex systems.

Table 3: Comparison with traditional regulatory supervision approaches

Approach	This research	Traditional
Theoretical background	CS; enriched by AI theories	Professional judgement; statistical techniques
Model	Quantitative	Qualitative
Detection basis	Algorithms	Causal relationship
Advantage	• Direct • Measurable • Fast response	• Experienced • Applicable for complex systems
Disadvantage	• Highly rely on accuracy of models	• Time consuming • Subjective

Definitely there is possibility of bias, when it comes to qualitative judgement from the perspective of the interviewee as well as the interviewer of the case study. Therefore, our research combines interviews with actual data analysis. In addition, the import process is too linear to be true. Real cases are more complicated and overlapped. In terms of different private sectors, different contract agreements, and different products, the sequence of some steps might change. But in majority cases, the compliance monitoring framework is universally applicable. Therefore, further research could consider these differences and generalize detailed processes for a more specific industry or product.

This research lacks sample companies for case study. We only chose one representing field of customs supervision to illustrate compliance. Although most of activities and errors regarding compliance are included and discussed, whether the approach could be scalable in international supply chains needs further research on compliance requirements.

However, with further access of inputs and outputs in data & document layer of Fig. 2, more relevant compliance and logistic information can be used by our framework from system engineering for more advanced fault detection and diagnosis. Moreover, with event data of detailed amount of cost, delay time, level of workload represented by human labor hours, the proposed approach will extend to more accurate results with numeric calculations.

To sum up, the scope of compliance is very broad. It requires concepts from several domains and theoretical foundations to accomplish compliance monitoring for regulatory supervision. Our framework combining methods from data sharing and process mining is theoretically innovative in IS compliance and controls. Practically, our control strategies developed at operational level also facilitate risk management in global supply chains, meanwhile, provide collaborative insights for private sectors and public sectors.

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