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## Conference Paper

# Control and Monitoring in International Logistics Chains

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# Control and Monitoring in International Logistics Chains

Albert Veenstra, Joris Hulstijn and Paul Griffioen

## **Abstract**

In this paper, we introduce an approach to monitoring and control in the international movement of goods that builds on value chain modeling. The approach is taken from the accounting domain and adapted to application in supply chains and logistics chains. This approach is based on identifying equations that can be used to verify the accuracy and integrity of data in the supply or logistics chain. This enhances visibility, and will contribute to compliance in the international movement of goods.

We introduce a case study of a retail company in the UK that ships containers from China to its warehouses in the UK. We obtained unique data from this chain, in which independent measurements were taken of the cargo volume in the containers. Based on the analysis of this data, we show that there is a considerable chance that recorded volumes on shipment documentation by manufacturers may be wrong. We show that the incorrect data follows patterns that can be detected, which provides a starting point for the development of analytical detection models.

**Keywords:** containers, supervision, risk management, supply chain

## 1. Introduction

Annually, there are 177 mln ocean container movements (Drewry, estimated 2012 data). Given the global imbalances in trade, 40-45% of these containers move empty. Therefore, there are about 80 mln full containers moving around the World. A container has obvious advantages: it keeps goods safe and dry, enables the loading of large volumes of goods in relatively limited time.

Since 9/11 a significant question has become: what is stored in these containers? As a result, customs agencies have strengthened existing and developed new mechanisms to supervise this flow of goods. At the same time, many companies are also struggling with the lack of information due to shipment in containers. In many cases, shipping lines provide little visibility as to where the container is at any time during transportation, and documentation such as the ship manifest and bills of lading are not very accurate. The result of this lack of visibility is that companies are not able to make a crucial match between what was ordered, what was shipped, and what was received, and consequently, which invoices need to be released for payment, see e.g. (Steinfeld et al. 2011, Klievink et al. 2012).

We observe that this lack of supply chain visibility leads to two potential problems:

1. Products that are expected to arrive may not arrive, or arrive later than expected, and, with the current lack of visibility, this is often only discovered upon arrival of the goods.
2. Critical information on the goods, such as number of boxes, weight and volume, on documents is often not correct, which means that errors occur in inventory management systems if the documents are used for data input, instead of observed information from the containers. Moreover, container capacity is not used in an optimal way, when volume and weight information are incorrect. Finally, customs declarations may also be incorrect, which can result in additional checks, scanning and physical inspection and corresponding delays in the arrival of the goods.

This paper will develop an approach that offers new opportunities for verification of trade information in international logistics chains. We will concentrate on the second problem mentioned above. We will therefore develop an approach for the verification of volume and weight data at different stages in the logistics chain. To do so, we adapt principles from accounting and apply these principles to the supply chain management context. To demonstrate the usefulness of this approach, we report on a case study that provides a unique insight in an international container transport chain, with data on volume and weight on several thousands of containerized shipments. This case study is part of the EU FP7 project CASSANDRA (SEC-2010.3.2-1, GA nr 261795) that aims to develop new technical solutions for international logistics visibility.

The remainder of this paper is structured as follows. First, we provide a brief overview of the state of the art in international logistics visibility. In the next section, we will introduce the container logistics chain, as well as the shipments data. The section after that, we will describe the technical visibility solution developed in the CASSANDRA project. We continue to develop a model that supports the continuous analysis of data in our container logistics chain with the aim to identify matching problems in an earlier stage.

## **2. State of the art international logistics visibility**

Before we start with a discussion on logistics visibility, we first introduce a simple data model that will help to structure our discussion. In principle, in international container logistics chains, there are three categories of data:

1. Data on product
2. Data on consignment
3. Data on container

The first class contains information on the product such as the product description, formal product classifications, composition of the product, individual weight and volume of the boxed product, value of the product and so on. The second class contains information on the grouping of products in so-called

consignment. These consignments are the batches of product that are sent from manufacturer to receiver, or in legal terms, from consignor to consignee. Usually, consignments are determined by the purchase order, or some standard order quantity determined by inventory optimization. The consignment is also the basis for declarations to customs. Information on the consignment is in principle similar to the information on the product, but it also contains information about the number of products, the number of boxes, total weight and total volume of the consignment. The third class is the container in which consignments can be moved. A container can contain one or multiple consignments, but a single consignment can also be moved in multiple containers.

In principle, businesses require visibility at the product level. Organizations such as GS1 cater for this with product level tagging solutions, and worldwide standardized product description data structures. Government agencies usually require information on consignments, since these are the basis for declaration processes.

The business case for visibility was recognized around the end of the 1980s, when international data exchange became a reality. The development of Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT) was published for the first time in 1987. Not long after that, international trade portals, such as GT Nexus and SmartCargo saw the light. Another well-known platform in ocean shipping, INTTRA, followed about a decade later. The business case for these platforms is to be a one-stop shop for shippers and transport operators, for the exchange of all data related to the international commercial transaction and related transport operations.

The type of visibility that is provided by these platforms is, in first instance, based on the data that shipping lines can provide. In a shippers' survey in a EU FP7 project INTEGRITY, we identified 11 crucial milestones in an international container logistics chain INTEGRITY 2009, pg. 34-35). These are reported in table 1.

nr	Milestone	Original source	Commonly provided by
1	Container stuffed at origin	manufacturer	Often not reported
2	Container closed and locked	manufacturer	Often not reported
3	Container gate in at terminal	Terminal at origin	Shipping line
4	Container loaded on ship	Terminal at origin	Shipping line
5	Ship departed	Terminal at origin	Shipping line
6	Ship arrived	Terminal at destination	Shipping line
7	Container unloading from ship	Terminal at destination	Shipping line
8	Container released by customs	Customs	Port community system
9	Container released by carrier	Shipping line	Shipping line
10	Container gate out from terminal	Terminal	Shipping line
11	Container arrived at warehouse	Logistics service provider	Warehouse operator

Tab. 1: International container logistics milestones

It is clear from this table, that the ocean transport community has a role to play in providing international logistics visibility: they can provide 6 out of 11 desired milestones.

There are several problems with these ocean transport milestones, however. First of all, they are at the level of the container. This means that a translation to the consignment level (which is relevant for both customs and the cargo owner) has to be done on the basis documentation that is put together by the manufacturer, or his local representative. Second, the milestones' original source is not the shipping lines, but the ocean terminal. They provide their data to the operational departments of shipping lines, who then process this data for their visibility services. This processing is not faultless (see for instance Schilt 2012). Many of these platforms, and several of their competitors, such as the Global Logistics Services platform of Descartes, and in-house platforms of global logistics service providers, such as the Korean Pantos Logistics, also provide services to upload and exchange other documentation, such as purchase orders, packing lists for consignments, transport orders, customs declarations, and so on. The data in these documents then provide an extra layer of visibility on top of the ship- and container-level milestones. The integrity of these visibility solutions depends crucially on three kinds of registrations, to provide linkages:

- Purchase Order: links products to consignments
- Container Manifest, or Packing List: links consignments to container(s)
- Loading List: links containers to a ship

Capturing these links is not easy. Purchase orders are often annual contract, where manufacturers can ship periodically whatever they have produced. Instead of a purchase order, they then issue a Shipping Order, which is the actual description of the consignments to be shipped. Packing lists of containers are sometimes reconstructed based on warehouse management systems after containers have been loaded and closed. This holds especially for large consignments that are distributed over several containers.

There is a specific reason why the container level visibility that the ocean shipping community can provide does not offer a complete solution to many companies. This reason is related to the structure of the commercial transaction for many container chains leading to Europe and the US. Many importers in Europe and the US buy their goods based on the standard Incoterm Free on

Board (FOB). This term specifies that the importers become owner of the goods when they are loaded onboard the ship in the port of origin. What happens before that time is the responsibility of the manufacturer/seller of the goods: the exact information on stuffing of the container, the customs declaration for export and the information provision to the ocean carrier that goes into the ocean transport document (called the bill of lading, or the seaway bill), the ship's manifest and any customs declaration the ocean carrier will make. This crucial information is all compiled outside the control of the buyer.

The ocean carrier is only interested in a general description of the goods, and the weight and some special requirements (dangerous cargo, refrigeration, oversized). As a result of this, the importer does not control the information quality at the beginning of the chain, and is often informed about shipment of the goods based on the documentation the ocean carrier provides, i.e. the bill of lading or seaway bill. In other words, the importer will have great problems capturing one of the crucial information linkages identified above: the container manifest that links information on exactly which consignments went into which container. To solve this problem, the only thing an importer can do is to require additional effort from the manufacturer, for which the manufacturer will often ask additional financial compensation. Against these immediate additional costs stand unclear benefits for the importer of having this additional visibility in an early stage in the chain.

This paper will attempt to clarify these "unclear" benefits, by offering an approach to verify data at the consignment level, and based on the insights this provides, calculate benefits for the consignee. For this purpose, we first introduce some methods from the accounting domain, and adapt these for application on container logistics chains.



### 3. Model-based Auditing

Business reality can be modeled as a value cycle: an interrelated system of flows of money and goods (Starreveld et al. 1994). The value cycle of a trading company for example contains two types of transactions: purchasing and selling goods. The flow of money exactly mirrors the flow of goods, but in reverse. The point of an accounting information system is to accurately and completely capture these flows using accounts. Figure 1 shows an example of the value cycle for two trading companies, connected by trade documents (quittance, invoice, purchase order). We use the following notation. Decisions (authorizations) are shown as an oval: an event or change of state. Rectangles are the recordings of a state of a certain value to the company, such as inventory or accounts payable. Records of states, i.e. accounts, are related through *reconciliation relationships*, indicated by dashed lines, which come together in the general ledger. The direction of the arrow indicates the influence of events. Arrows generally indicate an increment, while the sign ‘-/’ indicates a decrement of the corresponding account. Thus, a purchase leads to an increment of the accounts payable, while the purchased goods are added to the inventory. A sale leads to an increment of the accounts receivable and a decrement of the inventory, and so on.

Depending on the type of business, the accounting relationship between the flow of money and the flow of goods is stronger or weaker. For manufacturing, the relationship is strong, because the resources needed to manufacture a product can be counted. In the services industry the relationship is much weaker. The stronger the relationship, the more the auditor can rely on expected proportions. In particular, to measure the completeness of revenue, the auditor can verify revenue against the number of goods sold and the sales price. Starreveld (Starreveld et al. 1994) developed a typology based on the type of business, to determine the expected internal controls. The typology also provides a model of what kinds of information are expected to be recorded for different types of businesses.

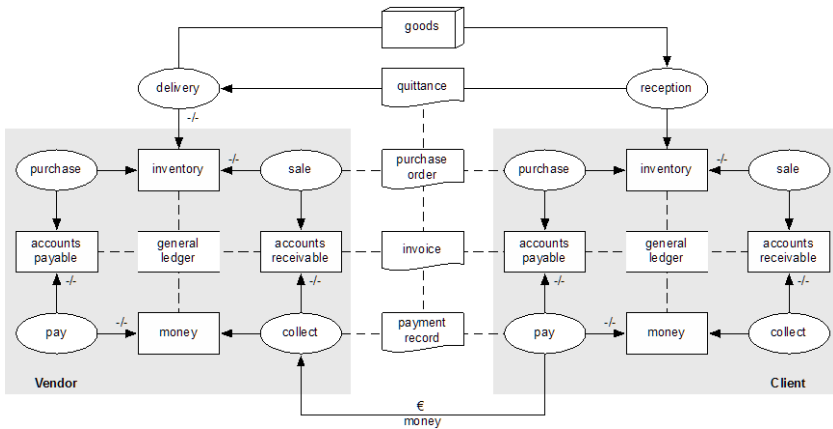


Fig. 1: Value cycle models of two trading companies, linked by trade documents

Auditing is the systematic, objective and documented process to obtain and evaluate evidence about some object of investigation, to ascertain the degree of correspondence with established criteria (Knechel et al. 2007). In assessing the risk of possible misstatements, auditors typically make use of the guarantees and internal controls inherent to the type of business. The purpose of model-based auditing is to develop and use a normative meta-model of the relationships between the flow of money and the flow of goods, for monitoring and auditing purposes (Weigand and Elsas 2012). The term 'model-based auditing' is chosen by analogy with model-based diagnosis (de Kleer and Williams 1987), and other model-based approaches to knowledge systems, see (Stefik 1995). Model-based approaches are opposed to more practical approaches that do not start from a mathematical model, but instead try to automate existing practices and heuristics.

The relationship between flows of money and goods can be expressed in two prescriptive 'laws', meaning that they express how the flows of money and goods should ideally be related, given the type of business (Starreveld et al 1994). The first law is concerned with *transformation*. It is called the law of the rational

relationship between sacrificed and acquired goods, and states that, for all events  $e$  that affect the incoming and outgoing states or accounts  $S, T$  according to the arrows in Figure 2,  $S \rightarrow (e) \rightarrow T$ , we have:

$$\text{input}(T, e) = f \cdot \text{output}(S, e), \text{ for some normative ratio } f \quad (1)$$

For example, if we look at a sales event, we have: *increase in accounts receivable = sales price • decrease in inventory*. Similarly, if we look at a purchase event, we get: *increase in inventory = increase in accounts payable • purchase price*.

The second law is about *preservation*. For all states  $S$ , the value at the end of a period should equal the value at the beginning, with increments added and decrements subtracted. Also losses are accounted for. We assume there are standards and norms for normally expected losses, given the type of goods.

$$S[t1] = S[t0] + \text{input}(S, [t0, t1]) - \text{output}(S, [t0, t1]) - \text{losses}(S, [t0, t1]) \quad (2)$$

Note that some accounts are counted in monetary value, while others, like inventory, are counted in other units: kilos, hours, boxes, or containers. Griffioen (2013) argues how important units of measurement are in expressing accounting equations.

A special instance of the first law therefore deals with *conversion* or *aggregation*.

$$T \text{ in unit } u = f \cdot T \text{ in unit } v, \text{ for } f \text{ a normative conversion ratio} \quad (1')$$

For example, suppose that we are looking at a shipment of shoes. Because of the size of a shoebox and the way shoes are stacked on pallets, suppose that on average a 20-foot container will contain 5600 pairs of shoes. So we get *Shoes in unit 20-ft-container-load = 5600 • Shoes in unit pair*. Another example is the conversion of weight to volume, or vice versa, for a box or some other unit of cargo.

The general idea of model-based auditing is to use such equations to define a normative meta-model of the flow of money and goods, made specific for each type of business, and use it to verify actual data against. Discrepancies can be either exceptions or violations, and will therefore have to be explained. If such verifications are automated, they can be used to monitor a process continuously (Alles et al. 2006).

### **APPLYING THE VALUE CYCLE MODEL TO LOGISTICS CHAINS**

To use the value cycle model approach in logistics chains, we have to make a number of adaptations.

First of all, the value-cycle model uses variables related to the commercial transaction (inventory, purchase, sales, credit and debt). In practice, however, there are many other transactions and pseudo-transactions, that could be the source of verification relationships. A very relevant transaction in this respect is the hiring of transport, where the seller requires proof that goods are taken into custody by the transport operator, and the buyer needs a document that proves to the transport operator that he is the rightful owner of the goods.

Another observation is that financial auditing, until now, has mostly dealt with individual firms. In international logistic, we are looking at a web of firms, collaborating in a chain or network. Therefore we need to be able to provide assurance over inter-organizational links. We argue that the model-based auditing technique is quite capable to do so, since, in principle, the kinds of reconciliation relations that we want to use also apply across inter-organizational links. In fact, the application of these relations for verification purposes may be stronger, since in the supply chain we can often use data derived from actors having opposed interests. An example is comparing import value of the goods and export value.

Finally, the value cycle model itself does not specify any physical relationship between resources and finished product. For each application domain, these 'laws' have to be found and tested in practice. Now clearly, if this value cycle

approach is to be applied to international container chains, the set of financial equations needs to be extended with physical goods equations.

Summarizing, we need to adjust the value cycle model in three respects: (1) adding variables and components related to transport and handling, (2) verifying across inter-organizational links, and (3) finding the individual 'laws' that govern the international trade domain, in particular, capturing equations related to the flow of physical goods. The next step is to develop reconciliation relations that are useful for our case study.

### **DEVELOPING RECONCILIATION RELATIONS FOR LOGISTICS CHAINS**

When applying the value-cycle approach to logistics chains, we focus on the relationship between containers and consignments. Based on the value cycle approach discussed above, type-(1) relationships can then be developed as follows (brackets contain alternate variable dimensions), ignoring, for the moment, values:

total consignment volume (weight) = box count \* volume (weight) per box (3)  
and

$$\text{total container volume(weight)} = \Sigma \text{ volume(weight) per consignment} \quad (4)$$

where the summation is over the total number of consignments.

In these relationships the number of boxes is the normative ratio. In a logistics chain with many different products or product types, however, there may be as many consignments as normative ratios. This makes this type of reconciliation relationship relatively useless for verification purposes.

We can also formulate type-(2) preservation equations. Again, we focus on physical variables, and ignore value. The basic preservation equation, expressed in total volume, is:

$$\text{goods underway} = \text{goods ordered} - \text{goods delivered} -$$

goods ready for shipment – goods in manufacturing (5)

In all these equations, the term 'goods' is short for 'consignments of goods'. The same variable can be expressed as:

goods underway = goods in pre-carriage + goods in terminal at origin + goods at sea + goods in terminal at destination + goods in on-carriage (6)

For each component, one can write:

- goods in pre-carriage = goods arrived at terminal of origin – goods ready for shipment
- goods in terminal at origin = goods in pre-carriage – goods at sea
- goods at sea = total goods underway – goods at terminal in origin – goods at terminal at destination – goods in pre-carriage – goods in on-carriage
- goods in terminal at destination = goods at sea – goods in on-carriage
- goods in on-carriage = goods delivered – goods arrived at terminal at destination

Note that the easiest way to fill all these equations is with data at the container level. This is also the level the parties in the logistics chain are implicitly verifying these equations. A shipping line will eventually carry all the containers that were booked for transport, and a terminal will load or unload all containers it was supposed to handle. Eventually all containers will leave a terminal for transport to the end destination. All these parties have an interest not to lose containers during their operations. For a party interested in the cargo, the visibility it is interested in is in the timely movement of containers. This is an important operational interest, that requires adding a time dimension to each of these equations, as well as finding norm durations for each step in the logistics chain. Given that in this paper, we aim to focus on the verification of weight and volume, and not timeliness, we leave this for further research.

The purpose of this paper is work with consignment level data (i.e. data on what is in the container), and to verify the correctness of the description of the goods,

especially their volume and weight. In this case, all the equations above should clearly indicate the types of goods and the corresponding unit they are expressed in. This may result in a lot of equations, but it will provide a new opportunity to identify mismatches between cargo descriptions and actual goods movements. Seen in this context, equation (3) and (4) contain variables that can be independently verified, by using data from different sources: the weight or volume of the container can be measured in the container terminal at origin or destination through weighing, and the box count can be derived from an independent tally at stuffing or stripping of the container, or from the stuffing/stripping company's invoice. Often, such companies are paid based on the number of boxes being handled, so the invoice provides a reliable independent source of evidence. The weight and volume of the boxes of goods can be recorded in the standard product data, or can be measured with a scale or volume scanner at the beginning or end of the chain. The weight and volume of the boxes as well as the box count are recorded on the packing list or container manifest.

With the help of these normative, or prescriptive, equations that describe the situation as it should be, deviations in the actual flows can be identified based on actual measurements of the variables during operations. Depending on the quality of the underlying information system, these deviations can point at more or less serious risks in the flow of goods. By mining transactions (see for instance, Rozinat and van der Aalst, 2008 or Khan et al., 2010), different recordings of, for instance, weight or item numbers, for the same shipment will emerge. These differences can indicate that things went wrong with the shipment.

#### 4. Case study

The case study concerns a specific trade lane between China and the United Kingdom set up by a number of cooperating freight forwarding companies, for the benefit of a British retail company, here called ABC. The freight forwarding companies involved are a forwarder based in Hong Kong, a forwarder based in the UK and a container handling company in the port of Felixstowe in the UK. The container handling company's role is to bring containers from the container terminal and unpack the containers for storage in a warehouse in the port area. From there, the forwarder brings the goods to the distribution warehouses of ABC. ABC's shop replenishment operation is based on just in time logistics, in which different timing and routing applies to different groups of products. It is crucial for the accurate replenishment of shops to know what goods will be arriving, when and in which container, preferably before the container arrives. Figure 2 shows a schematic representation of the container logistics chain, with the main parties involved.

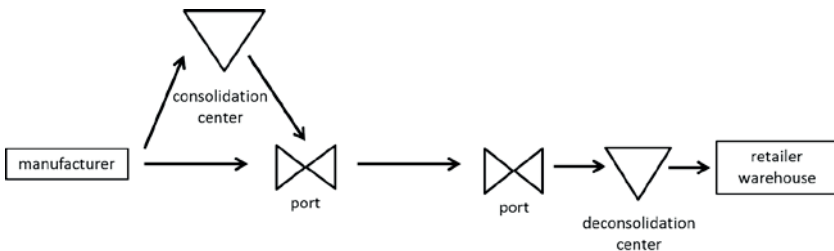


Fig. 2: Container logistics chain

The manufacturers are mostly located in China. The freight forwarder at origin operates two consolidation centers in Hong Kong and Shenzhen. The ports used are either Hong Kong or Yantian in China. The port at destination is Felixstowe, while the consolidation center is run by a logistics service provider that is based in the port, located next to the container terminal. The UK based part of the same freight forwarder that consolidates at origin, takes care of transportation from the deconsolidation center into the retailer's warehouse.



This case study has been part of two European R&D projects: INTEGRITY (2008-2011) and CASSANDRA (2011-2014). In this period, the level of control in the chain underwent significant changes. We will describe three main stages of developments here.

### **Stage one**

Initially, 80% of containers were stuffed at manufacturers' premises. Documentation was also provided by manufacturers. This documentation, together with original orders and shipping line documentation (bill of lading) was collected in a so-called purchase order registration system. This system keeps track of the fulfillment on individual purchase orders. It is updated only after the ship sails, because ocean shipping companies usually deliver their documentation several days after ship sailing. In this stage, about 20-30% of the containers' content was a complete surprise. As a result, the retailer did not use this system to fill its inventory systems, but relied on the container handling company to supply accurate counts of boxes and products. The container handling company had to count the boxes anyway, since they were paying employees by the box.

### **Stage two**

As part of the EU FP7 project INTEGRITY, two improvements were made:

1. The retailer introduced a rule that an accurate container manifest had to be attached to the inside of the container door, and that any discrepancy with the count of the container handling company in Felixstowe would result in a penalty for the manufacturer.
2. The INTEGRITY project provided access to accurate container terminal milestones from the ports at origin as well as tracking data from CSDs, providing advance information on containers, as well as information on the link between container and ship. This facilitated mitigating actions for containers that were delayed (due to unannounced rerouting of

ocean vessels, or unexpected transshipment of containers in Singapore to another ship).

The penalty rule led to a 99% accuracy on container manifest documentation.

### **Stage three**

A remaining problem was consistent underutilization of container space, particularly in terms of volume. Around one-third (!) of the containers were found to have a volume discrepancy. A standard 40ft container has a capacity of about 67,5m<sup>3</sup>. The retailer ships about 6000 40ft containers annually. Therefore, a 10% underutilization of 33% of the containers results in the loss of space that is equal to about 200 containers. At an average shipment cost of about €3.000 per container, this amounts to savings on the total freight bill of €600.000. This amounts to about 3,3% of the total freight bill.

One mitigating measure was to move more of the container stuffing process to the retailer's freight forwarder controlled consolidation centers in the two main loading ports Hong Kong and Shenzhen/Yantian in China. About 25% of ABC's shipments now go through these warehouses in Yantian and Hong Kong. Many full container load (FCL) shipments are still sent directly by manufacturers. In fact there is a rule from the retailer that shipments above a certain volume (55m<sup>3</sup>) can be shipped directly, while shipments below that threshold need to be consolidated in the consolidation centers.

At the moment, however, the underutilization of container space persists. As part of the EU FP7 CASSANDRA project, the freight forwarder and the logistics services provider initiated a joint project to reconcile weight and volume data at both ends of the chain, in order to find early signals of underutilization of containers. In the next section, we will analyze the volume data, in order to gain some insight in the reasons for the persistence of the underutilization of container volume.

## 5. Data analysis

We have obtained data on container shipments for the period from 11th of April 2013 to 28th of June 2013. In this period, 1250 containers were shipped, with a total of 2515 consignments. On average, a container contains two shipments. The maximum number of shipments in a container we found in the data was 8. For this period we have descriptions of containerized shipments, consisting of: date of shipment, supplier identifier, container number, product description, container type (20ft, 40ft, 40ft high cube), loading pattern (full container loaded by manufacturer, or consolidated container), quantity of product, number of boxes, volume of boxes, total volume of cargo in the container. All this data originates from the shipment orders submitted by manufacturers, from which the shipment documentation is derived. During this period, volume measurements were performed at the logistics service provider in Felixstowe, by means of a cube scanner. This is a device that scans boxes in 3D, and determines the exact volume, as well as measures for height, width and depth. For about 16% of the containers, discrepancies were observed between the volume of the boxes listed on the documentation and the measurements. This section provides an analysis of these discrepancies. We will refer to the two different sources of the volume data as the document data and the measurement data.

First we analyze some histograms, based on the documentation data, for the three main container types (20ft, 40ft and 40ft high cube). We display the histogram for the 40ft container data below.

A standard 40ft container has a cargo capacity of 67,7 m<sup>3</sup>. Observe that virtually none of the shipped standard 40ft containers achieves this maximum. In fact, the average utilization rate of the 20ft, 40ft and 40ft high cube containers is 82,3%, 80,8% and 86,4% respectively. If instead of high cube containers, normal 40ft containers would have been used, the utilization rate of these containers would have been 98,8%. On average, we find an 18% underutilization of container space.

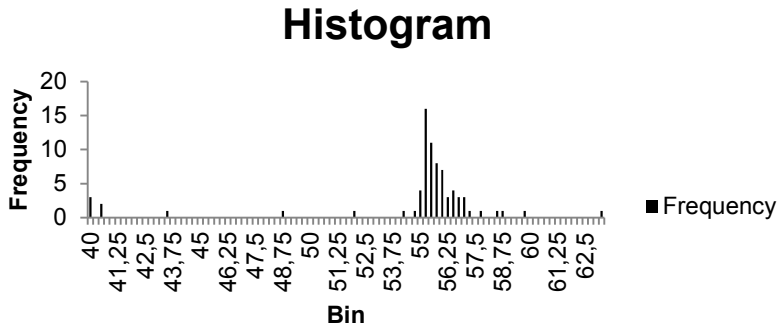


Fig 3: histogram container volumes, 40ft containers

The histogram of the 40ft containers also shows another interesting feature: it peaks around 55 m<sup>3</sup>. This is the threshold that was introduced as a business rule by the retailer for container loading by manufacturers.

Now we confront these document data with the measurement data. We deduct our measurement from the document data. This means that a positive difference refers to overstating the volume in the container by the manufacturer. The results are listed in Table 2 below.

	20ft	40ft	40ft high cube
Maximum negative	-2,14	-12,03	-10,07
Maximum positive	8,93	19,78	6,82
Average	1,50	1,82	-0,703

Tab. 2: Overview of discrepancies in container shipments

Observe that the differences between documented volumes and measurements are substantial. On average, for 20ft and 40ft containers, there is more than 1,5 m<sup>3</sup> more volume on the documentation than actually in the containers. Notice also the large spread: differences can be both negative and positive, and the

spread is substantial. The largest spread is found for 40ft containers, and it is more than 30m<sup>3</sup>.

One might expect the differences to follow a normal distribution. We performed an analysis based on a normal probability plot of the discrepancy data, which shows that the distribution deviates from the normal distribution in the area close to the mean, but not in the extreme tails.

If we compare the discrepancies against the documented data, we can see that most of the discrepancies are clustered around three volumes that we can associate with an almost full 20ft container, the 55m<sup>3</sup> threshold and the 65,7m<sup>3</sup> maximum volume of a 40ft container.

From this analysis, we conclude that manufacturers are not very accurate about the stuffing of containers, and they tend to label a volume with a specific number (55m<sup>3</sup>, of 67,5m<sup>3</sup>), without providing an accurate measurement of the volume.

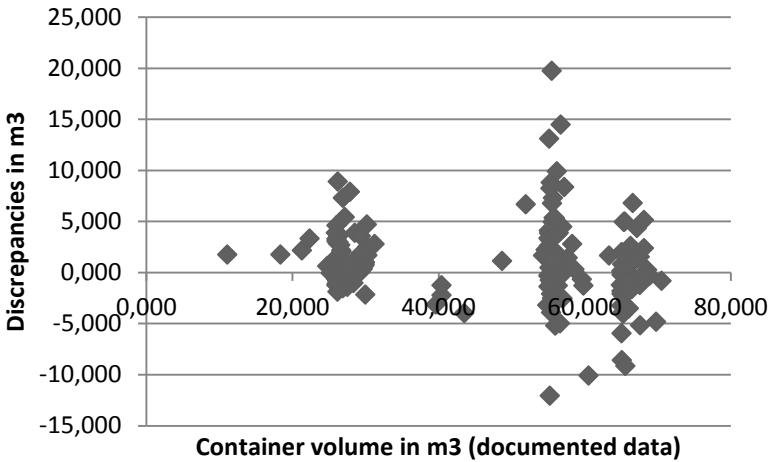


Fig. 4: Scatter of discrepancies against documented volume data

The retailer in our case has two solutions available. One is to route even more volume through the consolidation centers of its logistics services providers. The second is to develop some early detection mechanism that allows them to identify

containers with unreliable volume data on the documents in an early stage, so that some mitigating action can still take place. We leave the development of such a model for further research.

## 6. Conclusions

Container shipping has led to enormous efficiency gains in international transport, but has also produced a lack of supply chain visibility. The poor quality of data about the flow of goods, may lead to several problems in supply chain management, including wrong deliveries, inventory problems, and delays due to additional customs inspections.

In this paper, we introduce a verification approach to enhance supply chain visibility. We use accounting principles to identify relationships between the flows of goods and money, and use these so called reconciliation relations to verify the accuracy and completeness of data. The relations are used for cross-verification of data sources taken from across the supply chain. When parties have opposed interests, cross-verification of data from those parties is a strong measure to identify errors and improve data quality.

We first adapted the approach to supply chain and logistics domain. We managed to identify sensible reconciliation relations, which capture the essential linkage of products to consignments, and consignments to containers.

Next, we introduce a case study of a trade lane between China and the UK. Under pressure of a retail company in the UK, containers are shipped, via two additional logistic service providers, one in China and one in Felixstowe. By sharing data, these service providers were able to implement a number of additional control measures, and improve data quality and reliability of delivery. We obtained unique data from this chain. Independent measurements were taken of the cargo volume in the containers, both at stuffing and unloading. Based on analysis of this data, we show that the volumes recorded on the shipment documentation issued by manufacturers may be wrong. We also show that the errors in the data follow patterns that can be detected. This suggests that

it is feasible to develop analytical error detection models. We leave the development of such models for further research.

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# **III. Performance and Collaboration**

**Insight Into Current Supply  
Chain Management  
Approaches**

