AN INTEGRATION TECHNOLOGY FOR LONG DISTANCE LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Hyunbo Cho
Industrial & Management Engineering, Technology Innovation & Management Graduate Program,
Pohang University of Science and Technology
Pohang 790-784, Republic of Korea

Jungyub Woo, Nenad Ivezic, Peter Denno, Albert Jones
Manufacturing Systems Integration Division, National Institute of Standards & Technology
Gaithersburg, MD 20899, USA

Yun Peng
Computer Science and Electrical Engineering, University of Maryland Baltimore County
Baltimore, MD 21250, USA

Abstract

Despite the global economic downturn, import/export trade will continue to grow. That trade depends on many intercontinental, long-distance, logistics partners. Those partners include exporters, brokers, truckers, customs, carriers, and importers who depend on information to do their jobs. The software support systems that generate, use, and exchange that information are exceedingly complex and highly heterogeneous in nature. Inadequate approaches to integration of such systems means that trading partners encounter recurring problems including late deliveries, inaccurate tracking, insufficient visibility, poor security, unreliable planning, and unnecessary disruptions.

In this paper, we propose an integration approach that will reduce or eliminate these problems. That approach must (1) ensure interoperability among logistics applications; (2) provide shipment visibility to all trading partners; (3) reduce the average and variance of transport times; (4) accommodate associated international standards; (5) reuse legacy applications, where possible; and, (6) facilitate recovery from supply chain disruptions. Our approach has four proposals. First, we propose a collaboration architecture and a federated network framework using SOA-based concepts. Second, we propose a standards-based approach to message specification that will facilitate interoperability among trading partners. Third, we propose a framework for fast recovery from supply chain disruptions. Fourth, we propose the concept of a test bed to verify that proposed commercial solutions conform to those standards..

We believe that our approach will impact the intercontinental logistics industry significantly – in terms of quantitative and qualitative measures. First, it will increase shipment visibility dramatically among global trading partners. Second, it will decrease both the average and variance of transport times significantly. Third, it will reduce the cost associated with premium freight, and improve data quality and integrity.

Keywords: Logistics, Supply chain management, Integration technology, Shipment visibility

Introduction

Globalization is changing the traditional business models of manufacturing. In the past, most OEM manufacturers sourced raw materials from nearby factories, located research and development laboratories in close proximity, and sold goods to local markets. Manufacturers sought to reduce internal manufacturing costs and sustain consistent quality internally. Today, those same OEMs source, conduct R&D, and sell all over the world. They do this to cope with intense pressure to achieve cost reductions and product innovations (Rushton and Walker, 2007). Material suppliers may be located in Asia, customers in North America, and designers in Europe. The continued integration of national companies into global enterprises requires increasingly complex logistics to increase the wealth of both the companies and the nations (Klaus, 2009). Developing strategies for dealing effectively with that complexity has proven to be quite difficult (Helmick, 2001).

Physically, logistics is concerned with both material supplies into the production process and product distribution to customers - either through warehouses or directly (Rushton et al., 2000). Simply stated, it seeks the efficient and effective movement of goods from suppliers to manufacturers to retailers to end customers. In the global arena, this movement can involve many trading partners including exporters, consignees, customs officials, administrative bodies, freight forwarders, consolidators, customs brokers, truckers, shipping lines, airlines, tariff unions, and shipping conferences (Straube, et al., 2008) (Seyoum, 2000) (Long, 2003). More and more, these partners are responsible for the movement of data/information and well as goods.

Problem Statement

Facilitating data flows among trading partners is not an easy task. The data can be exceedingly complex in structure and content and the computers that deal with the data can be highly heterogeneous in nature. This leads to numerous recurring problems including late delivery to the designated location, inaccurate tracking of materials, insufficient visibility and security, unpredictability and uncertainty of trade lanes, and late response to supply chain disruptions (Comerford and Denno, 2007). In this paper, we focus on three of those problems.

Poor Visibility: Under normal intercontinental logistics flow, information exchanges among partners for tracking goods are not well coordinated. This leads to very poor shipment visibility, which is the ability to obtain actionable awareness of the status of goods. Although great efforts are being made to improve the local visibility within each country, achieving shipment visibility in international logistics remains a challenge. With the analysis of Automotive Industry Action Group (AIAG)'s survey, Figure 1 shows the desired shipment visibility between Korea and USA trade lanes.

Today, intercontinental logistics is supported by a complex network of loosely-federated information and communication technologies including EDI messages (Antje Hohlfeld, 2008), fax, phone, and email. The (mis)use of these technologies is a principal cause of poor shipment visibility. The current process of exchanging information using these technologies has the following flaws

(i) Excessive use of paper documents, resulting in errors and increased costs
(ii) Manual interventions to resolve problems in the business process
(iii) Various data exchange protocols that are not interoperable
(iv) Numerous proprietary systems with ill-defined interfaces

(v) Noncompliance to international standards
(vi) Faulty interpretation of data content and business processes across organizations
(vii) Inability to respond to disruptions in the flow of goods

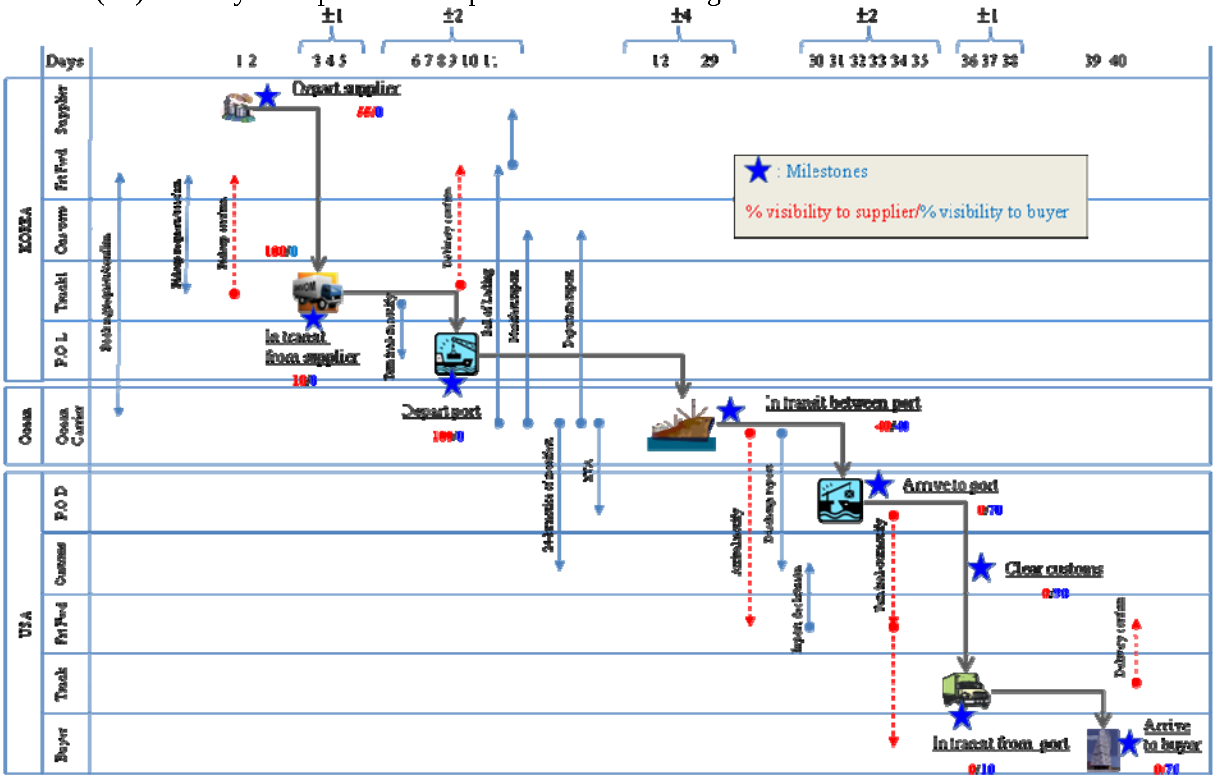

Figure 1: Information flow and shipment visibility between Korea and USA

Transport Variability: The high variability in transport times of international trade lanes results in avoidable cost increases. To shift the right goods to the right place at the right time, thereby minimizing the impact of variability, international trading partners must often change transportation modes. These changes result in tens of millions of dollars in avoidable costs for expedited and premium transportation, additional resources to fix problems, increases in buffer stock inventories.

New Partners: The cost of integrating new partners into an existing supply chain is high. This cost could be reduced significantly by designing an infrastructure with system components that are validated in advance. This validation would ensure that the components conform to the necessary standards and integration methodologies before they are deployed.

The integration approach described below will help overcome the aforementioned pragmatic global logistics issues. That approach has four parts: a collaboration architecture and federated network framework based on SOA (Service Oriented Architecture); standardized message specifications to facilitate interoperability; a framework for fast recovery from supply chain disruptions; and, a test bed to verify that proposed commercial solutions conform to those standards.

Collaboration Architecture

The proposed collaboration framework is similar to a publish/subscribe messaging paradigm. The process works as follows. Each partner publishes tracking event messages to a centralized server located in its home country; other trading partners subscribe to various events of interest to them. The publishing partner simply posts an event every time it occurs; it has no knowledge of what subscribing partners there may be. In this way, partners are not required to talk directly to one another. This concept facilitates shipment visibility, leads to a loosely-coupled relationship among partners, and helps new partners join the global supply chain more easily.

On the other hand, trading partners can communicate with each other directly when business transactions other than tracking events are needed – such as purchase orders or invoices. These transactions require the exchange of business documents that are not meant to be shared with other partners.

The hybrid model of a publish/subscribe paradigm and direct exchange of business transactions is implemented by using a layered structure with SOA (Service Oriented Architecture) and CBD (Component Based Design) concepts, as shown in Figure 2. These technologies help migrate legacy systems with minimal modifications. The developed system supports international standards such as ebXML (ebXML.org), WEB service (www.w3.org), UNeDocs (http://www.uncefactforum.org/TBG/TBG2/tbg2_unedocs.htm).

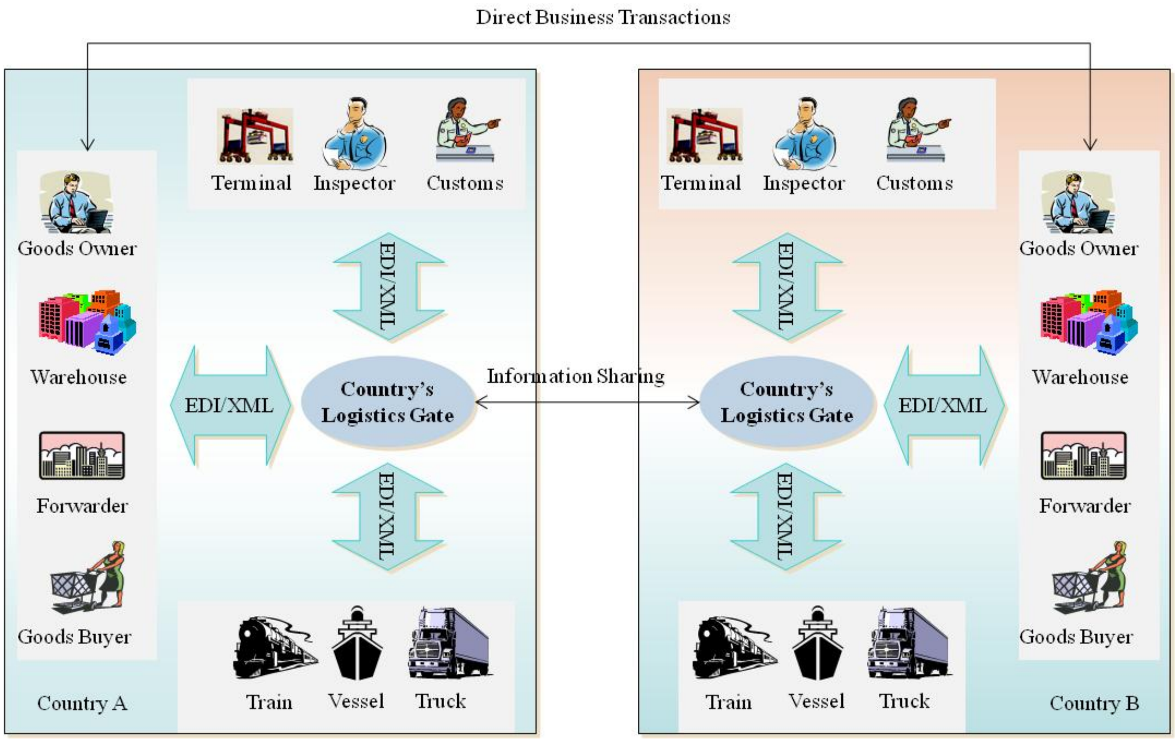

Figure 2: Hybrid model for international logistics integration

The detailed implementation specifications are as follows:

(i) System & implementation aspects
  (a) Service-oriented design: SOA and CBD-based architecture
  (b) Adoption of a 3-tier architecture for security: database, application, WEB
  (c) Security structure: PKI-based security, HTTP (Hypertext Transfer Protocol), SSL (Secure Sockets Layer), keyboard security
  (d) Application of EJB (Enterprise JavaBeans)based on J2EE and XInternet (Rich Client)
  (e) Employing a reliable service and fault-tolerant configuration

(ii) Work process aspects
  (a) Unification of electronic document elements (tag).
  (b) Removal of manual processing in terminal gate check-in and check-out.
  (c) Assurance of data correctness through semantic check as well as syntax check for events and documents.

(iii) Application service provider aspects
  (a) Composition of parsing module, database engine, template engine, communication interface, database system.
  (b) Database engine: Stores the parsed value into a database, extracts data from the database system and sends that data to the template engine.
  (c) Template engine: Transforms the received data from the database engine to a standard message format.
  (d) Communication Interface: Communicates with other messaging systems.

Interoperable Data Exchange

A standard set of messages that enable trading partners to interoperate efficiently in an intercontinental logistics supply chain is critical to our approach. These standards (specifications) must specify the format, structure, and content of all information conveyed during the movement of goods from their origin to their destination. Message content is derived from an analysis of the shared business process associated with that movement. That analysis identifies the information needed to enable that process. In the case of our work, the process includes product ordering, in-land foreign transport, consolidation, drayage, export customs clearance, ocean carriage, import customs clearance, and in-land domestic transport. The form and structure – and sometimes content - of message specifications typically are not created without regard to prior work. Rather, message specifications are tailored to particular usages from ‘templates’ defined as standards. Several such standards exist and they will provide the foundation for our work.

Standards, by themselves, do not guarantee interoperability. Sometimes they do not provide the complete information necessary to enable the business process. Sometimes they allow options and frequently, they allow multiple interpretations of the information content. This means that the content of messages may be interpreted incorrectly by recipients and their business information systems. When such problems arise, costly and error-prone manual intervention is required. This intervention can lead directly to shipment delays and lost visibility.

To ensure that the necessary information is provided in messages, and to ensure that it is interpreted correctly by recipients, we propose an ontology of the trade lane and its business process. An ontology is a logical formalism based on a mathematical theory of sound inference. Its principal use is to restrict the interpretation of terms in some domain of discourse. We define, using formal means, the correspondence between terms used in the message structures and the terms used in the trade ontology. This approach has three primary advantages. First, it facilitates a common interpretation of message specifications – the current practice of “message implementation guidelines” does not facilitate this. Second, it enables harmonization of data interpretations across messages. This avoids the common, error-prone practice of rekeying of data. Third, it facilitates the development of validation and quality assurance technologies.

Disruption Recovery

Managing logistics-related disruptions is a long-standing issue in supply chain management. Disruptions are one of the major contributors to the large average and variance of transport times, resulting in higher transportation costs and lower profitability. Increased shipment visibility through better interoperability may help to substantially reduce the risk of disruptions. Elimination of those risks, however, is not possible, because of the unpredictable nature of the events that cause them. The solution lies in using methodologies and techniques that can (1) accurately predict potential disruptions based on available information, (2) quickly identify and locate the causes of a disruption, (3) analyze the impact on downstream partners and notify the relevant partners, and (4) form alternative plans for quick recovery. Figure 3 illustrates a framework for fast recovery from supply chain disruptions.

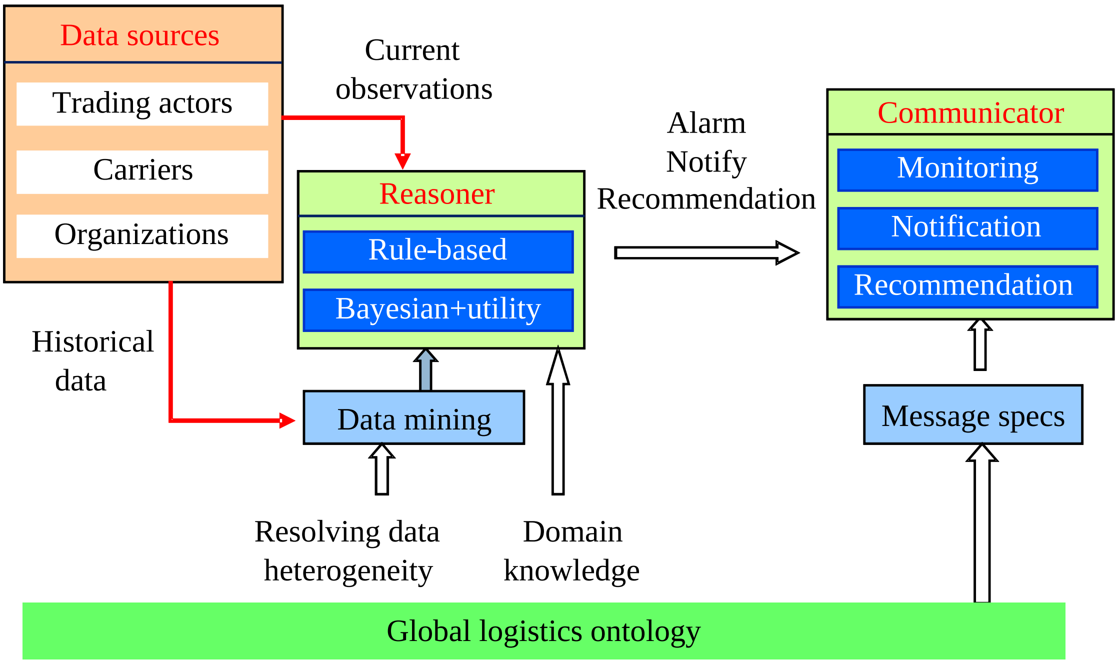

Figure 3: Framework for fast recovery from supply chain disruptions

Events that cause supply chain disruptions are, in general, unexpected. Their impacts on supply chain operations are frequently difficult to predict. As a result, these events can be best modeled as random variables and their impacts best modeled as posteriors in a Bayesian framework (Devinderjit Sivia, John Skilling, 2006). Several Bayesian models are investigated, including simple correlation, multivariate regression, and Bayesian networks (BN). Particular attention is given to BN because such networks support what-if analysis and it is easy to incorporate the utility theory for multi-criteria decision making. Both of these features are desirable for disruption impact analysis and recovery recommendations.

Clues regarding the complex relationships between disruptive events and their impacts on supply chain operations are buried in a huge volume of historical data. Such clues can be extracted using appropriate data mining and pattern recognition techniques. We will investigate neural networks, which are popular techniques discovering such relationships (Sarmiento, 2008). The knowledge obtained from these techniques will provide the basis for constructing the aforementioned Bayesian framework.

The ontology for disruption recovery specifies the semantics for the terminologies and the relations involved in disruption description, analysis, and notification. This ontology can be seen as an extension of or complement to the business process ontology of the trade lane. The ontology for disruption recovery provides the basis for semantic interoperability for message exchanges during the disruption recovery process. It also provides abstract domain-specific knowledge to guide the mining of data from multiple, heterogeneous data sources.

Finally, the communication protocols and messages will ensure that disruption information can be exchanged among the participating partners in a timely fashion and with a uniform understanding. Protocols and messages developed for normal supply chain operations are closely examined for maximum reuse.

Validation and Quality Assurance of Integration Technology

Most of the advanced validation and quality assurance technologies are being developed at research institutes. Typically, these technologies are prototypes with shortcomings that preclude their further exploitation in realistic systems integration situations. These shortcomings arise for many reasons. Two of the most important reasons are (1) some of the problem's key dimensions such as organizational complexity have been ignored (2) issues of legacy solutions have been simplified by assuming an ad-hoc interface technology, and (3) the scale of the real problem has been reduced to show the effectiveness of the prototype.

To assure that our integration technology addresses the "right" type of problem and that our prototype solutions are ready for further exploitation, we will build a validation test bed. The problems will use real messaging standards, real logistics usage scenarios, and real performance goals. The test bed will verify the technology prototypes with the selected messaging standards using the selected usage scenarios and against desired the performance goals. The testing processes will facilitate the introduction of new partners because it focuses on enhancing logistics systems integration and interoperable data exchange. Figure 4 illustrates a test procedure when new requirements are introduced to a global supply chain.

The verification approach will involve conformance testing of the technology implementations with respect to efficient data transmission, secure messaging transport, secure documents (including encryption and digital signatures), secure trading (including authentication of user roles), reliable delivery of messages, and non-repudiation. Conformance testing is designed to assess whether an implementation's behavior violates normative statements of the specification to which it was designed to conform. Determining whether a product faithfully implements a standard is essential to creating robust, interoperable solutions. Selection of the specific communication, business process, and business document standards follows from the usage scenario.

The validation approaches will assess the capability of the developed technology for effective interoperable data exchanges. Business requirements are gathered from the required behaviors of integrated logistics systems that manage international supply chains. Increasingly complex scenarios of international supply chain management will form the basis for iterative validation of the technology. The parameters that affect the complexity of the system include the number of goods and shipments within consignment, presence of consolidation/deconsolidation centers, inclusion of RFID data, and treatment of multiple modes of ground transportation. The assessments are performed using both a simulated environment and actual logistics management systems with their data feeds.

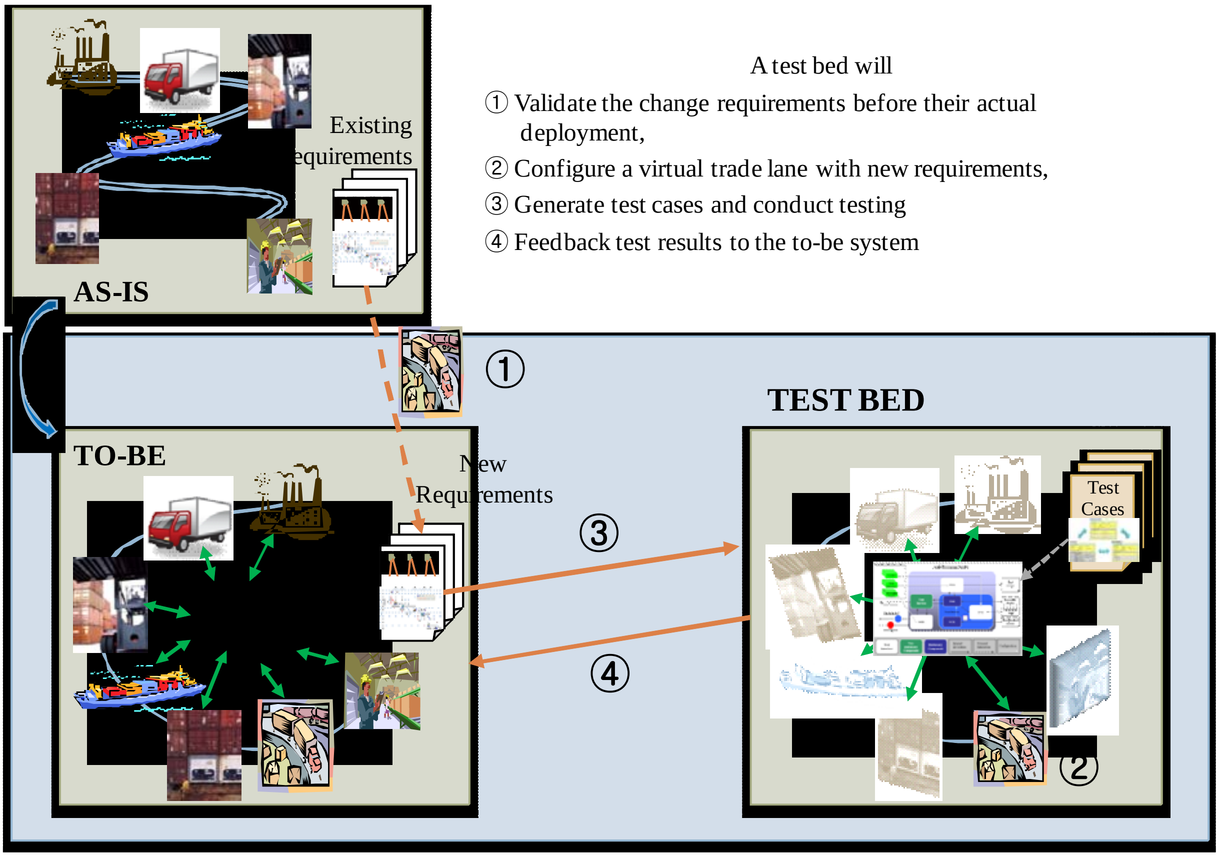

Figure 4: Testing procedure when new requirements are introduced

The fundamental basis for effective testing is the Event-centric Test Scripting and execution Model (eTSM) under development by the OASIS Testing and Monitoring Internet Exchanges (TaMIE) Technical Committee. The model is used for eBusiness/eGovernment test suites, with a particular focus on communication events, versatile usage for the quality assurance testing phase as well as the monitoring of deployed systems, and extensible design to leverage specialized validation processors as well as XML tools.

Conclusion and Further Studies

Development of the proposed integration technology will significantly impact the intercontinental logistics industry in terms of quantitative and qualitative measures. First, the proposed integration technology will dramatically increase shipment visibility between countries. Second, it will decrease both the average and variance of transport times dramatically. Third, it will reduce the cost of expedited and premium freight, and improve data quality and integrity.

The successful implementation of the proposed technology will have a great impact on several business areas. First, systems management services for intercontinental logistics can be extended to logistics business services to increase shipment visibility and reduce transport time and variance according to profit-making models. A few target industries may include the automotive and electronics industries. Second, consulting services for intercontinental logistics can be created to advise companies that have their own trade lanes and logistics systems. Third, a joint solution for intercontinental logistics can be developed with existing solution vendors. The developed technologies and their implementation can be embedded into existing ERP and supply chain solutions. The configurability of the development system makes it easy to develop a joint solution.

Acknowledgements

The authors wish to acknowledge the partial financial support of the NIST and TTA (Validation of UNeDocs data model).

References

Alan Rushton, John Oxley, Phil Croucher (2000). *The Handbook of Logistics and Distribution Management*, Institute of Logistics and Transport, Kogan Page Publishers, London.

Alan Rushton and Steve Walker (2007). International Logistics Supply Chain Outsourcing: From Local to Global, Chartered Institute of Logistics and Transport in the UK., Kogan Page Publishers, London.

Alfonso Sarmiento, Luis Rabelo, Reinaldo Moraga., Albert Jones, “A parameter estimation method to minimize instabilities in system dynamic models,” Proceedings of The 2008 International Conference of the System Dynamics Society, Athens, Greece, July, 2008.

Belay Seyoum (2000). Export-import Theory, Practices, and Procedures, Haworth Press.

Douglas Long (2003). International Logistics: Global Supply Chain Management, Springer.

Michael Comerford and Peter Denno (2007). “Dealing with data deficiency,” Actionline, pp. 18-22, January/February.

Frank Straube, Shihua Ma, Michael Bohn (2008). Internationalization of Logistics Systems, Springer.

Peter Klaus (2009). “Logistics research: a 50 years’ march of ideas,” Logistics Research, Published Online, January 14.

Jon S Helmick (2001). “Intermodal ports and liner shipping: A 21st century status report,” Logistics Spectrum, January-March.

Antje Hohlfeld (2008). The Internationalization of EDI in the Automotive Industry, VDM Verlag.

Devinderjit Sivia, John Skilling (2006). Data Analysis: A Bayesian Tutorial, Oxford University Press.