5-2014

Proactive model to determine information technologies supporting expansion of air cargo network

Grayson C. McClain

University of Tennessee - Knoxville, gmcclain@utk.edu

To the Graduate Council:

I am submitting herewith a dissertation written by Grayson C. McClain entitled "Proactive model to determine information technologies supporting expansion of air cargo network." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Industrial Engineering.

Rapinder Sawhney, Major Professor

We have read this dissertation and recommend its acceptance:

Xueping Li, Joseph Wilck IV, Bogdan Bichescu

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Proactive model
to determine information technologies
supporting expansion of air cargo network

A Dissertation Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Grayson C. McClain
May 2014

ABSTRACT

Shippers and recipients expect transportation companies to provide more than just the movement of a package between points; certain information must be available to them as well, to enable forecasts and plans within the supply chain.

The transportation companies also need the information flow that undergirds a transportation grid, to support ad-hoc routing and strategic structural re-alignment of business processes.

This research delineates the information needs for an expanding air cargo network, then develops a new model of the information technologies needed to support expansion into a new country. The captured information will be used by shippers, recipients, and the transportation provider to better guide business decisions. This model will provide a method for transportation companies to balance the tradeoffs between the operating efficiencies, capital expenditures, and customer expectations of their IT systems. The output of the model is a list of technologies – optimized by cost – which meet the specific needs of internal and external customers when expanding air cargo networks into a new country.

Table of Contents

Chapter I Introduction and Problem Statement ... 1
1.1. Introduction of problem ... 1
1.2. Multiple perspectives ... 2
1.2.1. Customers' needs ... 2
1.2.2. Transportation Provider's needs ... 3
1.3. Guiding Hypothesis ... 4
1.4. Sources of Data ... 4
1.5. Data Availability ... 6
1.6. Sensitivity of Solution ... 6
1.7. Structure of paper ... 6
Chapter II Literature Review ... 7
2.1. Importance of information flow ... 7
2.1.1 Calculating the benefits of information flow ... 9
2.1.2 Counter-arguments to the benefits of Transportation data collection ... 10
2.1.3 Electronic Data Interchange ... 10
2.2. Transportation models and optimization ... 11
2.2.1 Geographic Information Systems ... 11
2.2.2 Transportation flows, routings, and demands ... 14
2.2.3 Airline scheduling ... 15
2.2.4 Cross-functional models of Logistics Networks ... 15
2.3. Optimization of physical flows within Air Cargo processes ... 16
2.3.1 General air cargo optimization ... 16
2.3.2 Optimal scheduling of air cargo networks ... 16
2.3.3 Air freight containers ... 18
2.3.4 Other air cargo concerns ... 18
2.4. Decision support ... 18
2.4.1 Design of Decision Support systems ... 20
2.4.2 Decision Support models for specific Logistics challenges ... 21
2.4.3 Decision Support models for investment selection ... 22
2.4.4 Data necessary for enabling Decisions ... 22
2.5. Technology selection ... 23

2.5.1 Mathematical models of technology selection 23
2.5.2 Decision drivers and success criteria for technology selection 25
2.6. Importance and role of IT and new technology 26
2.6.1 Current state of Logistics IT 27
2.6.2 Roles of Logistics IT organizations...28
2.7. RFID insights..28
2.8. Use of Fixed Charge Integer Models 30
2.9. Summary of Literature Review...31
2.10. Literature Search and central hypothesis...31
Chapter III Problem Formulation and Model..32
3.1. Introduction to the Modular Technology Model 32
3.2. Interviews for operational and customer requirements..32
3.2.1 Selection of interviewees...32
3.2.2 Content and purpose of interviews 33
3.2.3 Breadth of interviews...33
3.2.4 Compilation of findings...34
3.3. Catalog of informational needs 35
3.3.1 Customer Expectations 35
3.3.2 Operational Requirements 35
3.3.3 Full Range of Information needs for network management 35
3.4. Structured categorization of information needs..37
3.5. Isolating data fields which must be locally gathered..39
3.5.1 Lifecycle view of the ten key information fields..39
3.6. Feasible Technology Options 41
3.7 Evaluation criteria for technology options...43
3.7.1 Monetization of Technology evaluation criteria...43
3.8. Establishing the mathematical framework for optimization..44
3.8.1 Advantages of Fixed Charge Integer Program 44
3.8.2 Published uses of the Fixed Charge Integer Program 44
3.8.3 Structure of Fixed Charge Integer Program..44
3.9 Model fulfillment of guiding hypothesis 46
Chapter IV Case Study 48
4.1. Assumptions for populating Modular Technology Model 48

4.2. Full Model with numerical values 51
4.2.1 Development of costs and expenses 51
4.2.2 Calculation of Net Present Value 53
4.2.3 Full mathematical model 54
4.2.4 Implementation in Gurobi 55
4.3. Fulfillment of guiding hypothesis in Case Study 56
4.4. Results of Modular Technology Model in Case Study 56
4.4.1 Industry standards for technology 56
4.4.2 Results from optimizing Modular Technology Model 56
4.5. Sensitivity Analysis of proposed model 57
4.5.1 Sensitivity to shipping volume 57
4.5.2 Sensitivity to Wage Rates 58
4.5.3 Sensitivity to Interest Rates 58
4.5.4 Sensitivity to Time Horizon 58
4.5.4 Summary of sensitivity analysis 59
Chapter V Analysis and Implications of Results 61
5.1. Beyond sensitivity analysis – the impact of Uncertainty 61
5.1.1 Pre-existing technology 61
5.1.2 Volume Forecasts 61
5.1.2.3 Method for analyzing unbalanced volumes 62
5.1.2.4 Results of analyzing for unbalanced volumes 64
5.1.3 Pace of Growth 64
5.2. Results of competing models 65
5.2.1 Comparison to Kengpol and O'Brien (2001) 65
5.2.2 Comparison to Yap and Souder (1993) 65
5.2.3 Summary of comparisons 67
5.3. Success toward guiding hypothesis 67
Chapter VI Conclusions 68
6.1. Contributions to the State of the Art 68
6.2. Audiences for the Modular Technology Model 68
6.3. General conclusions 69
List of References 70
Vita 78

LIST OF TABLES

Table 1 Importance of information flow 8
Table 2 Transportation models and optimization 12
Table 3 Optimization of physical flows within Air Cargo processes 17
Table 4 Decision support 19
Table 5 Technology selection 24
Table 6 Importance and role of IT and new technology 26
Table 7 RFID insights 29
Table 8 Use of Fixed Charge Integer Models 30
Table 9 Full range of data fields, categorized 38
Table 10 Categorization of data fields 40
Table 11 Information inputs to the derived data fields 41
Table 12 Mapping information needs to feasible technologies 42
Table 13 Assumptions: operational parameters for air cargo carrier 49
Table 14: Assumptions: cost parameters of technology options 50
Table 15 Calculated capital costs for each technology option 52
Table 16 Calculated expense costs for each technology option 52
Table 17 Calculated present values for each technology option 53
Table 18 Indexing nomenclature for mathematical model 54
Table 19 Industry standard technologies 57
Table 20 Results from optimizing Modular Technology Model 57
Table 21 Operating parameters in sensitivity analysis 58
Table 22 Total technology costs at differing volumes 59
Table 23 Total technology costs at differing wage rates 59
Table 24 Total technology costs at differing interest rates 59
Table 25 Total technology costs for varying time horizons 59
Table 26 Indexing nomenclature for model with unbalanced volumes 63
Table 27 Results of optimizing Modular Technology Model, excluding low-volume Lean methods 66
Table 28 Results of Kengpol and O'Brien model 66
Table 29 Results of Yap and Souder model 66

LIST OF FIGURES

Figure 1 Path to Modular Technology Model 32
Figure 2 Customer and operational process map 35
Figure 3 Lifecycle view of ten key information fields 39
Figure 4 Non-linear effects of sensitivity parameters 60

Chapter I
Introduction and Problem Statement

1.1. Introduction of problem

Electronic data forms the underpinning of any large transportation company. For this research, the electronic information will encompass any data field stored for a shipment or for an asset. This paper will first explore the minimum data fields that are required, either by customers or by the transportation provider. The research then explores the definite ways by which each of these minimum data fields must be obtained, to accommodate by the ever-transient nature of the transportation industry. Then, a data model is developed which establishes a standardized method of evaluating technologies for network expansion into another country.

Air cargo transportation systems rely upon daily transactional data for continuity of operations and customer communications. Operational groups, quality departments, and customer advocates continually request "More data!" from the infrastructure planning teams. Shippers and recipients expect transportation companies to provide more than just the movement of a package between points; they also expect certain information to be available to them in order to forecast and plan their supply chain activities. The transportation companies need the undergirding information to support ad-hoc routing and strategic structural re-alignment of business processes.

This problem statement draws its relevance not only from the critical importance of information for operational and customer experience reasons, but also because of the potential for wasteful spending that may result from poorly selected information technology (IT) infrastructure.

The larger air cargo providers have a significant presence in the established markets and industrial nations. Therefore, any expansion of an air cargo grid is likely into a low-cost developing country. These network expansions are highly cost sensitive. The IT infrastructure decisions must be carefully balanced to provide just the right amount of information without layering additional complexities. Excessively complex information gathering systems result in upfront costs that become a steep hurdle for a new operation to clear as they climb to profitability in their first years.

Data storage is cheaper today than ever before; however, there remains a penalty for surplus quantities of data. Specifically, the penalty is the financial cost of the *ongoing collection* of data. This struggle requires an objective method of comparing the data collection options. This struggle also occurs within the context of Lean solutions that can bypass traditional data entry methods and may be able to stand on their own economically.

A third aspect of wasteful spending is not only the upfront technology purchase or the data storage costs, but also the burdensome requirements to feed data into the information system. Systems that continually require manual data entry may please some customers with the infinite variety of free-form text that can be passed along. Those systems, however, will also raise labor costs by doing so. Network expansion models must consider low-tech options for capturing sufficient information, in order to manage that balancing point.

The data model takes these minimum assumptions of required fields and proposes a manner of optimizing the cost and efficiency of providing them. The optimization methods utilize both the latest technology as well as techniques employed by process-improvement practitioners in the more traditional areas of manufacturing and production.

As the data model is established, it will first explore the minimum data fields that are required, either by customers or by the transportation provider. Each of these minimum data fields must be obtained concretely, yet accommodate the ever-transient nature of the transportation industry. These two competing ideas drive two of the criteria: the four year time horizon and the penalties for poor accuracy, which will be discussed further below.

1.2. Multiple perspectives

The information collected by an air cargo expansion serves needs that are both external and internal. The external customers' needs are crucial for building loyal customer base, and for cementing the customer experience. The internal transportation provider's needs are crucial for effective and efficient management of the operation. Both will be discussed in the following sections.

1.2.1. Customers' needs

Some information is required to satisfy an external customer's data expectations. A transportation company interacts with different types of customers at each point in the shipment's life cycle:

(a) A *shipper* will supply the transportation company with an expected pickup date and time window. The transportation company should have the ability to store and recall this information for recurring pickups, or react uniquely for ad-hoc pickup requests. Small quantities of small or medium-sized packages may be left at a drop-off point within a drop-box or retail location. The transportation provider should then follow up with timely confirmation of possession to the shipper.

Two important pieces of information should go to shippers early in the process: drop point restrictions and packaging restrictions. These are not customized to the shipment, and may be published in a generalized form for all shippers.

(b) A *Recipient* or *Consignee* expects to be informed of the guaranteed delivery window, the probable delivery window if different, and any deviation from that plan. If working with freight forwarders or limited transportation companies without door-to-door handling, the recipient must know in advance how to retrieve shipments that will be held at the destination depot. Recipients must also be advised of cash they must produce upon the delivery of COD (cash on delivery) shipments.

(c) The *Importer of Record* will be closely monitoring all trans-border shipments regardless of whether they actually receive the shipment at their location. Therefore, data must be provided which informs them of any needed Clearance paperwork such as a more robust item description, a commodity code, or an updated power of attorney. Importers of Record should be made aware of any Clearance delays and their causes to facilitate feedback to the shippers who first completed the clearance documentation. Importers of record will require knowledge of duties and taxes that are incurred during the clearance process, because many brokers will not incur the financial risk of releasing shipments without payment in full. The selection of a broker and brokerage requirements vary by country and shipment value, and may be summarized in a manageable table.

(d) The *Payor* needs less operational data and more financial data in order to successfully manage his role in the supply chain. This will involve the original quote. This will also involve the invoicing of the required Payment and how any ancillary fees impacted the original quote. Payors need verification of successful completion of contract – that the shipment was on time with no damage. If that was not the case, then Payors should have access to any data needed for submitting a reimbursement claim, such as a package's unique ID number within the shipment and proof of its lateness and damage. These will be referred to as the *quality status* of each shipment.

1.2.2. Transportation Provider's needs

Transportation providers must execute their tasks with efficiency. Many aspects of the business lend themselves to rigorous optimization routines, if only the correct data remains available.

(a) A large scale transportation network does not plan based on individual shipments, but upon the number of vessels and the size of vessels transiting between origin and destination. These vessels can be optimized with appropriate understanding of several data points. For example, knowledge of the number of shipments must be supplemented with an understanding of the number of packages within those shipments. Each package must be described by its dimensions and its weight – factors that can be initially estimated by the shipper but should be verified within the transportation provider's system, or else compensated for with knowledge of the error rates in customer-supplied information. The dimensions are then fed into the load organization optimization systems as well as the billing adjustment system. Load planners must also have access to the handling restrictions of a shipment which might require it to be on the top of a stack, segregated with hazardous goods, given airflow for live animals, refrigerated for pharmaceuticals, etc.

(b) After the number and size of vessels has been determined, a transportation provider must select the most expensive portion of service: long distance linehaul route planning. If the vessels will be trucks, the routing follows directly from vessel sizing. However, if the vessels are unitized containers, then linehaul route planning requires a preliminary knowledge of aircraft gauging options, train length options, or ocean-vessel sizing. Then the plan is refined with visibility into the cutoff times for different hubs and sort points. Finally, the plan is optimized to maximize profitable backhauls on all lanes.

The best linehaul plan is only followed for a few hours. A transportation company must have the requisite data to facilitate ad-hoc re-routing. These data pieces are often at a macro level and not shipment level, therefore this model will allow for aggregation and scaling accordingly. This includes items such as the status of each sort location; the real-time location of ships, aircraft, and vehicles; the traffic patterns and road closures that affect trucking; the air traffic control abnormalities that restrict entry to certain airports; the weather; and any unforeseen security concerns.

(c) A second contributor to the expense structure of a transportation provider is the Labor that must sort and handle each shipment. Labor demand planning can be minimized with a flexible and cross-trained work force. Alternatively, the risk can be deferred by adopting a contractor model for certain aspects of the handling. But ultimately, the best cost structure will result from having a real-time predictor of which tasks will receive which package volumes on a given night.

(d) Delivery route planning takes over following the linehaul route planning. These routes are more local in scope, and focus more on the optimization of driving paths rather than the optimized placement of certain vessels into certain lanes. The delivery route planning requires input of the recipient's address as well as the number of packages and their dimensions. However, it also requires visibility to any special handling restrictions that might dictate a choice of courier's equipment, such as ventilation for dangerous goods or a forklift for heavyweight shipments. Lastly, the delivery route planning needs an updated source of the city's street addresses to serve as a source for error-correction as well as for route optimization.

(e) All transportation providers keep a stock of low-capital equipment, whose placement must be managed. These are not normally tracked at the shipment level, yet are critical for effective package movement. They are included in this analysis as a resultant cost that is driven by each shipment. The low-capital equipment to be tracked includes dunnage, air cargo containers, sea cargo containers, cargo nets, and reusable totes. For this model, such equipment is assumed to be owned or leased; therefore the calculation of rental quantities is not included.

(f) Each transportation provider seeks to improve quality performance in order to retain customers. Quality status can only be managed if it is measured. Data fields must therefore be assigned to each shipment to capture the criteria that are important for customers. Customers will be concerned about packages which are picked up late or delivered late. Customers will also be frustrated by damage and loss. Other quality hallmarks include pricing errors or the communication that surrounds clearance delays. In order to facilitate root cause analysis, the quality status of a package may be recorded at multiple points in the package lifecycle.

1.3. Guiding Hypothesis

The guiding hypothesis of this paper is that the information technology (IT) decisions supporting expansion of an air cargo network can be effectively modeled to reduce costs. Furthermore:

1. The model can be general enough to include upfront and ongoing costs
2. The model can be general enough to include high-technology and low-technology solutions
3. The IT expansion model can then be optimized based upon cost while meeting a minimum established customer expectation

This hypothesis forms the boundaries of this paper, as the problem and solution are shown to be cost effective, robust against information needs, and easy to model. The above hypothesis and its components will be illustrated through Chapters III, IV, and V of this paper.

1.4. Sources of Data

A data model cannot recommend new data fields without first understanding the costs associated with acquiring that information. A transportation provider has several options to collect the types of data mentioned above.

(a) Employee-applied barcode scans remain the industry standard for data acquisition. Employees must visually observe a package's status, then select a code which describes that status, then locate the package's barcode and perform the scan, linking the observed characteristic with the package's unique identifier. This process adds considerable labor costs into the transportation company. It also restricts knowledge to an attribute-type variable rather than continuous feed of location and status.

(b) RFID tags are increasingly affordable for industry, as the technology has neared a state of maturity. Transportation providers such as Air France Cargo use RFID tags in company-owned equipment to track when a unitized container or a yard truck has passed a checkpoint. As prices fall, some industry professionals hypothesize that the industry will begin to see RFID tags in each package. Due to the requirement for RFID readers, this data will also be subject to the same attribute-type limitations as employee scans and will not give continuous feed of worldwide positioning.

RFID will be discussed in both Active and Passive applications. Active RFID broadcasts information for a short range, requiring fewer readers to gather information. Passive RFID must be singled out and read at close range to capture the imbedded information.

(c) Visual management is an alternative that will have little ongoing cost. This may take the form of painted zones on min/max inventory control systems. It may also be a transparent layout that shows the status of packages within a sortation area. The technique may also leverage status lights and scorecards, commonly known as Andon systems. In this research, visual management will be analyzed alongside Kanban systems.

(d) Kanban systems will not be card-based within a high volume transportation environment. Instead, these operations may employ Kanban as part of a two-bin arrangement to feed information regarding the shipments. Bins may take the form of unitized containers, and the exchange of cards will take the form of an exchange of dispatch records for pickup records, an exchange of packages for clearance paperwork, or an exchange of empty cargo containers for full containers.

(e) Customer-reported shipment data will be manually input by the customer. Small shippers may type the needed information directly into the transportation provider's web portal. Medium shippers are more likely to upload shipment parameters from their order-fulfillment software into a semi-automated system that will generate bar codes and labels as well as dispatch a courier to pick up the shipment. Large shippers will be further automated and patch their shipment requests directly into the transportation provider's mainframe.

(f) For this research focusing on expansion into low-cost countries, some manual input may require a phone call to centralized customer service agents. This is an extension of the manually input data described above, but allows for increased questioning and clarification from the customer service agent, hopefully resulting in increased customer confidence and reduced error rate.

(g) Automatic in-line dimensioning devices will verify and correct the key parameters that shippers originally submitted on the waybill. These require access to the package's bar code which often implies a manual labor step of positioning all packages with the label facing upward, though some newer tunnel scanners can avoid the added labor. Newer equipment can also ascertain the package weight along with the physical dimensions.

(h) Manual scales and hand-held dimensional scanners may be an affordable way for on-road couriers to ascertain package sizing. These have the disadvantage of not being integrated with the courier's hand-held scanner. All data must therefore be entered in free-form text by the courier. These also require

1.5. Data Availability

Each of the recommendations for data flow has certain minimum expectations for availability. Hand-held scanners may not communicate wirelessly with the transportation company's mainframes, particularly when used on-road. Status updates will therefore be limited to end-of-shift docking of the scanners. Even scanners that do have a continuous communication path will be limited by the refresh rates and latency of post times that occur in any real life system. The selection of this equipment must be balanced against the query capabilities for customer service, for package tracking, and the complications from interfaces of multiple systems.

1.6. Sensitivity of Solution

The ensuing model will be tested for its sensitivity to significant fluctuations in shipping volume (from 50% to 300% variation), to varying wage rates (from 50% to 500%), to varying interest rates (from 50% to 400%), and to time horizon (50% to 250%).

1.7. Structure of paper

In order to best lay out the model for meeting technologies needs while expanding an air cargo network into another country, this paper begins with an overview of the problem statement, to explain the information needs to satisfy all stakeholder requirements for expansion of an air cargo network. The second chapter explores the relevant literature that has touched upon capacity expansion, air cargo networks, or other examples of decision models. The paper then proposes the model which will represent the needs (information fields) and the sources (technology options). The fourth chapter shares results from a case study, optimizing the case study model and its sensitivity to varying parameters. Conclusions are then drawn to bring perspective to the contributions of this research relative to the air cargo and information technology industries.

Chapter II
Literature Review

This literature search seeks to identify the papers which have explored electronic data models for transportation networks. The effort to model the electronic underpinnings of a transportation network has not yet been explored thoroughly, yet there are publications in adjacent areas of study which approach similar problems with a variety of methods and perspectives.

This literature review explores those adjacent areas of study in order to better understand the published use of electronic data models, or transportation networks, or fixed charge integer problems, or capacity expansion problems, etc. Each of these adjacent areas has the potential to offer insight to the specific area of research for the present paper.

This literature review summarizes the current state of the research, including authors' methods and conclusions. For each paper, the distinctions between the published work and this paper's problem statement will be highlighted.

2.1. Importance of information flow

Much of the research on information flow within a supply chain models the tiers of customers, warehouses, and suppliers, and then derives insights from the inter-relationships among them. Though no research has been found that touches upon the flow of information within a single-entity supply chain or transportation provider, many of the principles remain the same. For example, the receiving station in a transportation company can better arrange its shift schedule if given greater visibility into the volume and type of freight that is inbound to it from around the world. These papers, then, give insight into the importance of that type of operational information.

Drucker (1995) describes the importance of tracking data on all phases of the value chain. It is only through this full understanding of what happens to a service (transporting a package, for example) that executives are able to understand their costing position and their pricing position. Lee et al. (1997) describe the information transfers that occur within a supply chain in light of how the transfers drive undesirable effects between the suppliers and receivers. Their research reveals mechanisms by which the information transferred in the form of "orders" tends to be distorted due to the variance of orders being larger than that of sales. This is a customer-centric model of supply chain performance that allows modeling of an ideal customer experience. The research was continued a few years later with a publication by Lee and Whang (2000) discussing the types of information shared within a supply chain: inventory, sales, demand forecast, order status, and production schedule. The paper proposes three alternative system models of information sharing: the information transfer model, the third party model and the information hub model. With these models, the paper explores methods of optimizing communication between suppliers and customers. A comparison of full information transfer versus a partial information transfer is enabled through a two-echelon model developed by Gavirneni et al. (1996). This model studies the relationships between capacity, inventory, and information flow to determine the optimum levels of information flow for supply chain management.

Table 1 Importance of information flow

Chapter and Section	Author	Publish date	Title	Section summary
2.1	Drucker, P.F.	1995	*The information executives truly need*	Establish the importance of information flow for transportation providers, both for internal efficiencies and as a key enabler of decision making within the entire supply chain
	Lee, H.L., Padmanabhan, V., and Whang, S.	1997	*Information distortion in a supply chain: the bullwhip effect*	
	Lee, Hau L., Whang, Seungjin	2000	*Information sharing in a supply chain*	
	Gavirneni, Srinagesh; Kapuscinski, Roman; and Tayur Sridhar	1996	*Value of Information in Capacitated Supply Chains*	
	Lai, Kee-Hung; Ngai E.W.T.; Cheng, T.C.E.	2005	*Information Technology Adoption in Hong Kong's Logistics Industry*	
2.1.1	Cachon, Gerard and Fisher, Marshall	2000	*Supply Chain Inventory Management and the Value of Shared Information*	Calculate benefits of information flow, namely the measureable benefits of lead-time reduction
	Lee, Hau; So, Kut; and Tang, Christopher	2000	*The Value of Information Sharing in a Two-Level Supply Chain*	
	Zhang, Cheng; Tan, Gek-Woo; Robb, David J.; Zheng, Xin	2006	*Sharing shipment quantity information in the supply chain*	
	Liu, Minhui; Srinivasan, Mandyam; Vepkhvadze, Nana	2009	*What is the value of real-time shipment tracking information?*	
2.1.2	Anderson, Eugene; Fornell, Claes; Lehmann, Donald	1994	*Customer Satisfaction, Market Share, and Profitability: Findings from Sweden*	Provide counter-arguments to the benefits of transportation data collection, showing hidden benefits in imperfect information flow
	Anderson, Eugene	1997	*Customer Satisfaction, Productivity, and Profitability; Differences between Goods and Services*	
	Iyer, Ganesh; Narasimhan, Chakravarthi; Niraj, Rakesh	2007	*Information and Inventory in Distribution Channels*	

Table 1 Importance of information flow (continued)

Chapter and Section	Author	Publish date	Title	Section summary
2.1.3	Johnston, Robert, and Mak, Horiace Cheok	2000	*An emerging vision of internet-enabled supply-chain electronic commerce*	Explore the Electronic Data Interchange, one of the earliest attempts at providing visibility into transportation network status
	Grieger, Martin	2003	*Electronic marketplaces: A literature review and a call for supply chain management research*	
	Webster, Juliet	1995	*Networks of collaboration or conflict? Electronic data interchange and power in the supply chain*	
	Evans, G.N.; Naim, M.M.; Towill, D.R.	1993	*Dynamic Supply Chain Performance: Assessing the Impact of Information Systems*	
	Neo, B.S.	1994	*Managing New Information Technologies: Lessons from Singapore's Experience with EDI*	

The key importance of information flow to global logistics providers is summed up, “Because they play the linking role among various parties such as manufacturers, retailers, transportation carriers, and final customers in the logistics networks, LSPs (Logistics Service Providers) need to be able to manage information effectively to integrate various logistics activities, including inbound and outbound transportation, distribution, warehousing, and fleet management, in order to streamline the physical product flows of their customer firms” according to Lai et al. (2005). This paper stems from 195 surveys of logistics firms within Hong Kong to determine the level of IT adoption among that community. The key benefits they uncovered were internal - improved service levels and efficiency - rather than the external benefit to customers of increased visibility into inventory levels. The hurdles that were uncovered by the questionnaires pointed to difficulties justifying the upfront investment, as well as the pitfalls of non-standard technology requiring specialized resources to maintain.

2.1.1 Calculating the benefits of information flow

A model of data flow is developed by Cachon and Fisher (2000), who investigate the importance of data flow within a supply chain by modeling the system as a single supplier with multiple identical retailers. By assigning costs to each facet of the process, the authors are able to determine the total savings resulting from information sharing versus the traditional method of sharing only the periodic orders. In the end, this cost savings is compared to the savings that would result from Lean improvements such as reduced cycle time and smoother physical flow of goods; the final conclusion is that the Lean improvements drive more cost savings than the information savings. Lee et al. (2000) likewise share analytical methods to quantify the value of shared information within a supply chain. They are able to empirically document a reduction in the inventory as well as reduction in the total logistical cost. These papers point to the importance of tracking and shipment-level awareness by both the shipper and recipient, but the calculation model also points to the measureable benefits resulting from lead time reduction – a factor which comes in to play significantly when considering the added cost of air freight.

Zhang et al. (2006) explore the value of advance shipment notice by a transportation provider. The authors provide a means to quantify the value of shared shipment information and help supply-chain members evaluate the cost-benefit trade-off of the various options for information system design. Liu et al. (2009) explore the impact of real-time shipment tracking information. This paper employs a stochastic model to place a value upon the real-time availability of information and concludes that each lag in information flow drives a measurable cost to the recipient for having to maintain inventory in system. It is noteworthy that this conclusion applies to recipients such as manufacturers or retailers who are making inventory and scheduling decisions based upon receipt. Therefore, a measureable value for real-time tracking information is not yet proved for non-business recipients.

2.1.2 Counter-arguments to the benefits of Transportation data collection

The two benefits often heralded from a logistics data system are customer satisfaction and productivity. Anderson et al. (1994) provides a theoretical framework for customer satisfaction in light of productivity improvements. The authors determine that customer satisfaction varies with actual quality, perceived quality, and the customer's own expectations – all of which will have some impact upon market share.

Anderson (1997) returns to the same topic a few years later and illustrates how the two benefits – customer satisfaction and productivity – may not go hand in hand. To illustrate this, Anderson develops a model of standardization and customization to describe the tradeoffs, as well as a cost model that derives from those tradeoffs. In particular, these tradeoffs are more likely to occur with services (such as air cargo transportation) than with manufactured goods. It is hypothesized that this results from the number of personal contacts that are made with the performance of a service; contacts that are difficult to replicate with productivity improvements. The author concludes by demonstrating lower returns on investment for productivity improvements in industries which provide only services.

A very different approach is seen as Iyer et al. (2007) explore the possibility that cargo recipients may actually benefit from imperfect information flow about the state of their supply chain. The authors posit that asymmetrical information will lead to signaling (or screening) incentives which will boost the recipients pricing and sales position, therefore bringing an advantage over competitors who lack information flow.

2.1.3 Electronic Data Interchange

The literature search revealed a significant body of work in the area of Electronic Data Interchange where business partners share data. This exchange is one of the earliest attempts to satisfy what the above research was encouraging regarding information sharing within a logistics chain.

Johnston and Mak (2000) discuss retailers that have set up Electronic Data Interchanges with their supplier base. They propose internet-based solutions to allow 100% participation from even the least sophisticated trading partners. This solution lacks the breadth to encompass all aspects of the transportation provider's operations, but provides an interesting method for gaining transparency and feedback. Grieger (2003) is a critical review of the existing literature regarding Electronic Data Interchanges and concludes with a call for more supply chain management research within this field. Webster (1995) is concerned with the way in which the design and use of inter-organizational information systems reflect the strategic interests of powerful corporate players and the struggles of those players for domination in the marketplace. Evans et al. (1993) outline cost benefits for information system implementation using electronic data interchange as the enabling tool. The paper highlights global integrated logistics information systems and describes their role in overall supply chain system optimization, concluding with a thorough case for the impact of such systems.

Neo (1994) focuses upon the Singapore government decision to adopt EDI during the 1980s. The lessons learned from that decision are crucial to implementing any logistics information system: the system must have common standards and information sharing across the global network; the system must be implemented with full partnership of the business and IT communities; and the new system must be a clear solution to a meaningful problem.

2.2. Transportation models and optimization

The value of studying this optimization of physical flow lies in the manner in which the routing optimization problem is solved: it typically requires up-to-date position data for vehicles and their origins/destinations. This same position data may prove useful in the modeling of a transportation provider's IT network due to the ability to pinpoint a package's location and therefore its estimated time of arrival. In addition, the optimization methods (operations research, Markov chains, etc.) for physical flow may also prove useful for the optimization of information flow.

2.2.1 Geographic Information Systems

Though Limão and Venables (2001) use different data sets to investigate the dependence of transport costs on geography and infrastructure, much of the basis for optimization of the physical flows in transportation systems are based around the information found in Geographic Information Sytems (GIS). Southworth and Peters (2000) develop a model for the actual flow of information within a transportation grid. The authors describe the development of a single, integrated of a multimodal and transcontinental freight transportation network. This paper focuses upon the optimization of route selection that can be accomplished with robust GIS technology.

Dueker and Butler (2000) develop a framework and principles for sharing transportation data, based on an enterprise geographic information systems-transportation (GIS-T) data model that defines relations among transportation data elements. This framework highlights the sharing of real-time positioning rather than the factors highlighted in the proposed model. Sutton (1997) analyzes the issues hampering Transportation industry adoption of GIS and reviews the potential for overcoming these constraints with current GIS technology, but stops short of advancing a model for transportation data flow optimization.

Sutton and Wyman (2000) describe a model to synchronize the management and query of temporal and spatially referenced transportation data in geographic information systems (GIS). This synchronization may provide certain hardware constraints that should be modeled within the electronic data model that this dissertation will pursue. Southworth and Peterson (2000) seek a method for computationally routing all US commodity freight through GIS systems and conclude that, though GIS data is invaluable, the most efficient calculations will be conducted externally. The digital network model is based upon zip code identifiers as a primary data field.

Table 2 Transportation models and optimization

Chapter and Section	Author	Publish date	Title	Section summary
2.2.1	Limão, Nuno, and Venables, Anthony J.	2001	*Infrastructure, Geographical Disadvantage, Transport Costs, and Trade*	Explore the Geographic Information Systems, their effect upon transportation models, and how GIS leads to network optimization
	Southworth, Frank; Peters, Bruce E.	2000	*Intermodal and international freight network modeling*	
	Dueker, Kenneth J., Butler, J. Allison	2000	*A geographic information system framework for transportation data sharing*	
	Sutton, John C.	1997	Data *attribution and network representation issues in GIS and transportation*	
	Sutton, John C., Wyman, Max M.	2000	*Dynamic location: an iconic model to synchronize temporal and spatial transportation data*	
	Southworth, F. and Peterson, B.E.	2000	*Intermodal and international freight network modelling*	
2.2.2	Chan, K.Y., Dillon, T., Chang E., Singh J.	2013	*Prediction of Short-term traffic variables using intelligent swarm-based neural networks*	Provide variety of options for optimizing transportation flows, routings, and demands
	Winston, Clifford	1982	*The demand for freight transportation: models and applications*	
	Baumol, W. J. and Vinod, H. D.	1970	*An Inventory Theoretic Model of Freight Transport Demand*	
	Abdelwahab, Walid and Sargious, Michel	1992	*Modelling the Demand for Freight Transport: A New Approach* Ahmed	
	Wu, Yue	2006	*Global Logistics Road Planning: A Genetic Algorithm Approach*	
	Wu, Yue	2010	*A time staged linear programming model for production loading problems with import quota limit in a global supply chain*	
	Goetschalckx, M., Vidal, C. J., & Dogan, K.	2002	*Modelling and design of global logistics systems: A review of integrated strategic and tactical models and design algorithms*	
	Dougherty, M.	1995	*A review of Neural Networks applied to Transport*	
	Rickman, T D, Hallenbeck, M E, Schroeder, M.	1990	*Improved method for collecting travel time information*	
	Goh, M., Lim, J. Y. S., & Meng, F.	2007	*A stochastic model for risk management in global supply chain networks*	

Table 2 Transportation models and optimization (continued)

Chapter and Section	Author	Publish date	Title	Section summary
2.2.3	Antesa, J.; Campena, L.; Derigsa, U.; Titzeb, C.; and Wolleb, G.D.	1998	*Synopse: A model-based decision support system for the evaluation of flight schedules for cargo airlines*	Explore similar models as section 2.2.2, but with specific parameters to accommodate airline scheduling requirements
	Kubya, Michael J. and Grayb, Robert Gordon	1993	*The hub network design problem with stopovers and feeders: The case of Federal Express*	
	Cheung, Raymond; Shi, Ning; Powell, Warren; Simao, Hugo	2008	*An attribute–decision model for cross-border drayage problem*	
	Leung, Stephen; Wu, Yue; Lai, K.K.	2006	*Cross-border logistics with fleet management: A goal programming approach*	
	Root, Sarah and Cohn, Amy	2008	*A Novel Modeling Approach for Express Package Carrier Planning*	
2.2.4	Crainic, T.G., Laporte, G.	1997	*Planning models for freight transportation*	Blend structural and scheduling challenges into cross-functional models of logistics networks
	Crainic, Teodor Gabriel	2000	*Service network design in freight transportation*	
	Wu, Yue	2011	*Linear robust models for international logistics and inventory problems under uncertainty*	
	Easwaran, Gopalakrishnan and Üster, Halit	2010	*A closed-loop supply chain network design problem with integrated forward and reverse channel decisions*	
	Leung, Stephen; Tsang, Sally; Ng W.L.; Wu, Yue	2007	*A robust optimization model for multi-site production planning problem in an uncertain environment*	
	Wu, Yue	2012	*A dual-response strategy for global logistics under uncertainty: A case study of a third-party logistics company*	
	Vidal, C. J., & Goetschalckx, M.	1997	*Strategic production-distribution models: a critical review with emphasis on global supply chain models*	

2.2.2 Transportation flows, routings, and demands

One of the efforts at optimizing the flow within transportations systems is Chan et al. (2013). The paper presents a particle swarm optimization algorithm to develop traffic flow predictors that is sensitive to memory requirements and to the need for newly updated traffic flow data.

Winston (1982) provides an overview of models of the demand for freight transportation and applications of these models. Aggregate and disaggregate freight demand models are presented and critically evaluated with regard to conceptual coherence and estimability. This deals only with the demand experienced by transportation providers and does not address their operations. Baumol and Vinod (1970) develop a model to explain the choice of transport made by shippers, as well as their total demand for transportation services. Abdelwahab and Sargious (1992) present a demand model for freight transport that combines the two decisions of Mode Choice and Shipment Size, and uses the same amount and quality of data that would be required to develop a standard disaggregate mode choice model.

Wu (2006) models a logistics network as a 0-1 integer programming problem, with decision variables set for the volumes flowed by different lanes and with the inventories and shortages coded as constraints. She is then able to solve the program via a genetic algorithm. Wu (2010) proposes a method that global exporters can use to model their optimum shipping volumes in light of import quotas imposed by Western nations. For this model, costs are modeled as indexed parameters for material costs, labor costs, variable equipment costs, etc. The primary constraints are set up as Demand and Quota variables. Decision variables are then left to be the production quantities as well as the resulting labor times resulting from that decision. The research concludes that import quotas have a significant effect upon the ability of global companies to maximize shipping volume.

Goetschalckx et al. (2002) explore a pair of models focused upon the optimization of the physical flow of goods through a global logistics enterprise. The authors then present a case study from the packaging industry which incorporates the data requirements necessary for successful implementation. They conclude that relevant data fields are capacity at each point in the chain, flow at each leg of the chain, component costs for each aspect, as well as an understanding of seasonality.

Dougherty (1995) reviews the current state of work being performed on the application of neural networks to transport problems. He defines neural networks as a modeling methodology that allows nodes to be set up which learn from previous inputs and adjust their leg parameters accordingly. Dougherty finds applications where these have been used in commercial global logistics chains, but little in the way of air transport; he hypothesizes this is due to the highly sensitive nature (military or commercial) of air transport. Rickman et al. (1990) describe a cost-effective and potentially more accurate alternative for collecting travel time information – an improvement over the "floating car survey". This paper addresses sampling methods for highway travel times that has some applicability to cargo and freight movements, particularly the last leg of ground transportation in an express network.

Supply chain risks are incorporated into a stochastic model by Goh et al. (2007). Their global network model is augmented by an understanding of supply, demand, exchange, and disruption risks. The model is then formulated to maximize profit and minimize risks.

2.2.3 Airline scheduling

Antesa et al. (1998) introduces a model-based decision support system for the evaluation of flight schedules for cargo airlines, by describing the underlying planning situation, the data model and the decision models used. This model is focused upon flight schedules exclusively and does not address the broader operational challenges represented in the model. Kubya and Grayb (1993) explore the tradeoffs and savings involved with stopovers and feeders as they are integrated into a traditional hub-and-spoke network. This paper exclusively explores the transit routing and does not explore the data architecture. Cheung et al. (2008) develop an attribute-based decision model for a transportation operation (drayage) that can be solved and optimized. The model establishes the attributes as different states of the resource being scheduled. This attribute model is then solved for an exact solution using a commercial integer programming solver (CPLEX), which is sufficient for small-scale models. Larger-scale models are recommended to be solved using a labeling algorithm.

Leung et al. (2006) develop a model for the cross-border logistics of an international freight network. The model establishes variables to capture the cost of different legs of the journey, as well as to capture the penalties of waiting for customs clearance operations. The model is then solved as a multi-objective problem using Goal Programming. Root and Cohn (2008) model the flow of freight within an express air freight network using a bundled approach, whereby combinations of loads are optimally routed rather than the individual shipments themselves. The authors present a set of templates that can be used to identify promising candidates for the bundling.

2.2.4 Cross-functional models of Logistics Networks

Crainic and Laporte (1997) have assembled a broad look at challenges facing freight transportation providers. Some of the problems they tackle include strategic design of the physical network, tactical assignments of routes and policies, and operational aspects such as yard scheduling. The authors then provide a broad view of the solution methods available for all three levels of problems, primarily as linear programs solved through CPLP, DUALOC, branch-and-bound, or tabu search procedures. Subsequently, Crainic (2000) offers a review of the state-of-the-art within the research into freight network design. The review covers the models that are being developed (network design and operation) as well as the solution methods being used to optimize them, primarily tabu search, simulated annealing, and genetic algorithms.

Wu (2011) proposes models to assist an integrated logistics enterprise with coordinated processes between two countries, given an uncertain customer shipment information. The variables are established to allow for differences in wage rates, trucking rates, clearance processes, etc. The author then proposes three different ways to establish the objective function: one which provides solution robustness, another with model robustness, and a third offering a trade-off. These are solved as non-linear-linear programming models. Wu concludes with empirical evidence of the trade-off between variability and infeasibility.

Easwaran and Üster (2010) consider a closed-loop logistics network to optimize total cost of system operation. This modeling of a closed-loop supply chain is not unlike the air freight network, with its constraints of a fixed fleet of aircraft and fixed numbers of reusable shipping containers. The model is set up with a set of products, sets of origins/destinations, and flow variables that are separate for each stage of the supply chain. The model is subsequently solved with a Benders' Decomposition approach to mixed-integer programming. Leung et al. (2007) address a multi-site planning problem that is subject to clearance restrictions, numerical constraints, and qualitative constraints. The model is crafted with design and control variables to improve robustness, and solved using goal programming in LINDO. The authors conclude with a comparison of the tradeoffs between solution robustness and model robustness. Wu (2012) establishes a stochastic model to develop a two-pronged response to shipping company needs to manage cross-border logistics. The dual response allows for flexibility in reacting to short lead times and to uncertainties which arise in global logistics.

Vidal and Goetschalckx (1997) provide a literature review of strategic distribution and logistics models, covering optimization models as well as additional issues within the realm of logistics network modeling. The review brings out research conducted in the area of data management for distribution networks.

2.3. Optimization of physical flows within Air Cargo processes

The air cargo (or air freight) value chain has many touch points subject to optimization. These will in many ways differ from the optimization opportunities seen in the above section on general transportation optimization. For example, air cargo enterprises struggle with the high capital cost of aircraft which necessitates a minimum of idle time for the transport vehicles during container unloading, sorting, and reloading. The express air cargo carriers have the additional burden of synchronizing then optimizing the last leg of delivery: ground transportation to the recipient's address. These factors and others call for research dedicated to air cargo modeling.

2.3.1 General air cargo optimization

Yan et al. (2006) combine airport selection, fleet routing and timetable setting to develop an integrated scheduling model. The objective is "to maximize operating profit, given the related operating constraints." This paper exclusively explores the transit routing and does not explore the data architecture. Bartodziej et al. (2007) presents a mathematical programming based approach for revenue management in cargo airlines, but stops short of addressing the cost-tradeoffs that will factor into the selection of a data architecture. Guimerá and Amaral (2004) present an exhaustive analysis of the world-wide airport network. The writers propose a new model that explains behavior in terms of the geo-political constraints that affect the growth of the airport network.

2.3.2 Optimal scheduling of air cargo networks

Scheduling has attracted research attention due to the large payback resulting from the improved utilization of capital equipment. Yan and Chen (2008) address scheduling models to optimize airline routing and timetables. Yan et al. (2006) develop an integrated scheduling model to maximize operating profit. Yan et al. (2008) develop a stochastic-demand cargo container loading plan model to minimize the total operating cost. This paper explores the methods of calculation for efficient transportation, but not the efficient transmission of the data required. Kritikos and Ioannou (2010) address a variant of the vehicle routing problem. This paper uses standard software for network planning to schedule transshipment operations of unitized air-freight containers. The model is based upon observations of container loading and unloading within the KLM air cargo hub at Schiphol airport near Amsterdam. The activities are modeled in SAS using the Critical Path Method of network planning. The paper further addresses intricacies of scheduling in the air cargo industry where activities tend to be postponed till as late in the feasibility window as possible in order to accommodate late arrivals into the sortation; this requires special accommodations in the SAS parameters. The authors conclude that the scale of this problem is so large that optimization is impossible and therefore express satisfaction with model results that are merely acceptable.

Table 3 Optimization of physical flows within Air Cargo processes

Chapter and Section	Author	Publish date	Title	Section summary
2.3.1	Yan, Shangyao; Lai, Chun-Hung; and Chen, Chia-Hung	2005	*A short-term flight scheduling model for international express package delivery*	Analyze air cargo questions at a high level, seeking broad optimization of network factors
	Bartodziej, P.; Derig, U.; and Zils, M.	2007	*O&D revenue management in cargo airlines—a mathematical programming approach*	
	Guimerà, R. and Amaral, L.A.N.	2004	*Modeling the world-wide airport network*	
2.3.2	Yan, Shangyao and Chen, Chia-Hung	2008	*Optimal flight scheduling models for cargo airlines under alliances*	Pursue optimal scheduling of air cargo networks
	Yan, Shangyao; Chena, Shin-Chin; and Chena, Chia-Hung	2006	*Air cargo fleet routing and timetable setting with multiple on-time demands*	
	Yan, Shangyao; Shiha, Yu-Lin; and Shiaoa, Fei-Yen	2008	*Optimal cargo container loading plans under stochastic demands for air express carriers*	
	Kritikos, Manolis and Ioannou, George	2010	*The balanced cargo vehicle routing problem with time windows*	
2.3.3	Li, J.A., Liu, K., Leung, S.C., Lai, K.K.	2004	*Empty container management in a port with long-run average criterion*	Analyze effective management of air freight containers
	Li, Jing-An; Leung, Stephen C.H.; Wu, Yue; Liu, Ke	2007	*Allocation of empty containers between multi-ports*	
	Wu, Y. and Wu, Yue	2010	*A dual-response forwarding approach for containerizing air cargo under uncertainty, based on stochastic mixed 0-1 programming*	
2.3.4	Hsu, Chaug-Ing; Shih, Hsien-Hung; and Wang, Wei-Che	2009	*Applying RFID to reduce delay in import cargo customs clearance process*	Discuss miscellaneous air cargo concerns
	Chan, Chi-Kong; Chow, Harry; So, Sunny; Chan, Henry	2012	*Agent-based flight planning system for enhancing the competitiveness of the air cargo industry*	
	Park, Yonghwa; Choi, Jung Kyu; Zhang, Anming	2009	*Evaluating competitiveness of air cargo express services*	

2.3.3 Air freight containers

The unitized loading containers which hold smaller parcels or netted freight safely within an aircraft are a key operations concern for air cargo enterprises. These containers are highly subject to unbalanced flows between import and export countries. Li et al. (2004) develop a method for inventory control of air freight shipping containers that may optimize total inventory levels between a pair of unbalanced origin/destination airports. Li et al. (2007) extended this model for a multi-city air freight network. The model begins with a max/min type inventory control system specifying the order point and the order-to point. This model is expanded to multiple ports by use of a stochastic view, with snapshots of the current inventory distribution at given increments of time. Yan et al. (2005) develop a short-term flight scheduling model for air express carriers to determine suitable routes and flight schedules at the least cost. Wu and Wu (2010) propose a dual-response forwarding approach for renting air containers and simultaneously determining how cargoes are distributed into the containers under uncertain information. The focus here is on rental containers, a factor that affects all air cargo enterprises.

2.3.4 Other air cargo concerns

Hsu et al. (2009) explores the customs clearance process of import cargos in international air cargo terminals, and proposes RFID technology to improve operating efficiencies. Chan et al. (2012) propose a framework for automation of two key processes in the air cargo industry: cargo consolidation and equalization. The automation builds upon RFID data available in the shipment receipt process, then allows for optimization of transportation processes using a simulated annealing engine.

For an overall summary of the field, a sound resource is Park et al. (2009) which compares five express air services based upon a set of factors selected by service users.

2.4. Decision support

One of the stated purposes for the data systems that this model will represent is the purpose of assisting managers and quality improvement teams with making tactical process-level decisions. The field of Decision Support Systems seeks to connect data with decision makers in a way that makes both more effective.

Table 4 Decision support

Chapter and Section	Author	Publish date	Title	Section summary
2.4.1	Holsapple, C.W. and Sena, M.P.	2005	*ERP plans and decision-support benefits*	Propose design parameters for decision support systems
	van Hee, K.M. and Lapinski, A.	1988	*OR and AI approaches to decision support systems*	
	Wixom, Barbara and Watson, Hugh	2001	*An Empirical Investigation of the Factors Affecting Data Warehousing Success*	
2.4.2	Kengpol, Athakorn; Meethom, Warapoj; Tuominen, Markku	2012	*The development of a decision support system in multi-modal transportation routing within Greater Mekong sub-region countries*	Present decision support systems for specific logistics challenges, such as routing, warehousing, and loading
	Lau, H.C.W. and Nakandala, Dilupa	2012	*A pragmatic stochastic decision model for supporting goods trans-shipments in a supply chain environment*	
	Chan, Felix; Bhagwat, Rajat; Kumar, N.; Tiwari, M.; Lam, Philip	2006	*Development of a decision support system for air-cargo pallets loading problem: A case study*	
	Kozan, Erhan and Liu, Shi Qiang	2012	*A demand-responsive decision support system for coal transportation*	
	Shen, W.S., Khoong, C.M.	1995	*A DSS for empty container distribution planning*	
	van Hee K., Huitink B., Leegwater D.K.	1987	*Portplan, decision support system for port terminals*	
	Manzini, Riccardo	2012	*A top-down approach and a decision support system for the design and management of logistic networks*	
2.4.3	Kengpol, A., Tuominen, M.	2006	*A framework for group decision support systems: an application in the evaluation of information technology for logistics firms*	Present decision support models for investment selection
	Baker, N.R., Freeland, J.	1975	*Recent advances in R&D benefit measurement and project selection methods*	

Table 4 Decision support (continued)

Chapter and Section	Author	Publish date	Title	Section summary
2.4.4	Dyer, Robert F. and Forman, Ernest H.	1992	*Group decision support with the Analytic Hierarchy Process*	Specify data required for optimal decision making
	Meixell, J., & Gargeya, V. B.	2005	*Global supply chain design: A literature review and critique*	
	Volonino, Linda; Watson, Hugh; Robinson, Stephen	1995	*Using EIS to respond to dynamic business conditions*	
	Liberatore, Matthew	1995	*Toward a Framework for Developing Knowledge-Based Decision Support Systems for Customer Satisfaction Assessment: An Application in New Product Development*	
	March, S.T. and Hevner, A.R.	2007	*Integrated decision support systems: a data warehousing perspective*	

2.4.1 Design of Decision Support systems

Holsapple and Sena (2005) discuss decision support capabilities in light of an Enterprise Resource Planning (ERP) system. The emphasis is upon the plan which enterprise leaders must enact for the data, moreso than on the data itself. In other words, the support system must be designed from the ground up in a manner which will support managerial decision making, rather than vice versa. The study included enterprises which have implemented an ERP system and evaluated their perceived usefulness of the system as a decision-support aid, concluding that significant connections exist between the two.

Hee and Lapinski (1988) define a “decision support system” to be a subset of an information system which computes the effects of some proposed actions and recommends optimal actions. The authors lay out the architecture of an operations-research-oriented decision support system as having a subset database which allows for parameters and constraints to be analyzed in different scenarios. Architecture for a decision support system may also be augmented by Artificial Intelligence methods such as theorem proving and search algorithms, in order to create new patterns for scenarios.

Recommendations for successful launch of a data warehousing system are found in Wixom and Watson (2001). They highlight three features deemed to be the most significant dimensions for success: data quality, system quality, and perceived net benefits. This leads to discussions of specific aspects of these terms, such as data accuracy, completeness, system flexibility, response time, and integration with other corporate systems.

2.4.2 Decision Support models for specific Logistics challenges

Routing: Kengpol et al. (2012) develop a decision support system to optimize multi-modal routing throughout a multi-country geographic area. The model is broader than many which only consider distance, and instead factors in cost, time, risk, and quality. These multiple factors require multiple algorithms in order to weight them and optimize appropriately. The authors have chosen AHP, Delphi, and ZOGP methods to optimize the combination of qualitative and quantitative parameters.

Warehousing: Lau and Dilupa (2012) place emphasis upon creating a decision support system that is simple enough for an “ordinary” logistics manager to implement. The purpose of this system is to guide decisions regarding the cost benefits of rushing orders versus allowing backorders on goods. Their model assumes a finite number of warehouses supplying the retailers, with each warehouse seeing a demand that is distributed as a poisson distribution and visible through periodic (R,Q) inventory and demand reviews. Backorder and holding costs are estimated from previous sales records.

Air Cargo loading: Decision support systems for air freight are introduced by Chan et al. (2006) in order to address the need to optimally load freight onto an air-freight pallet. This model is set up as a bin packing problem, with a wide variety of available shapes and sizes of cargo that can be placed onto the pallet footprint. The end result is a heuristic for cargo handlers to follow in order to maximize density on the pallet.

Vertical supply chain: Kozan and Liu (2012) outline a decision support system for the transportation of a single commodity (coal) through all phases of its production cycle. The transportation is modeled based upon the time required for each task (travel time, loading time, etc.), which allows for optimization to be performed upon the resulting model, with constraints that can be adjusted by employees in real time. Furthermore, the authors propose a graphical solution method for the model which requires Gantt and other charts to be used in an iterative fashion according to their supplied algorithm, due to the complexity of the model.

Empty Returns: Shen and Khoong (1995) outline a decision support system for the planning problem of empty shipping containers. The system is based on a network-optimization model which allows graphical representation and is solvable by efficient algorithms.

Port Management: Methods for integrating various operations research models into a single plan for logistics operations (specifically a port management plan) are described by van Hee et al. (1987). The models include Markov models, queuing models, and simple optimization models to address the need for resource allocation and scheduling. The authors also define a decision support system as one that meets three criteria:
Computes the effects of decisions
Generates suggestions of optimal decisions
Analyzes sensitivity of the outcome to individual parameters

Integrated: Manzini (2012) presents a high-level decision support model for a supply chain, one that encompasses the operational planning as well as the strategic planning aspects of transportation. This research attempts to model not just the location planning or route planning, but all aspects of supply chain management. This results in several distinct models which can then be combined with an operational model to determine the optimum management strategy for a given time period.

2.4.3 Decision Support models for investment selection

Kenpol and Tuominen (2006) present a framework for a decision support system that allows for comparison of information technology (IT) proposals. They apply three methods: analytic network process (ANP), Delphi, and Maximise Agreement Heuristic (MAH), in order to analyze the quantitative and qualitative factors involved in selecting IT components for five logistics companies. The authors step through these three in sequence in order to compare the quantitative and qualitative benefits against the quantitative and qualitative costs. There is considerable emphasis upon the collaborative nature of these tools, since they require the input of a group of decision makers. This paper concludes with the assertion that this blend of three tools is effective and efficient up to a group size of ten decision makers, as tested in five logistics firms.

Baker and Freeland (1975) provide an assessment of various proposals to allocate resources to technology investments and R&D expenditures. They score the proposals on their treatment of risk and uncertainty, treatment of multiple (often related) criteria, recognition and incorporation of the personnel experience, recognition of non-monetary aspects of the investment decision, perceptions that the decision support models are easily understood by the implementing personnel, and an understanding of the time varying properties of many technology investment decisions (or R&D investments). The authors conclude that none of the models adequately address these criteria for effectiveness.

2.4.4 Data necessary for enabling Decisions

Dyer and Forman (1992) describe the core functioning of a group decision support system (versus a traditional decision support system) as being empowered by the techniques of the Analytic Hierarchy Process (AHP). The paper illustrates use of this model to work through four different business scenarios including one which is applicable to this paper's research area: the allocation of investment resources to a research and planning function. The authors conclude that modern decision making models require broad views of the enterprise in order to facilitate the group-based perspectives that will come into play with at decision time.

Meixell and Gargeya (2005) offer a review of the current literature for the decision support systems of global supply chains. Their review classifies work by the decisions that are addressed by each model, the performance metrics of the model, modeling of integrated processes, and globalization considerations. The globalization considerations are particularly relevant to this effort, so note is taken of what are found to be relevant parameters:
Tariffs/duties
Non-tariff trade barriers
Currency exchange rate
Corporate income tax
Transportation time
Inventory cost
Worker skill / availability
Industry context

Volonino et al. (1995) describe how decision support systems can be modified to meet executive-level criteria for management decisions. The authors conclude with a discussion of the impact of (then) emerging technologies such as distributed databases, and open architecture formats.

Liberatore (1995) describes the ability of companies to measure the data elements that are critical to customer experience. In particular, he emphasizes the requirement for any data collection system to conduct system validation and verification as a closed-loop method to relate data collection back to customer satisfaction.

March and Hevner (2007) address the ability of data warehouses to bring business intelligence to decision makers. The authors emphasize the broadness of data that should populate a data warehouse in order to maximize utility: “support for all levels of management decision-making processes through the acquisition, integration, transformation, and interpretation of internal and external data.” The paper highlights four aspects that must be present for successful decision support: integration, implementation, intelligence, and innovation. The authors bring out the integration requirements that enable data warehouses to move from being merely tactical to being truly strategic. The implementation of data warehousing is a layered affair, with content management layers surrounded by design, use, and evolution layers. Intelligence arises from the sophistication of data mining tools. Innovation is brought about by the executive vision and change management.

2.5. Technology selection

Though this section has clear overlap with section 2.4.3 above (Decision Support models for investment selection), it is distinct in that these models offer more of a mathematical foundation for the technology selections, whereas the research highlighted in section 2.4.3 are inclined to address more of the framework around decision making. Therefore the two sections complement each other in the same manner that a strategic discussion necessarily precedes a more tactical operational plan.

2.5.1 Mathematical models of technology selection

Narasimhan and Mahapatra (2004) illustrate five decision models of value to supply chain management: investment implications of innovation-based competition, bidding for contract, bid evaluation, integrated operations within the supply chain, and distribution. Of these, the most relevant to this study is the investment implication question; this the authors model with a production rate and price function along with a differentiator for the level of innovation. Kengpol and O’Brien (2001) lay out a decision support tool to assist with product development lifecycles, specifically to determine the value of investing in time compression technologies. The paper discusses the methods for selection of advanced technology. The authors make a case for simplifying the model to determine cost/benefit solely on an accumulation of profits over the first five years; the model is then solved using the Analytic Hierarchy Process (AHP).

Yap and Souder (1993) propose a mechanism for selecting technology components and systems which has two stages. The first is a filter to eliminate all undesirable candidate technologies. The second is a selection process they prove to be robust. The authors suggest five characteristics necessary to judge the candidate technologies: uncertainties of commercial success, funding history of the technologies, resource requirements to develop the technologies, the degree to which technologies contribute to the enterprise mission, and the current life-cycle stage of the technology. The elimination filter brings in these five necessities with a multiplicative scoring model to analyze weighted scores as assigned by a cross-functional panel of co-workers. The selection procedure is implemented with a hierarchy and utility values which are then optimized with a linear programming methodology.

Table 5 Technology selection

Chapter and Section	Author	Publish date	Title	Section summary
2.5.1	Narasimhan, R., and Mahapatra, S.	2004	*Decision models in global supply chain managemen*t	Establish mathematical models for technology selection
	Kengpol, A., O'Brien, C.	2001	*The development of a decision support tool for the selection of advanced technology to achieve rapid product development*	
	Yap, C.M. and Souder, W.E.	1993	*A Filter system for technology evaluation and selection*	
	Mandakovic, Tomislav and Souder, Wm. E.	1985	*A flexible hierarchical model for project selection and budget allocation*	
	Banker, Rajiv; Chang, Hsihui; Janakiraman, Surya; Konstans, Constantine	2004	*A balanced scorecard analysis of performance metrics*	
2.5.2	Geoffrion, A.M., and Powers, R.F.	1980	*Facility location analysis is just the beginning (if you do it right)*	Describe decision drivers and success criteria for technology selection
	Geoffrion, A.M., and Powers, R.F.	1995	*Twenty years of strategic distribution system design: An evolutionary perspective. (Implementation in OR/MS: An evolutionary view)*	
	Ching, Chee; Holsapple, Clyde; Whinston, Andrew	1996	*Toward IT support for coordination in network organizations*	
	Gallagher, Keith; Hatch, Andrew; Munro, Malcolm	2008	*Software Architecture Visualization:An Evaluation Framework and Its Application*	
	Kendall, K.	1997	*The significance of information systems research on emerging technologies: seven information technologies that promise to improve managerial effectiveness*	

Mandakovic and Souder (1985) add to the multiple-criteria problem with a proposal for a decision making model using flexible hierarchies. In this model, a flexible objective statement contains a weighted sum of the constituent criteria. A committee is then allowed to participate in the selection of the weights for each criterion.

Relevant performance measures is a topic that Banker et al. (2004) incorporate into their research. They describe how emphasis has shifted to a portfolio of performance metrics that relate to customers, business process, and technology. The authors conclude that these additional performance metrics bring value when they trend non-correlatively with the purely financial metrics that have long dominated performance scorecards. This correlation is determined through a combination of three test statistics: Banker’s sum ratio test, Banker’s sum of squares ratio test, and the Kolmogorov–Smirnov test

2.5.2 Decision drivers and success criteria for technology selection

Geoffrion and Powers (1980) offer a list of questions for consideration prior to logistics investments. Though the paper focuses upon the investment in warehouse location, the same logic also applies to other investments required in logistics expansion. Some considerations they recommend are: the need for optimization capability, rationalization of flows within the existing network, and the ability to adapt to changing environments and business conditions. The authors conclude with an emphasis that logistics investments must be full-spectrum in their approach in order to maximize value to the enterprise. Geoffrion and Powers (1995) trace the incorporation of data-based management into logistics enterprises and the benefits to leadership decisions. The authors also note the importance of client-server compatibility in order to maximize benefit from logistics models, as well as the requirement that data fields be structured and accessible through interfaces such as SQL.

Information technology needs in a networked (or matrixed) organization are described by Ching et al. (1996). The authors propose that an IT system in this type of enterprise will be successful depending upon such factors as participant reliability in the data usage, compatibility with other business technologies, mutual trust in the data integrity, cooperation, creativity, and prudent evaluation of the data that is warehoused. The paper explores a measure of reputation as a way to determine the likelihood of technology adoption within the matrixed portions of the enterprise.

Gallagher et al. (2008) offer means to enhance internal customer adoption of new technology, by exploring options to help system users visualize how they will interact with the system before it is implemented. This architecture visualization is set forth in a variety of different frameworks that the authors offer for the reader to choose from.

Kendall (1997) describes five phases of technology life-cycles, which may apply to RFID or other logistics tracking technologies:

1. technological invention or discovery,
2. technological emergence,
3. technological acceptance,
4. technological sublime (in which its value is fully appreciated), and
5. technological surplus.

2.6. Importance and role of IT and new technology

The purpose of this dissertation is to present a cohesive proposal for technology that will have a meaningful chance of adoption by an air cargo enterprise. Adoption is predicated upon an understanding of the role of this new technology and role that the technology department (IT) will play in the ongoing enterprise operations. These articles therefore address the adoption, relevance, and responsibilities for IT departments and services.

Table 6 Importance and role of IT and new technology

Chapter and Section	Author	Publish date	Title	Section summary
2.6.1	Azadian, Farshid; Murat, Alper; Chinnam, Ratna Babu	2012	*Dynamic routing of time-sensitive air cargo using real-time information*	Explore current state of information technology networks in Logistics industry
	Lin, Pei-chun and Lee, Chia-hui	2009	*How Online Vendors Select Parcel Delivery Carriers*	
	Ramani, K.V.; Yap, Robert; Pavri, Francis	1995	*Case study: Information technology enables business process reengineering at YCH DistriPark (Singapore)*	
	Thomas, D.J. and Griffin, P.M.	1996	*Coordinated supply chain management*	
	Hui, George W.L.; Van Hui, Yer; Zhang, Anming	2004	*Analyzing China's air cargo lows and data*	
	Forster, Paul W. and Regan, Amelia C.	2001	*Electronic Integration in the Air Cargo industry: an Information Processing Model of On-Time Performance*	
	Ngai, E.W.T., Lai, K.H., Chang, T.C.E.	2008	*Logistics information systems. The Hong Kong experience*	
	Kim, Soo Wook and Narasimhan, Ram	2002	*Information system utilization in supply chain integration efforts*	
2.6.2	Holsapple, Clyde and Luo, Wenhong	1996	*A framework for studying computer support of organizational infrastructure*	Describe varying roles played by IT organizations within the Logistics industry
	Reinheimer, Stefan and Bodendorf, Freimut	1999	*A Framework for Electronic Coordination in the Air Cargo Market*	
	Riddle, W.E., Williams, L.G.	1987	*Technology selection: an educational approach*	
	Li, Sheng-Tun and Shue, Li-Yen	2003	*A study of logistics infomediary in air cargo tracking*	
	Verwijmeren, Martin	2004	*Software component architecture in supply chain management*	

2.6.1 Current state of Logistics IT

Azadian et al. (2012) study air cargo routing in light of the availability of real time data. For instance, if the data collection system has been designed to accommodate flight availability, departure delays, travel times, etc., the routing can be improved measurably. The authors demonstrate the feasibility of that real-time re-routing through use of a Markov decision model solved through online backward induction. Key air cargo information fields which have become an expectation within e-commerce providers are explored by Lin and Lee (2009). In their survey of online seller shipping preferences, they found that delivery speed and the tracking of that delivery were key drivers of shipper satisfaction. Secondary but important criteria were the speed of pickup and the shipper's ability to react to unplanned events.

The role of IT within a Singapore-based global transportation company is explored by Ramani et al. (1995). The paper describes how three major systems were developed: Warehouse management system, Logistics management system, and Freight management system, and were then subsequently integrated into the extra-company trade networks for cooperation and electronic data interchange.

Thomas and Griffin (1996) offer a dated but relevant literature review of what was the state-of-the-art research regarding the electronic coordination of multiple legs of the logistics pipeline. This results in a few key fields that are necessary for cooperative planning: anticipated volumes, batch size, anticipated routings, clearance and duty implications, and leg capacity.

Hui et al. (2004) describe the environment for air cargo providers in China and Hong Kong. It also speaks broadly about the air cargo industry, naming it "the fastest-growth area in the cargo sector." In particular, it singles out the increase in growth of air cargo within mainland China – an area that is fertile ground for air cargo network expansions.

Forster and Regan (2001) examine electronic integration into the business practices of the US air cargo industry. The authors describe the nature of the air cargo industry which supports large integrated carriers (such as FedEx and UPS) to meet on-time commitments with greater regularity than freight integrators who lack vertical control of their value chain. The paper seeks to describe ways in which smaller freight integrators can achieve the on-time benefits of vertical integration through better use of electronic integration. Important differentiation points for international freight integrators are advice on packaging, international payments, and customs clearance information. These can all be incorporated into data collection systems to better compete globally. The system need is described as: "The problem of coordination is a problem of information: how to communicate information between decision makers involved in the performance of interdependent subtasks." The key pieces of information, therefore, become tracking, tracing, and document exchange. The electronic system must be able to navigate task uncertainty, environmental uncertainty, and information exchange among extra-corporate partners. The authors then aligned with a sampling of freight integrators in order to find operational definitions for these requirements – detailed options for measuring them.

To assess the levels of information technology adoption among logistics companies, Ngai et al. (2008) conducted a survey of 195 transportation providers in Hong Kong. They concluded that technology has a strong presence in these companies and is fulfilling its perceived benefits of reduced paperwork, reduced errors, improved tracing and customer service, among others.

A survey by Kim and Narasimhan (2002) focused on verifying the structural relationships between three major information system utilization areas and supply chain management performance while taking into consideration the stage of supply chain integration that the companies had attained. The authors conclude that information system utilization for logistical operations has a significant effect on both cost reduction and differentiation of services in the face of competition.

2.6.2 Roles of Logistics IT organizations

The term “organizational computing” is used by Holsapple and Luo (1996) to describe the study of technology support for enterprises. They begin with the assumption that “computer technologies employed by organizations should enable or facilitate achievement of organizational objectives” which serves as the guiding framework for selecting enterprise technologies, particularly in areas such as quality and efficiency. The authors then explain how fellow researchers have employed three models to guide the selection of technology investments - whether that hardware is treated as an independent variable, a moderator variable, or using a consensus approach.

Reinheimer and Bodendorf (1999) outline how market orientation can be accomplished in the air freight community by applying communication infrastructures and by considering qualitative aspects of pricing mechanisms. The desired outcome of this coordination is to better align forwarders and carriers, with related services such as customs, banks, and handling companies. The authors suggest some data elements to be included in a coordinating electronic logistics system: handling restrictions, special requests, or other qualitative demands

Riddle and Williams (1987) describe the adoption of new technology into the enterprise as having four (sometimes parallel) activities: selection of technology satisfying some criteria, acquisition of suitable versions of the technology, integration of the technology with existing technology, and propagation of the result throughout a target community. These requirements can be assisted by a decision support system. Li and Shue (2003) discuss the benefits of creating a logistics infomediary which pools and consolidates air cargo information for shippers in a readily usable format. The authors emphasize the need to present data from all components of the logistics chain, including agents, brokers, industrial park administrators, cargo terminal operators, and customs.

Lastly, Verwijmeren (2004) incorporates a holistic view of the common layers of logistics information architecture. In particular, the author seeks ways to bridge the warehouse management system with the ERP system and the transportation system. To create these bridges, some key aspects of a transportation management system are delineated: confirmation of booking, transport planning, and periodic monitoring. These key components are then implemented using different layers: communication engines, information engines, and management engines.

2.7. RFID insights

One of the most oft-discussed new technologies to enable logistics excellence is the RFID (radio frequency identification) tag and reader. This technology offers benefits internally to the shipper, as well as externally to the customer. A number of research areas have been found surrounding RFID, particularly in the areas of warehousing and interference with avionics; however, the focus of the below articles is to illustrate (or calculate) its usefulness within an end-to-end multi-site transportation chain.

Table 7 RFID insights

Chapter and Section	Author	Publish date	Title	Section summary
2.7	Angeles, Rebecca	2005	*RFID Technologies: Supply Chain applications and Implementation Issues*	Provide insights into current state of the RFID industry
	Angeles, Rebecca	2009	*Anticipated IT infrastructure and supply chain integration capabilities for RFID and their associated deployment outcomes*	
	Chang, Yoon Seok; Son, Min Gyu; Oh, Chang Heun	2011	*Design and implementation of RFID based air-cargo monitoring system*	
	Kohn, W., Brayman, V. and Littleton, J.	2005	*Repair-control of enterprise systems using RFID sensory data*	
	Cao, Qing; Good, Brandon S.; DeRose, Lynn A.	2011	*RFID for Air Cargo operations: return on investment analysis through Process Modeling and Simulation*	

Angeles (2005) offers an introduction to the incorporation of RFID technology into a Logistics enterprise. The author bases the research upon seven case studies which, though all single locations, have some application for rollout to a global logistics network. She also offers typical investment levels required to outfit a network with approximately 800 receiving locations. The paper then describes updates needed to existing data warehouses to accommodate the dramatically increased flow of data from shipments (up to 30% increase, according to the author's surveys). The increased data requires increased analytical capacity as well – including a meaningful decision support system that alerts managers to only those situations which require true intervention. To evaluate the ease of implementation for RFID systems, Angeles (2009) hypothesized that effective integration (IT system architecture, information flow, physical parcel flow, and financial flow) would predict the successful outcome of a new RFID installation. She tested this hypothesis with surveys to 155 major logistics providers. Her framework is based upon IT infrastructure integration capability, data consistency, and supply chain process integration capability. Using multiple regression on the survey results, the best predictors for RFID operational efficiency were found to be "data consistency" and "cross-functional application integration."

Chang et al. (2011) identified some key parameters for RFID implementation within air cargo sorting facilities. They pinpointed the optimal (uncluttered) frequency to be 433.92 MHz, and the reliable transmission range to be 1-3 meters, though readings up to 20 meters were possible. The authors then suggested the most relevant data to be collected for each shipment: business location identification data, MAWB identification data, skid identification data, and time data. These four data fields would be stored at each new process point, and augmented with two other data fields (ULD number, and precise storage location) when passing through a few special process points. RFID technology is employed by Kohn et al. (2005) as the data link to provide a continuous feedback loop into an enterprise-wide control system. This sensory data is combined with a corporation's ERP system to provide a "repair" signal into the supply chain.

Cao et al. (2011) address the question of investment and return on investment (ROI) within the air cargo industry by conducting a simulation of improvements in decreasing processing times and resources. The simulation derives from data taken at a Korean Air Lines cargo terminal. The simulation model primarily includes the flow of air-freight containers (ULDs) within the confines of the cargo terminal, including the load, unload, and waiting areas, among others. The combination of labor savings, improved throughput, and quality improvements results in a simulated payback of 1.5 years, which would have been even quicker had the employer been willing to reduce the workforce immediately upon implementation of the RFID system.

2.8. Use of Fixed Charge Integer Models

The program adopted for this dissertation is the Fixed Charge Integer Model. The flexibility of this model has broadened its appeal to a variety of uses.

Thomadsen and Stidsen (2007) lay out a generalized approach to leveraging fixed charge integer programs for network designs. This problem is formulated by viewing clusters in their relationship to the network, rather than looking at the individual nodes. Each of these clusters carries the fixed cost, so that the problem is then generalized and solved by common algorithms. For illustration purposes, the authors use a branch-cut-and-price algorithm. The algorithm is shown to effectively obtain optimal solutions for problems with up to 30 clusters and up to 300 nodes.

Table 8 Use of Fixed Charge Integer Models

Chapter and Section	Author	Publish date	Title	Section summary
2.8	Thomadsen, Tommy and Stidsen, Thomas	2007	*The generalized fixed-charge network design problem*	Detail past usage of Fixed Charge integer models to solve variety of problems
	Ahmed, Shabbir; King, Alan J., Parija, Gyana	2003	*Multi-Stage Stochastic Integer Programming Approach for Capacity Expansion under Uncertainty*	
	Lee, Patrick and Vora, Gautam	1993	*A two-stage approach to multi-period allocation of savings among investment plans*	
	Li, Qingwei and Savachkin, Alex	2013	*A heuristic approach to the design of fortified distribution networks*	

Ahmed et al. (2003) study capacity expansion using the fixed charge model. The authors apply the model to a two-stage expansion with uncertainties that call for stochastic capabilities within the model. The authors address this need by adopting a scenario tree approach to model the uncertain parameters while using the fixed charge portion of the model to scale the expansion costs.

Lee and Vora (1993) apply a fixed charge model in a similar manner as above but again as part of a two-stage investment decision process. This model incorporates complications into the fixed and recurring charges, such as discount rates and risk levels. The authors employ a linear relaxation of the integer program to analyze sensitivity toward investment strategies.

Li and Savachkin (2013) use the fixed charge program to select locations for reliable uncapacitated distribution networks, in support of Lean supply chains. The authors then develop a Lagrangian relaxation based heuristic solution algorithm and demonstrate its computational efficiency for solving large-scale problems.

2.9. Summary of Literature Review

These research areas have been selected for their ability to enlighten the dissertation focus area of a data collection model which will enable the expansion of an express air cargo enterprise. The papers offered a blend of strategic framework as well as mathematical optimization. The research has touched on transportation networks almost exclusively and in many cases has offered insight to the air cargo industry.

2.10. Literature Search and central hypothesis

The literature search has not uncovered any examples of models for meeting information technology needs while expanding an air cargo network into another country. None of the literature identified in this search addresses the core hypothesis laid out in section 1.3 above. The basic hypothesis of ability to effectively model the IT expansion of an air cargo network remains unproved.

Chapter III
Problem Formulation and Model

3.1. Introduction to the Modular Technology Model

The model introduced in this section allows an infrastructure planner to efficiently expand transportation operations to another country. This Modular Technology Model starts with operational and customer information requirements as model inputs. The model outputs are the technologies which can meet the requirements at optimized cost.

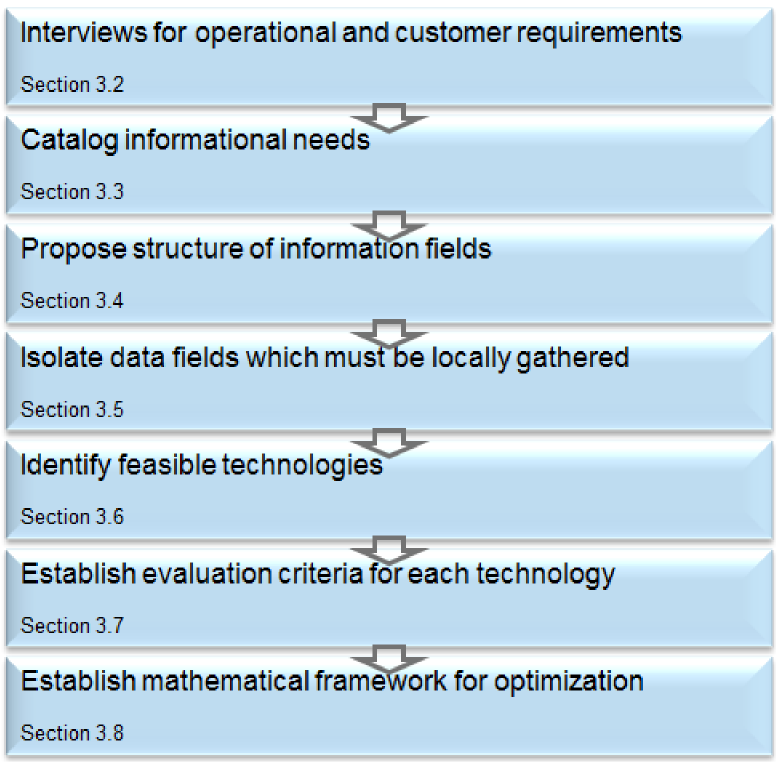

Figure 1 Path to Modular Technology Model

3.2. Interviews for operational and customer requirements

The assessment of information needs for air cargo network expansion into another country was conducted systematically.

3.2.1 Selection of interviewees

For this first step of the problem definition, the interviewees are drawn from companies representing over 13% of the international air cargo volume, by tonnes-carried (Air Cargo Management Group, Nov. 2000).

These three companies transport 25 billion tonne-kilometers of international and domestic shipments. By comparison, the top-ten air cargo providers transported 86 billion tonne-kilometers during that same time frame (International Air Transport Association, Cargo Facts – July 2013). Therefore, this sample size represents approximately 30% of the tonne-kilometers transported by the largest air cargo providers.

This selection of cargo carriers is representative of the total customer and industry needs, based upon survey sample-size research conducted by Krejcie and Morgan (1970). Krejcie and Morgan assert that a chi-squared technique for determining sample size from a given population is accomplished by the formula:

$$s = X^2\, NP(1 - P) \div d^2\,(N - 1) + X^2 P(1 - P)$$

where s = required sample size
X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level
N = population size
P = the population proportion, which we can assume to be 0.50 to provide the maximum sample size
d = the degree of accuracy expressed as a proportion (0.05)

This sample size curve levels off at a population of approximately 75,000 transactions or 75,000 distinct interactions. The cargo companies in the scope of this research conduct millions of transactions with distinct customers and distinct cargo types each day. Conservatively assuming a population of 1,000,000 transactions, the above equation yields that the survey must represent at least 384 transactions. Therefore, a 0.0384% survey rate is a conservative estimate to capture the transactional data needs of air cargo carriers.

This survey, which represents over 13% of the air cargo volume, easily meets that standard for sufficiency of sample size.

3.2.2 Content and purpose of interviews

The visits to air cargo providers were conducted as part of a larger process improvement effort for air freight handling techniques. The interview questionnaire therefore primarily included probing questions regarding physical movement of air cargo. The question which yielded information relevant to this paper was a simple open-ended one, “Tell me about the information your internal and external customers require.”

3.2.3 Breadth of interviews

Sixteen interviews and eight observational visits were conducted at air cargo handling facilities

- Three major air cargo providers were represented. One of these is a passenger airline earning a significant portion of revenue through third party freight forwarders. The second is a passenger airline which has a prominent air cargo presence with direct customer relationships. The third is a dedicated freight airline. Each of the three is currently ranked among the top twenty air cargo carriers in the world, as ranked by tonnage carried
- Six countries and regional markets were represented in the interviews: France, Amsterdam, Canada, Hong Kong, Singapore, and the United States

- Each visit included interviews with an operational employee (courier or package handler) as well as a professional employee (manager or engineer)
- Two visits allowed for discussions with clearance brokers and customers
- Activities included tours of major sort facilities, local service stations, and regional airport ramps, as well as courier rides to customer locations and in-depth observations of import clearance processes

3.2.4 Compilation of findings

The notes from these interviews and observations were subsequently compiled and aggregated. Verbatim responses from the open-ended question of information flow were analyzed for both consistency and completeness.

The first finding was that sorting and linehaul employees have a consistent understanding of the data needs for their customers. For these employees, customers are primarily internal. Internal operations remain similar across the larger air cargo networks. Despite the varying degrees of automation, the information kernels remain similar.

The second finding was that variation in customer data expectations is more prevalent in other areas of the company, particularly in Clearance and Pickup/Delivery organizations. This results from variation in two features of services: a guaranteed commitment time for delivery, and an integrated courier service for pickups and deliveries. For purposes of this research, a moderate approach has been selected which encourages prompt notification of clearance delays and needs, yet which is less rigorous on the pickup requirements, such as electronic proof-of-possession records.

Through these interviews and operational observations, a series of needs was delineated which guide the problem statement, resulting in the catalog of informational needs reported below in section 3.3.

3.3. Catalog of informational needs

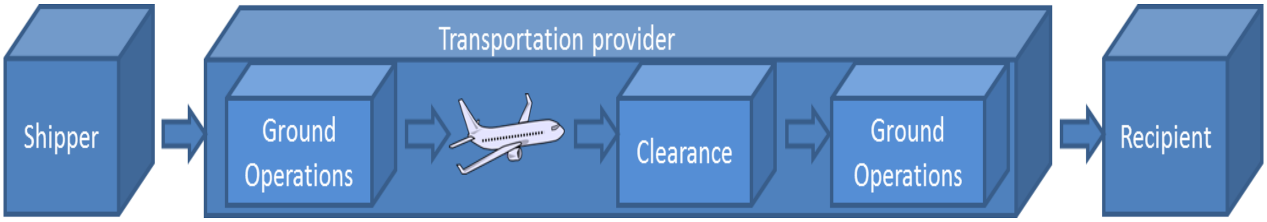

Figure 2 Customer and operational process map

The electronic information that must be collected will encompass all data fields needed for air cargo network expansion into a new country.

3.3.1 Customer Expectations

Some information is required to satisfy an external customer's data expectations. This model begins by looking at the different types of customers with which a transportation company interacts at each point in the shipment's life cycle:

- Shipper
- Recipient or Consignee
- Payor

3.3.2 Operational Requirements

Transportation providers must execute their tasks with efficiency. Many aspects of the business lend themselves to rigorous optimization routines if only the correct data were available.

- Load Organization (number and size of vessels)
- Route planning
- Ad-hoc route planning
- Labor demand planning
- Delivery route planning
- Status of low-capital equipment
- Quality performance

3.3.3 Full Range of Information needs for network management

As a result of the interviews conducted in section 3.2 above, forty specific information needs have been cataloged. The needs are divided below into Customer information and Transportation Provider information.

3.3.3.1 Customer information expectations

Each shipper must be aware of the expected pickup window, which is the earliest and latest time in which a courier is expected to arrive for package pickup. This timing drives a shipper's choice of transportation provider as well internal production and packaging schedules. Likewise, the shipper must be aware of any restrictions related to the packaging of their commodities. Knowing this before the courier arrives will prevent re-work or damaged contents. Drop point restrictions are constraints related to the ultimate recipient of the shipment; such restrictions may include dock door access, lift-gate availability, elevators, or needed security codes.

In a similar manner, recipients must have knowledge of the expected delivery window. This delivery window will drive production or sales plans as well as potential staffing decisions. Recipients must also have insight to hold-at-location restrictions if needed. For shipments sent with “cash on delivery” instructions, recipients should have foreknowledge of COD payment requirements to facilitate prompt payment. Since this new country network will primarily deliver international packages, recipients must be informed of needed Clearance paperwork and Brokerage requirements, such as power of attorney letters, commodity declarations, and intended usage of shipment contents. Duties and taxes will be due as a result of the clearance activities, and therefore recipients must be notified of payments obligations prior to release from the airport.

The payor for each shipment must be promptly informed of the payment required. Prior to paying, that payor will require visibility of the Proof of Delivery, indicating the package arrived on time and undamaged. This will be seconded by the Proof of Delivery signature which provides an internal assurance of delivery to the proper disposition. Lastly, should abnormalities be uncovered at a later time, payors need full shipment data in a format that is needed for the transportation provider’s claims process.

3.3.3.2 Transportation provider information needs

The transportation provider must organize each load aboard the aircraft according to certain parameters. For example, the total aircraft payload must be respected, as well as the payload per individual air cargo container or pallet. This requires knowledge of not only the number of shipments and number of pieces within those shipments, but also the package weight for each. A second parameter is the bulk loading of the aircraft. This becomes a factor of the package dimensions, and requires knowledge in particular of oversize and unusual shipments. A third parameter is the handling restrictions placed upon aircraft loaders. Such handling restrictions include “top of stack” expectations, hazardous goods, live animals, refrigerated goods, and others.

Within each transportation provider, route planners organize the linehaul network according to capacity and growth requirements. Each route decision relies upon knowledge of the size (known as gauging) of the individual vessels, such as aircraft and trucks. This vessel gauging varies due to the maintenance status of aircraft and trucks, as well as with the gauge-specific containers which have been loaded by the local stations. Route planners also require visibility to the backhaul activities within the network. Such visibility allows for anticipatory placement of the proper equipment in each market. Lastly, linehaul route planning requires knowledge of the operational timing of the pickup operations in each market. These times, known as Cutoff times, are the times at which couriers will cease pickups and return to the stations and sort facilities to begin consolidation activities to prepare for the aircraft departure.

Not all linehaul routing decisions can be pre-planned as described in the preceding paragraph. Rather, a certain amount of ad-hoc linehaul routing occurs each day. Accomplishing this ad-hoc re-routing requires information as well. For example, knowing the status of each sort location allows for volume to be redirected away from a slow sort and toward a location currently operating at a greater throughput. That same knowledge may also allow for re-sequencing in downstream operations which may suffer from an unexpectedly late flight out of the slower sort location. Ad-hoc planning also requires real-time knowledge of the location of ships, aircraft, vehicles, and containers in order to accurately calculate remaining travel times and arrival times. Information regarding the status of package at each point in lifecycle allows for targeted intervention where necessary to satisfy delivery commitments. Traffic patterns and weather patterns are a key input to ad-hoc routing for their ability to dramatically influence transit times and wait periods. Lastly, security considerations such as unplanned government screening activities or safety emergencies must be visible to linehaul planners in order to accurately calculate network performance.

Labor demand planning requires specific information regarding the constraints and capacities of a given operation. For example the degree to which a country's work force is flexible and cross-trained, can determine the extent to which volume fluctuations can be absorbed. The workforce model – which may be full-time employees, part-time employees, independent contractors, or third-party providers – is an important aspect of knowledge which is required to effectively structure the local operations.

Planning the delivery routes is a well-studied operations research challenge, and requires detailed information for adequate optimization. The primary piece of knowledge is the location to which delivered is to be made, commonly referred to as the recipient address. Though this point forms the basis for the delivery route arrangement, ad-hoc changes require recipient contact information to allow for schedule changes, special directions, gated community access, or dock door preferences. For frequently visited locations, that access information for multi-tenant locations can be stored and referenced. Delivery routes will also be affected by the same traffic and weather patterns as described above for linehaul planning.

Low-capital equipment must be available for these operations. Therefore, complete information about inventory status is required. Package handlers require access to dunnage in order to brace and reinforce stacks of parcels. Dunnage availability will help minimize package damage and unsafe shifts in the load. The containers themselves, whether specialized air cargo containers, air cargo pallets, or the more generic sea cargo containers used by many freight forwarders must be in supply in order to safely transport smaller parcels as they interface with the air cargo network. Packages on either end of the spectrum require special considerations as well – cargo nets for larger pieces of palletized air freight and reusable totes for quantities of smaller parcels and envelopes.

Transportation providers are judged upon their quality. Effective process management requires measurement and visibility to the quality status for each package, whether it is late or damaged. Further information is valuable to help investigate the cause of any poor trends in quality status.

3.4. Structured categorization of information needs

Working from the above lists of customer and operational requirements, a table of important elements (Table 9) can be generated. This table represents a realistic picture of all the information needed for effective performance in a new market.

The data fields are categorized based upon their relative location in the value chain as well as the intended audience for that information.

Table 9 Full range of data fields, categorized

Customer's data expectations	Shipper	Expected pickup window
		Drop point restrictions
		Proof of Possession
		Packaging restrictions
	Recipient /Consignee	Expected delivery window
		Hold-at-location restrictions
		COD payment requirements
		Needed Clearance paperwork
		Brokerage requirements
		Duties and taxes notification
	Payor	Payment required
		Proof of Delivery
		Proof of Delivery signature
		Data needed for claims
Transportation provider's needs	Load organization	Number of shipments
		Number of pieces
		Package Weight
		Package Dimensions
		Handling restrictions
	Linehaul route planning	Vessel gauging
		Backhauls
		Cutoff times
	Ad-hoc Linehaul routing	Status of each sort location
		Real-time locations
		status of package at each point in lifecycle
		Traffic patterns
		Weather patterns
		Security
	Labor demand planning	Flexible and cross-trained work force
		Contractor model
	Delivery Route planning	Recipient address
		Recipient contact information
		Traffic patterns
		Weather patterns
		Access information for multi-tenant locations
	Low-capital equipment placement	Dunnage
		Air cargo containers
		Sea cargo containers
		Cargo nets
		Reusable totes
	Quality performance	Quality status for each package
		Cause of quality status

3.5. Isolating data fields which must be locally gathered

The 40 unique pieces of information in Table 9 are all necessary for an effective transportation service in a new country. However, they are not all relevant for specifying the technology infrastructure and collection methods. Many of these items are derived elements, such as Payment Required. Others are look-up elements, such as Brokerage Requirements or Cutoff Times. Still other elements can be centralized and need not be duplicated when extending into an additional country – examples include Weather predictions and Backhaul planning.

Table 10 below illustrates the four categories of Data Fields: Derived, Lookup, Centralized, and Locally generated.

The Modular Technology Model developed in this paper will focus upon technologies for providing the ten information fields which must be locally generated. What remains is a list of ten data elements that must be locally generated inside the incremental operating country:

- Proof of Possession
- Needed Clearance paperwork
- Duties and Taxes monies required
- Proof of Delivery (time)
- Proof of Delivery (signature)
- Status of package at each point in lifecycle
- Package dimensions
- Package weight
- Location of containers
- Quality status of each package

3.5.1 Lifecycle view of the ten key information fields

These ten information fields which must be locally generated are arranged in the package lifecycle as shown below:

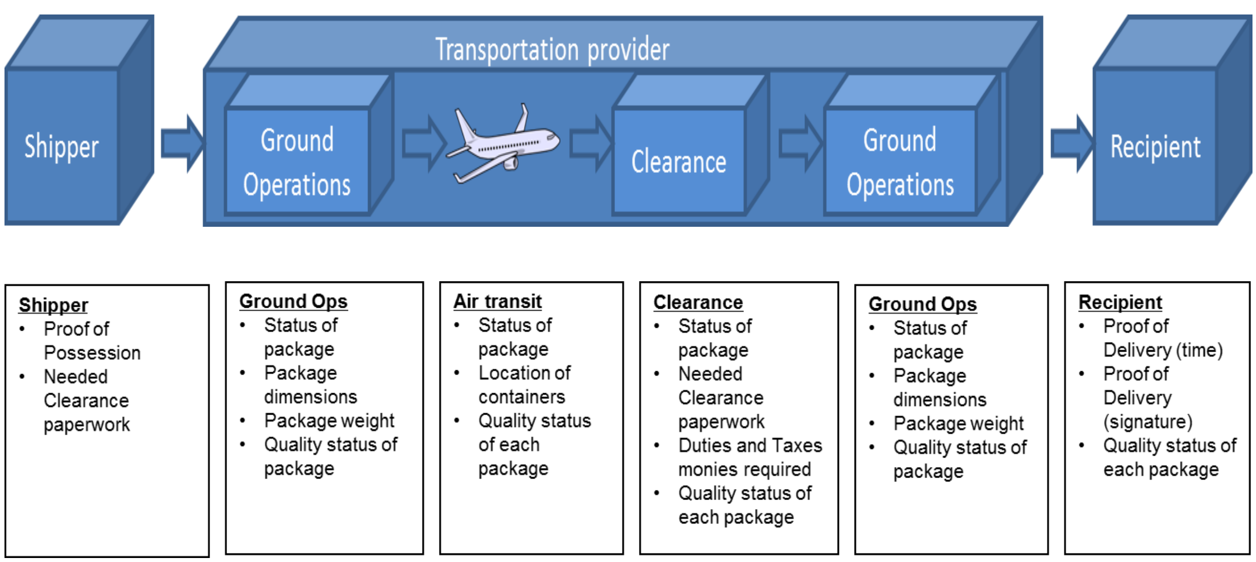

Figure 3 Lifecycle view of ten key information fields

Table 10 Categorization of data fields

Needed Clearance paperwork	Locally generated: Data fields which must be independently captured in the new country, typically unique for each shipment
Proof of Possession	
Duties and taxes notification	
Package Weight	
Proof of Delivery	
Proof of Delivery (signature)	
Quality status for each package (late or damaged)	
Package Dimensions	
Real-time location of ships, aircraft, vehicles, and containers	
Status of package at each point in lifecycle	
Expected pickup window	Lookup: Data fields which may be obtained once for each country, then referenced in lookup tables as necessary
Drop point restrictions	
Brokerage requirements	
Data needed for claims	
Packaging restrictions	
Contractor model	
Expected delivery window	
Hold-at-location restrictions	
COD payment requirements	
Cutoff times	
Access information for multi-tenant locations	
Handling restrictions (top of stack, hazardous goods, live animals, refrigerated, etc.)	
Traffic patterns	Centralized: Data fields which will apply to the new country, but which can be assessed and managed from a centralized operations headquarters or control center
Weather patterns	
Security	
Flexible and cross-trained work force	
Contractor model	
Status of each sort location	
Dunnage	
Air cargo containers	
Sea cargo containers	
Cargo nets	
Reusable totes	
Backhauls	
Vessel gauging	
Number of shipments	Derived: Data fields which can be calculated using other data fields as input
Number of pieces	
Payment required	
Recipient contact information	
Recipient address	
Cause of quality status	

Table 11 Information inputs to the derived data fields

Number of shipments	Derived from Proof of Possession
Number of pieces	Derived from Proof of Possession
Payment required	Derived from shipment weight, dimensions, origin proof of possession, destination proof of delivery, and current tariff table
Recipient contact information	Derived from Proof of Possession
Recipient address	Derived from Proof of Possession
Cause of quality status	Derived from Quality status at each point

3.6. Feasible Technology Options

Gathering the local information can be accomplished in a variety of methods. The collection methods employ both the latest technology as well as techniques employed by process-improvement practitioners in the more traditional areas of manufacturing and production. The methods listed below are robust technologies that have been proved through several years. These methods therefore have known costs and success rates:

- Passive RFID – the least expensive version of RFID
- Active RFID – powered RFID tags that can be read from anywhere within a facility
- Employee scan – manually applied, using a bar code and a menu of assignable attributes
- Automatic in-line scan – applies an attribute to all packages passing through the scanner
- Employee-entered free-form text – applies comments to any package in any format
- Visual Management or Kanban – facilitates local operational decisions without IT overhead
- Manual scales – inexpensive method to secure package sizing while on-road
- Customer-entered data – inexpensive method to obtain package sizing without employee involvement
- Automatic in-line dimensioner – applies full package sizing data to a package without employee input
- Call Center employee entered – allows for human discussion to help customers enter correct sizing

Table 12 Mapping information needs to feasible technologies

	RFID	Barcode scan	Free-form text	Lean techniques	Scales	Customer -entered
Needed Clearance paperwork		Employee	Employee or Call-center	Visual Management		
Proof of Possession	Passive	Employee or automatic	Employee	Visual Management		
Duties and taxes notification			Employee or Call-center			
Package Weight			Call-center		Manual or Automatic	Manual
Proof of Delivery	Passive	Employee	Employee			
Proof of Delivery (signature)			Employee			
Quality status for each package (late or damaged)		Employee	Employee	Visual Management		
Package Dimensions			Call-center		Manual or Automatic	Manual
Real-time location of ships, aircraft, vehicles, and containers	Active	Employee	Employee	Kanban		
Status of package at each point in lifecycle	Passive	Employee or automatic	Employee	Visual management or Kanban system		

3.7 Evaluation criteria for technology options

These ten information gatherers will be judged upon the following criteria:

- Time to perform the information gathering step
- Loss rate of equipment
- Cost per piece of disposable equipment, such as RFID tags
- Cost per piece of fixed equipment, such as RFID scanner, bar code scanner, or dock
- Accuracy rate

The numerical values for these evaluation criteria will be provided later in Table 13.

3.7.1 Monetization of Technology evaluation criteria

The method for monetizing each of these is divided into four sections: initial capital cost, monthly non-labor expenses, monthly labor expenses, and monthly costs related to customer complaints.

Initial capital costs are derived from vendor estimates and quotes. This value is scaled by the number of items required to purchase, resulting in a single initial cost for the expanded operation.

Monthly non-labor expenses are driven by three main areas. The first is disposable items such as passive RFID tags. Such tags are assigned to each package, typically in the form of a sticker, and therefore are continually disposed of by the recipients. The second recurring non-labor expense is that of a communications signal. Wireless or cellular signals will be required for all the technologies relying on bar-code scanning. The third recurring expense will be due to the inaccuracies of relying upon customers to report weights. This reliance would open up the company to significant missed revenue due to misquoted weights.

Monthly labor expenses are incurred when employing technologies that require human intervention. This will occur with most of the bar-code scanning options, with the manual scales, or with the phone-based customer-service agents entering information.

Monthly costs related to customer complaints will vary with the technology's accuracy, or perceived accuracy. For example, a technology such as using visual management to regulate each package's status will be very accurate for operational purposes. It will not, however, be electronically visible to a shipper and will therefore result in an increased number of customer service complaints. This Modular Technology Model allows the modeler to incorporate complaint rates and call costs in order to reflect this impact.

Accuracy rate can be determined through equipment specifications as well as through established industry usage. Each of the techniques and technologies described in this paper are well used in the supply chain industry, with known error rates. Similarly, if the network expansion into a new country occurs through acquisition, the acquired company's existing technology can be tested for accuracy rates. A less tangible measurement associated with accuracy is the relative likelihood of an inaccurate information field to result in a customer complaint to the call center. In this case, it is assumed that the either the shipment origin or destination is in a more industrialized nation. For this, the relative likelihood of customer complaints can be estimated and is included in the case study of Chapter IV.

3.8. Establishing the mathematical framework for optimization

3.8.1 Advantages of Fixed Charge Integer Program

This problem is set up as a Fixed Charge Integer Program. Fixed Charge Integer Programs are adaptable for location and production type problems. In this model, the program will be adopted for a decision problem.

Fixed Charge Integer programs are comprised first of the binary decision variables common to all integer programs. An additional layer of decision variables are then added in to reflect the fixed costs of making a certain decision, whether the decision is to open a new factory or purchase new IT technology.

The structure allows for all of the complications mentioned below, but is still concise enough to be modeled in an off-the-shelf optimization application (Gurobi optimizer) without customization. Lee and Vora (1993) employed a similar model for personal investors and noted, “the model remains tractable enough for implementation by individuals who may not be experts in mathematical programming and financial planning.”

3.8.2 Published uses of the Fixed Charge Integer Program

As detailed in the literature review, 2.8, several instances of this model have been found in published works. The majority of usages are for location selection, with two being broadened to investment applications and capacity expansion. None of the published instances employ the fixed charge integer program to make Information Technology investment decisions for expansion of an Air Cargo network.

3.8.3 Structure of Fixed Charge Integer Program

Gathering local information will require expenditures of capital as well as ongoing costs to collect the data. The Fixed Charge Integer Program structure allows for both to be modeled effectively.

The model is set up with *decision variables* that are varied to satisfy the constraints. The decision variables are written as:

x_{ij} where i is the type of technology and (1)
j is the required information to be gathered

When a decision variable x_{ij} equals 1, then the i^{th} technology is used to gather the j^{th} data element. When x_{ij} equals 0, some other technology has been chosen to fulfill the j^{th} data element.

The model has an *objective function* to minimize the cost. At its simplest, this would be a dot product of the matrix of decision variables (x_{ij}) times the matrix of costs (c_{ij}, which are capital plus present-value expenses). However, this setup would not allow for cases where a technology such as employee-entered scans is used to gather more than one data element. The fixed costs should only be incurred once in such a situation, rather than penalizing each new application of the already-purchased equipment.
To accomplish this, a dummy variable is established. The dummy variable y_i will indicate whether the fixed charge should be added to a certain portion of the integer program.

y_i = 0 when no data elements require the i^{th} technology (2)

1 when any data element requires the i^{th} technology

The constraints for this integer program are established to accomplish the goals. First, a constraint is established to regulate the type of data:

$$x_{ij} \quad \text{is binary for all } i, j \tag{3}$$

Secondly, constraints are added which guarantee that every data element is satisfied by only one technology:

$$\sum_{i=0}^{n} x_{ij} = 1 \text{ for each data element } j \tag{4}$$

Thirdly, constraints are needed which employ the dummy variable in properly assigning the fixed charges as shown by Winston [1]. To accomplish this, we must employ a method to test if any $x_{ij} = 1$ for a given technology i and if so then set the dummy variable $y_i = 1$.

$$\sum_{j=0}^{m} x_{ij} \leq M\, y_i \text{ for each technology } i \tag{5}$$

where M is a very large number. In the case of this model with only ten possible data elements, M was selected to be 1,000, but theoretically only needed to be eleven.

The complete expression of the model becomes:

Minimize: (6)

$$\sum_{j=0}^{m} \sum_{i=0}^{n} x_{ij}\, c_{ij}$$

Subject to:

$$x_{ij} \quad \text{is binary for all } i, j$$
$$\sum_{i=0}^{n} x_{ij} = 1 \text{ for each data element } j$$
$$\sum_{j=0}^{m} x_{ij} \leq M\, y_i \text{ for each technology } i$$

3.8.3.1 Incorporating unique complications for this model

Continuing this data stream will incur some ongoing monthly expenses for perishable equipment, service charges or labor costs. Therefore the model has significant complications:

The first unique complication of this model is the need for efficient treatment of ongoing expenses. This is accomplished through the use of a Present Value calculation. Use of the present value formulation is common in finance, accounting, and economics research; however, the literature review conducted for this paper uncovered no instances of this more sophisticated treatment of costs imbedded within a Fixed Charge integer program. The Net Present Value is calculated as shown in section 4.2.2 for the associated case study.

The second unique complication of this model is the ability to make allowances for compatible technologies, when technologies in one aspect of the operation work more efficiently if paired with certain technologies in other aspects of the operation. This means that even certain ongoing monthly expenses must be treated as a “fixed charge” within the model to account for the advantages of shared technology.

A common example of this distinction is that of a hand-held scanner. The following three points outline the considerations:

(1) The scanner equipment has an up-front cost which is modeled by the “fixed charge” portion of the c_{ij}. That means that the scanner equipment needs only to be purchased once, no matter how many pieces of information it collects.

(2) The labor to operate the scanner varies with the number of data elements which the scanner collects. That is, couriers and package handlers incur a greater labor cost for performing five scans per package than for performing one scan per package. Therefore, each additional data field has an incremental impact upon the c_{ij}. The labor cost is incurred month by month, and therefore is treated as a Net Present Value to be incorporated into the primary model.

This labor calculation is similar to the treatment of ongoing accuracy costs. Each pairing of technology to data need has an associated accuracy penalty. That penalty is an ongoing monthly cost and is therefore quantified as a Net Present Value. The penalty is scalable, however, according to the number of data elements a technology captures and is therefore modeled in the same manner as labor costs.

(3) The wireless fees to operate a scanner also drive month by month costs. However, unlike the labor costs, these wireless contracts are not incremented based upon the number of data elements collected. Therefore, collecting one data field requires the same wireless contract as collecting five data fields with that hand-held scanner. This monthly fee is calculated using net Present Value, then modeled by the “fixed charge” portion of c_{ij}.

These complications are instrumental in establishing the accurate representation of the component costs, c_{ij}. The component costs are a driving factor in the case study of Chapter IV, which underscores the need for the more sophisticated treatment of c_{ij} which is shown here, but not seen in other published literature.

3.9 Model fulfillment of guiding hypothesis

As stated in section 1.3, the guiding hypothesis of this research is that the information technology (IT) decisions supporting expansion of an air cargo network can be effectively modeled. Furthermore:

- The model can be general enough to include upfront and ongoing costs, as well as high-technology and low-technology solutions
- The model can be simple enough to be solved within a common business application
- The IT expansion model can then be optimized based upon cost while meeting a minimum established customer expectation

Each of these components is addressed through a portion of the model described in Chapter III. Specifically:

- The upfront costs are accomplished by the incorporation of a dummy variable, y_i, to indicate whether the fixed charge should be added to a certain portion of the integer program

- The ongoing costs are modeled by the cost matrix described in section 4.2. This cost matrix is populated using the net present value of ongoing costs
- The mixture of high-technology and low-technology solutions is possible due to the adoption of a fixed-charge integer program with compatible criteria so that each technology solution only competes to supply those pieces of information with which it is well-suited
- The model is established with a straight-forward binary structure and a minimum of variables, allowing it to be solved with simple software
- The model is optimized as described in Chapter IV below

Chapter IV
Case Study

4.1. Assumptions for populating Modular Technology Model

As a starting point for this model, certain reasonable assumptions were made regarding the nature of operations in this new country. These assumptions do not restrict the model capabilities in any way; rather, they are programmed as input variables that can be easily set to different values depending on the situation.

- Only one aircraft ramp (or gateway) will be employed in this new country. The assumption will be valid in almost all Southeast Asia, Eastern Europe, Middle East, or African nations due to the existence of only one major city. This assumption may need modification in geographically dispersed areas such as Brazil or sub-Arctic regions.
- Ten accumulation stations will be scattered throughout the country. This allows for three or four in the largest city and others to be positioned in minor cities or industrial zones.
- The package flow through this country is assumed to be 5,000 shipments inbound each day, and an additional 5,000 shipments outbound each day. This is a reasonable assumption for emerging markets worldwide.
- New countries do not have a dense network of customers, therefore this research has assumed that couriers will be able to handle forty packages per day (twenty pickups and twenty deliveries). Air cargo companies expanding into denser urban markets may be able to quickly grow this three-fold or more.
- Nationwide, this country will need package handlers who can sort and process the volume in about 1 hour each day. 10% of these will be available to gather requisite package information.
- Wages were selected to be representative of several of these areas. $2.00 per hour is representative of opening markets such as Ukraine and was the starting point for this analysis. If expanding into countries such as Philippines those wages will be even lower, at approximately $0.60 per hour.
- Customer call centers are often located in English speaking areas which will command a slightly higher wage than the population which is physically handling the package. Therefore, an industry-standard $2.50 per phone call is used in this analysis.
- A standard revenue per pound value was selected to calculate the revenue that might be lost due to incorrect data regarding package sizing. A nominal $1.00 per pound is selected in deference to corporate financial sensitivity. Several companies have published their revenue-per-pound statistics with typical values being in the $0.50 range, but industry experience indicates these are among the lower values seen by air cargo transportation providers.
- Calculation of the number of air cargo containers follows from an assumption of 100 packages per container. This allows for high-revenue documents, but also recognizes that a typical emerging market relies heavily upon air cargo for transportation of heavyweight and bulky freight as it expands its industrial base.

Within the cost calculations, further data elements are needed to estimate the financial impact of choosing a certain technology infrastructure. Values for these are selected from vendor quotes, time-motion analysis of employees, and results of equipment testing performed within the air cargo industry. These values will vary for each technology, but are listed here to communicate the scale of the research.

- Time to perform the information collection step
- Loss rate of equipment, especially RFID tags
- Capital costs (initial RFID tags, handheld scanners, installed readers, Kanban area setup, etc.)
- Accuracy rate (for scanners, dimensioners, or human decisions)
- Percent of customers who will complain when data inaccuracy occurs
- Cost for wireless services to support certain technologies
- Average weight error

The table of assumptions is then populated as shown below in Table 13. Any of these values can be modified in the model.

Table 13 Assumptions: operational parameters for air cargo carrier

Interest Rate (monthly)	0.25%
# of months	48
# of ramps	1
# of stations	10
# of couriers	250
# of package sorters/handlers	200
% of sorters with handheld scanners	10%
# packages per day inbound	5000
# packages per day outbound	5000
wage rates	$2.00
days per month	21
cost per customer phone call	$2.50
revenue per pound	$1.00
# of containers	50

Table 14a: Assumptions: cost parameters of technology options

	time to perform (minutes)	loss rate of RFID tags	cost per RFID tag	cost per RFID scanner	accuracy rate	cost per hand-held scanner	cost per scanner dock
Passive RFID	0.00	0.5	$0	$2,000	70%	n/a	n/a
Active RFID	0	0.005	$15	$5,000	95%	n/a	n/a
Employee scan	0.1	n/a	n/a	n/a	95%	$350	$1,000
Auto in-line scan	0	n/a	n/a	n/a	99%	$0	$50,000
Employee-entered free-form text	2	n/a	n/a	n/a	90%	$350	$1,000
Visual management	0.1	n/a	n/a	n/a	99%	n/a	n/a
Kanban system	0.1	n/a	n/a	n/a	99%	n/a	n/a
Manual scales	2	n/a	n/a	n/a	90%	n/a	n/a
Customer-entered	0	n/a	n/a	n/a	30%	n/a	n/a
Auto in-line dimensioning devices	0	n/a	n/a	n/a	99%	n/a	n/a
Call-center employee entered	5	n/a	n/a	n/a	15%	n/a	n/a

Table 14b: Assumptions: cost parameters of technology options (continued)

	cost for wireless communications (monthly, per scanner)	cost to set up and train bin systems (per location)	cost for scale	cost for wireless dimensioner	avg weight error (oz)	likelihood of customer complaint
Passive RFID	n/a	n/a	n/a	n/a	n/a	100%
Active RFID	n/a	n/a	n/a	n/a	n/a	100%
Employee scan	$30	n/a	n/a	n/a	n/a	100%
Auto in-line scan	$0	n/a	n/a	n/a	n/a	100%
Employee-entered free-form text	$30	n/a	n/a	n/a	n/a	100%
Visual management	n/a	$10,000	n/a	n/a	n/a	100%
Kanban system	n/a	$10,000	n/a	n/a	n/a	100%
Manual scales	n/a	n/a	$15,000	$300	2	100%
Customer-entered	n/a	n/a	n/a	n/a	24	5%
Auto in-line dimensioning devices	n/a	n/a	$70,000	n/a	0.5	30%
Call-center employee entered	n/a	n/a	n/a	n/a	16	5%

4.2. Full Model with numerical values

4.2.1 Development of costs and expenses

The first matrix to be calculated is that of the capital costs and expenses. Values are calculated as follows:

Capital Cost = (# of stations + # of ramps) x (equipment costs)

An example of this is with the Active RFID technology, where

Capital Cost = (10 stations + 1 ramp) x ($5,000 per scanner) + (50 containers) x ($15 per container)
= $55,750

Non-labor monthly expenses will vary with each technology type. A representative example is:

Employee Scan Monthly expenses (non-labor)
= (# couriers + # sorters) x (monthly wireless cost per scanner)
= (250 couriers + 200 sorters) x ($30 per month per scanner)
= $13,500

The accuracy of each technology drives costs as well, namely the costs to maintain customer service functions that address customer concerns regarding incomplete or incorrect information. These customer service costs are modeled as a call-center contact. Each of the technology types is modeled similarly. An example of the format is:

Employee-entered free-form text Accuracy
= (# packages per day outbound) x (# operating days per month) x (1- accuracy rate) x (% of customers likely to complain, given the type of technology) x (cost per phone call to customer service)
= (5000 packages) x (21 days) x (1-90%) x (100%) x ($2.50)
= $26,250 per month

Additional labor costs may be a concern for technology selection, even in low-cost countries. The formula for each of these will vary slightly, but two representative formulas are:

Visual Management additional labor
= (# packages per day) x (# operating days per month) x (time to perform the step in minutes) x (hourly wage rate / 60)
= (5000 packages) x (21 days) x (0.10 minutes) x ($2.00/hour) / (60 minutes/hour)
= $350 per month

Call-center employee-entered additional labor
= (# packages per day) x (# operating days per month) x (time to perform the step in minutes) x (hourly wage rate / 60)
= (5000 packages) x (21 days) x (5.0 minutes) x ($2.00/hour) / (60 minutes/hour)
= $17,500 per month

Table 15 Calculated capital costs for each technology option

	capital cost
Passive RFID	$24,000
Active RFID	$55,750
Employee scan	$105,500
Auto in-line scan	$2,200,000
Employee-entered free-form text	$105,500
Visual management	$55,000
Kanban system	$0
Manual scales	$345,500
Customer-entered	$0
Auto in-line dimensioning devices	$70,000
Call-center employee entered	$0

Table 16 Calculated expense costs for each technology option

	monthly expenses (non-labor)	Accuracy (monthly customer complaints)	Additional labor (monthly)
Passive RFID	$21,000	$78,750	$350
Active RFID	$0	$13,125	$0
Employee scan	$7,500	$13,125	$350
Auto in-line scan	$0	$2,625	$0
Employee-entered free-form text	$7,500	$26,250	$7,000
Visual management	$0	$2,625	$350
Kanban system	$0	$2,625	$350
Manual scales	$7,500	$7,875	$14,000
Customer-entered	$147,000	$0	$0
Auto in-line dimensioning devices	$0	$788	$0
Call-center employee entered	$178,500	$11,156	$17,500

4.2.2 Calculation of Net Present Value

Investment decisions involving recurring or planned future expenses require the use of a Net Present Value calculation to properly ascertain the expenses' impact. Net Present Value is calculated as:

Net Present Value = $\sum_{t=0}^{N} R_t / (1 + i)^t$ where t is the spacing of the expenses
and i is the discount rate in effect
and R is the amount of the net expenses

One of the additional complexities is that the monthly service fee for wireless communications required by scanners is calculated as a present value, and is then added in to the model as a fixed charge. This is a non-labor monthly cost that which is not scaled up depending on how many times per day the wireless signal is used. The three technologies which receive this treatment are noted in Table 17.

Table 17 Calculated present values for each technology option

	Present Value of Monthly Expenses
Passive RFID	($4,533,693)
Active RFID	($594,453)
Employee scan	($610,305) ($366,862) ** treated as fixed cost
Auto in-line scan	($118,891)
Employee-entered free-form text	($1,505,947) ($366,862) ** treated as fixed cost
Visual management	($134,743)
Kanban system	($134,743)
Manual scales	($1,602,192) ($366,862) ** treated as fixed cost
Customer-entered	($6,657,871)
Auto in-line dimensioning devices	($35,667)
Call-center employee entered	($9,382,447)

4.2.3 Full mathematical model

Inserting each of the above tables of numbers into the given modeling objective and constraints given above, results in the following detailed model. The system of indices to be adopted here is shown in Table 18:

Table 18 Indexing nomenclature for mathematical model

Type of Technology	Index value *i*
Passive RFID	A
Active RFID	B
Employee scan	C
Auto in-line scan	D
Employee-entered free-form text	E
Visual management	F
Kanban system	G
Manual scales	H
Customer-entered	I
Auto in-line dimensioning devices	J
Call-center employee entered	K

Information to be gathered	Index value *j*
Proof of possession	1
Needed Clearance paperwork	2
Duties-and-taxes monies required	3
Proof of delivery (time)	4
Proof of delivery (signature)	5
Status of package at each point in lifecycle	6
Package dimensions	7
Package weight	8
Location of containers	9
Quality status	10

Minimize:

$\$4,533,693\ (X_{A1} + X_{A6})$
$+ \$594,453\ (X_{B9})$
$+ \$610,305\ (X_{C1} + X_{C2} + X_{C4} + X_{C6} + X_{C9} + X_{C10})$
$+ \$118,891\ (X_{D1} + X_{D6})$
$+ \$1,505,947\ (X_{E1} + X_{E2} + X_{E3} + X_{E4} + X_{E5} + X_{E6} + X_{E9} + X_{E10})$
$+ \$134,743\ (X_{F1} + X_{F2} + X_{F6} + X_{F10})$
$+ \$134,743\ (X_{G6} + X_{G9})$
$+ \$1,602,192\ (X_{H7} + X_{H8})$
$+ \$6,657,871\ (X_{I7} + X_{I8})$
$+ \$35,667\ (X_{J7} + X_{J8})$
$+ \$9,382,447\ (X_{K2} + X_{K7} + X_{K8})$
$+ \$24,000\ Y_A$
$+ \$54,750\ Y_B$
$+ (\$105,500 + \$366,862)\ Y_C$
$+ \$2,200,000\ Y_D$
$+ (\$105,500 + \$366,862)\ Y_E$
$+ \$55,000\ Y_F$
$+ \$0\ Y_G$

$+ (\$345{,}500 + \$366{,}862)\ Y_H$
$+ \$0\ Y_I$
$+ \$70{,}000\ Y_J$
$+ \$0\ Y_K$

Subject to:
$\{X_{A1}, X_{A6}, X_{B9}, X_{C1}, X_{C2}, X_{C4}, X_{C6}, X_{C9}, X_{C10}, X_{D1}, X_{D6}, X_{E1}, X_{E2}, X_{E3}, X_{E4}, X_{E5}, X_{E6}, X_{E9}, X_{E10}, X_{F1}, X_{F2}, X_{F6}, X_{F10}, X_{G6}, X_{G9}, X_{H7}, X_{H8}, X_{I7}, X_{I8}, X_{J7}, X_{J8}, X_{K2}, X_{K7}, X_{K8}, Y_A, Y_B, Y_C, Y_D, Y_E, Y_F, Y_G, Y_H, Y_I, Y_J, Y_K\}$ are binary

$X_{A1} + X_{C1} + X_{D1} + X_{E1} + X_{F1} = 1$
$X_{C2}, + X_{E2} + X_{F2} + X_{K2} = 1$
$X_{E3} = 1$
$X_{C4} + X_{E4} = 1$
$X_{E5} = 1$
$X_{A6} + X_{C6} + X_{D6} + X_{E6} + X_{F6} + X_{G6} = 1$
$X_{H7} + X_{I7} + X_{J7} + X_{K7} = 1$
$X_{H8} + X_{I8} + X_{J8} + X_{K8} = 1$
$X_{B9} + X_{C9} + X_{E9} + X_{G9} = 1$
$X_{C10} + X_{E10} + X_{F10} = 1$

$X_{A1} + X_{A6} \leq 1000\ Y_A$
$X_{B9} \leq 1000\ Y_B$
$X_{C1} + X_{C2} + X_{C4} + X_{C6} + X_{C9} + X_{C10} \leq 1000\ Y_C$
$X_{D1} + X_{D6} \leq 1000\ Y_D$
$X_{E1} + X_{E2} + X_{E3} + X_{E4} + X_{E5} + X_{E6} + X_{E9} + X_{E10} \leq 1000\ Y_E$
$X_{F1} + X_{F2} + X_{F6} + X_{F10} \leq 1000\ Y_F$
$X_{G6} + X_{G9} \leq 1000\ Y_G$
$X_{H7} + X_{H8} \leq 1000\ Y_H$
$X_{I7} + X_{I8} \leq 1000\ Y_I$
$X_{J7} + X_{J8} \leq 1000\ Y_J$
$X_{K2} + X_{K7} + X_{K8} \leq 1000\ Y_K$

4.2.4 Implementation in Gurobi
Gurobi optimization software provides a robust, business-friendly interface that allows for models to be executed from a variety of interfaces. A typical user of this model would employ the software on an infrequent basis. That is, this model can be set up once in a text-based “linear program” file. For each network expansion into another country, the entering arguments need to be updated with wage rates, expected volumes, and other inputs as described in section 4.1.

Once this linear program file is created, Gurobi allows for on-demand execution of the program through a command-line interface. Gurobi also allows for more complex executions through C#, Python, or Java portals, but those will not be necessary for this anticipated scenario.

The full model as given in section 4.2.3 is then implemented into the linear program file.

4.3. Fulfillment of guiding hypothesis in Case Study

Following this case study, it is useful to revisit the guiding hypothesis: that the information technology (IT) decisions supporting expansion of an air cargo network can be effectively modeled to reduce costs.
Each of these components is exemplified in this case study:

- The upfront and ongoing costs are accommodated in tables 15, 16, and 17
- The blend of high and low-technology solutions are reflected in tables 15, 16, and 17
- The model is optimized for cost considerations as described in section 4.2

4.4. Results of Modular Technology Model in Case Study

4.4.1 Industry standards for technology

A sampling of prominent air cargo companies indicates a bias toward bar-code scanning technology. As seen implemented in a variety of cargo handling facilities around the globe, bar-code scanners are preferred for all attribute-level information regarding a package. Typical technology usage is shown below in Table 19, and will be used as a baseline for comparison against the optimized model.

The technologies employed in Table 19 are expensive, both in terms of initial startup costs and ongoing labor costs. The total cost for the industry-standard collection of technologies is $8,248,932.

4.4.2 Results from optimizing Modular Technology Model

Upon execution of the linear program detailed in section 4.2.4, the resulting list of optimum technologies is available. The full results are shown below in Table 20.

The total cost to implement the technologies in Table 20 is $5,436,972, which represents the capital cost plus the present value of future expenses, as is consistent throughout this research. This result is a 34% improvement over the typical industry standard assemblage of technologies. The improvement in upfront cost is an immediate impact upon the profitability of a new country operation. Furthermore, the savings can also be invested elsewhere, to drive increased revenue growth from additional investments.

Inspection of the results indicates a preponderance of lower technology options, such as visual management and Kanban systems. The operational simplicity of the systems has outweighed the availability of information to external customers. An exception to this trend is the method for obtaining the package dimensions and weight. The biggest driver to automate the package sizing is the probability of lost revenue with most the competing technologies.

Table 19 Industry standard technologies

Data Requirement	Optimum Technology for Gathering Data
Proof of possession	Employee scan
Needed Clearance paperwork	Employee scan
Duties-and-taxes monies required	Employee-entered free-form text
Proof of delivery (time)	Employee scan
Proof of delivery (signature)	Employee-entered free-form text
Status of package at each point in lifecycle	Employee scan
Package dimensions	Auto in-line dimensioning system
Package weight	Auto in-line dimensioning system
Location of containers	Employee scan
Quality status	Employee scan

Table 20 Results from optimizing Modular Technology Model

Data Requirement	Optimum Technology for Gathering Data
Proof of possession	Visual management
Needed Clearance paperwork	Visual management
Duties-and-taxes monies required	Employee-entered free-form text
Proof of delivery (time)	Employee scan
Proof of delivery (signature)	Employee-entered free-form text
Status of package at each point in lifecycle	Kanban system
Package dimensions	Auto in-line dimensioning system
Package weight	Auto in-line dimensioning system
Location of containers	Kanban system
Quality status	Visual management

4.5. Sensitivity Analysis of proposed model

For sensitivity analysis, the key operating parameters are varied according to the values shown in Table 21 below. Each column represents a scenario, or a country, which might be encountered over a period of expansion. The ranges of operating parameters mimic the variation that would be seen in countries which are likely expansion targets.

4.5.1 Sensitivity to shipping volume

Assumed volumes were varied from half of the likely amount up to three times the likely amount. That is, from 5,000 packages per day to 50,000 packages per day (inbound plus outbound). With this assumption, all related assumptions were similarly scaled, such as the number of couriers and number of stations.

4.5.2 Sensitivity to Wage Rates
Assumed wage rates were varied from half of the likely amount up to five times the likely amount. That is, from $1.50 USD per hour to $5.00 USD per hour. This sensitivity analysis included the wages of couriers, package handlers, and call-center costs.

4.5.3 Sensitivity to Interest Rates
Assumed interest rates were varied from half of the likely amount up to four times the likely amount. That is, from 0.125% monthly rate to 1% monthly rate. This sensitivity analysis affects the impact of monthly costs versus up-front capital expenditures

4.5.4 Sensitivity to Time Horizon
Assumed time horizon was varied from half of the likely amount up to two-and-half times the likely amount. That is, from 24 months to 120 months. This sensitivity analysis affects the present value calculation for all technologies. The impact will seem significant when looking at the total up-front cost, because the comparisons are for a two-year cost versus a ten-year cost, for example. However, when expenditures are normalized on a per-year basis, the impact of time-horizon changes has a relatively flat curve. The portfolio of projects remains unchanged.

Table 21 Operating parameters in sensitivity analysis

Operating Parameter to be varied	Low range	mid-range (used in case study)	High range	highest range
Interest Rate (monthly)	0.00125	0.0025	0.005	0.01
# of ramps	1	1	3	5
# of stations	5	10	30	50
# of couriers	125	250	750	1250
# of package sorters/handlers	100	200	600	1000
% of sorters with handheld scanners	0.1	0.1	0.1	0.1
# packages per day inbound	2500	5000	15000	25000
# packages per day outbound	2500	5000	15000	25000
wage rates	1.5	2	3	5
cost per customer phone call	1.875	2.5	3.75	6.25
revenue per pound	0.75	1	1.5	2.5
# of containers	25	50	150	250
# of months (time horizon)	24	48	96	120

Table 22 Total technology costs at differing volumes

low-range	mid-range	high-range	highest range
$2,756,985	$5,436,972	$5,926,122	$27,184,853

Table 23 Total technology costs at differing wage rates

low-range	mid-range	high-range	highest range
$3,371,023	$5,436,972	$6,504,711	$10,202,970

Table 24 Total technology costs at differing interest rates

low-range	mid-range	high-range	highest range
$5,309,014	$5,436,972	$4,900,969	$4,427,380

Table 25 Total technology costs for varying time horizons

low-range	mid-range	high-range	highest range
$2,824,104	$5,436,972	$9,453,273	$11,411,067

4.5.4 Summary of sensitivity analysis

Technology costs vary with the various input parameters, yet not linearly. For example, a threefold increase in the volume barely increases the technology costs, yet a fivefold increase in volume causes a corresponding fivefold increase in technology costs. Increasing wage rates by 50% results in only a 20% increase in technology costs. And the increasing interest rates actually make investments with recurring monthly costs appear to be more attractive, due to their lower Present Value. The chart below (Figure 4) indicates the significant non-linear effects, particularly of volume increases.

What remains constant through all these variations, however, is that the mix of technologies is unchanged by the varying operational and economic parameters. None of the combinations of inputs resulted in a new portfolio of technologies to be selected.

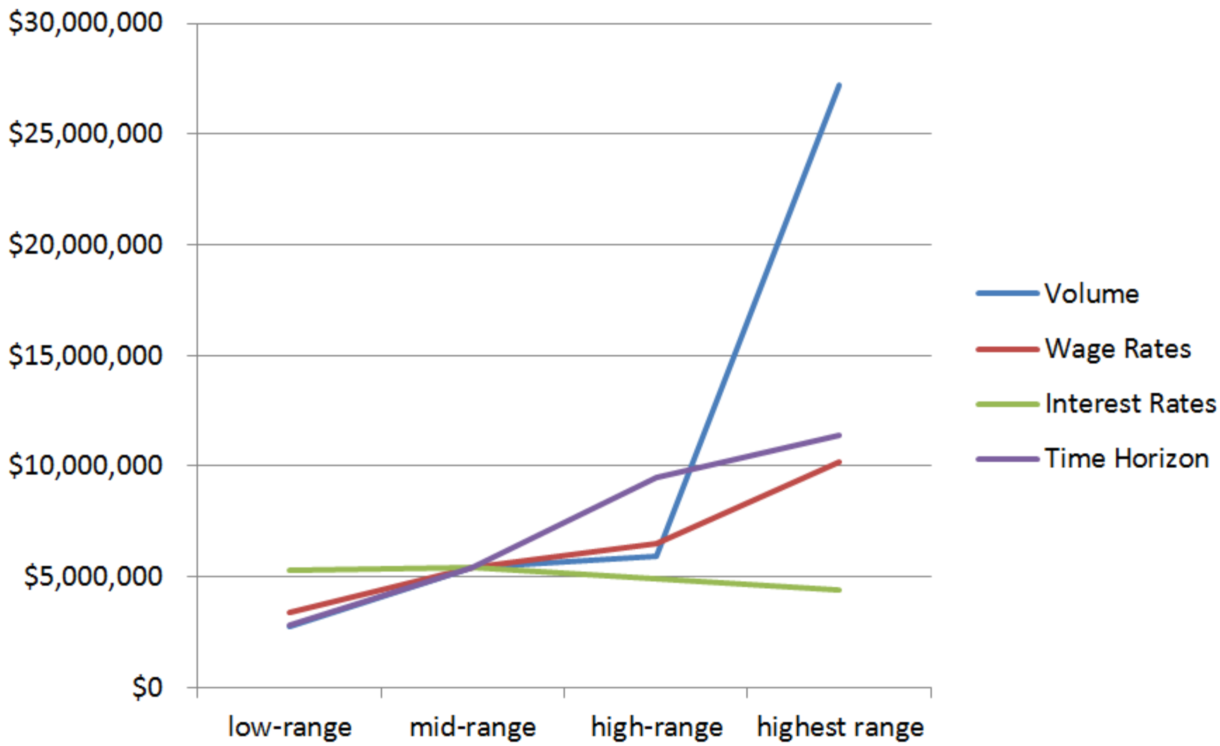

Figure 4 Non-linear effects of sensitivity parameters

Chapter V
Analysis and Implications of Results

5.1. Beyond sensitivity analysis – the impact of Uncertainty

Network expansion into a new country is subject to uncertainty. Such uncertainty may arise from the level of pre-existing technology in that country. The marketing estimates of shipping volume may be skewed or exhibit variability. The pace of growth may also differ from forecasts.

5.1.1 Pre-existing technology

An organic expansion, which is entirely developed by the expanding cargo carrier, has the benefit of a fresh slate for basing technology decisions. If network expansion into a country is accomplished via acquisition of a local freight forwarder or courier service, then the model must be adjusted to accommodate the situation.

One such adjustment is the Fixed Charge portion of the model. Pre-existing technologies, such as the existence of hand-held equipment or scales can be modeled by setting the one-time fixed charge to equal zero. The model will then look only at the ongoing costs to operate and staff the equipment, turn these ongoing costs into a present value, and optimize accordingly.

5.1.2 Volume Forecasts

The financial business case for network expansion requires an initial marketing estimate of the expected volumes. The sensitivity analysis in section 4.5 accounts for variations at that aggregate level. However, variations at more granular levels may also become factors. For example, a country with significant import/export imbalance will require special operational adjustments beyond what is initially calculated from the aggregate volume estimates. Likewise, major customers with day-to-day fluctuations in volume can drive adjustments within the network.

5.1.2.1 Import/export imbalances

(1) The low-capital equipment placement becomes a major factor resulting from import/export imbalances. If more cargo containers and dunnage are shipped out of the country, the supply must continually be renewed while minimizing the impact to linehaul cost, commonly known as an “empty backhaul.” This management, however, has already been determined to be one that is centrally managed.

(2) The second disruption, which is relevant to the model, arises from the pace of pickups and deliveries. A typical cargo company is aligned to deliver to recipients early in the day, then pickup from shippers later in the day. Shifting the import/export balance results in a surge of volume at one time of the day over another. That is, the new operation must purchase sufficient technology capacity for the highest demand times of day, knowing that the technology will be less utilized for the remainder of the day.

This situation, if it arises, can be handled in the model by dividing deliveries and pickups into two separate data requirements, and solving as shown in section 5.1.2.3 below.

5.1.2.2 Day-to-Day fluctuations

Day-to-day fluctuations may result from a single shipper who batches products for shipping on a single day of the week. Or, it may result from a local government’s clearance operations which close down on Friday or Saturday, then release a surge of inbound volume on Monday morning. The fluctuations may also result from customer demand, such as a flower exporter in South America who needs to ship inventory on Tuesday evening so that flowers will be on display at optimum freshness in the US or Europe on Friday afternoon when most customers purchase flowers.

Each of these scenarios can be modeled with a similar approach to the above, where the scenario is split into high-volume days and low-volume days, or further divisions as necessary. Then the solution proceeds as shown in section 5.1.2.3 below.

5.1.2.3 Method for analyzing unbalanced volumes

Unbalanced shipping volumes may result from a trade imbalance or a unique scenario of peak versus non-peak operating days. The process will be shown below for two levels: import/export or peak/non-peak. The two levels are captured simultaneously in the model, which allows for an optimal solution without iteration or heuristics. This process can be expanded to as many levels as required, up to approximately 300 decision variables, which is a practical limit for tractable solution as described in Thomadsen and Stidsen (2007) and Ahmed et al. (2003).

First, the model is augmented with data needs that reflect the different processes. Notice how the *Information to be gathered* portion of Table 18 is augmented with additional process information in Table 26 below. These are referred to as Levels of the information. For the case of a trade imbalance, the information technology planner may assign the Level 1 index to inbound processes and the Level 2 index to outbound processes. For the case of a day-to-day variation in volumes, the planner may assign Level 1 index to a peak day and Level 2 index to a non-peak day. The over-arching purpose of the levels is to allow greater granularity when optimizing for distinct processes.

For example, if trade imbalance results in an inbound volume that is significantly different than an outbound volume, the new network will have processes that work on two levels. Level 1 will be the unloading, sortation, and delivery of inbound volume. This level of the process often occurs early in the day. Level 2 will be the pickup, sortation, and loading of outbound volume. This level of the process often occurs later in the day. The two process levels already require different workforces due to their differing time periods. By also modeling the technology purchases with these two levels, information technology planners are now able to consider the possibilities that two different sets of technology may also be required within the processes.

For the second example of a day-to-day variation in volumes, a similar situation applies. A day with peak operating volumes will certainly require different labor planning than a day with non-peak volumes. The same process operates at two levels of labor demand. By modeling the technology usage with different levels, the technology purchases can now be modeled and optimized at a more granular level than if they had been merely averaged together, possibly resulting in distinct sets of technology purchases for the two process levels.

Table 26 Indexing nomenclature for model with unbalanced volumes

Type of Technology	Index value *i*
Passive RFID	**A**
Active RFID	**B**
Employee scan	**C**
Auto in-line scan	**D**
Employee-entered free-form text	**E**
Visual management	**F**
Kanban system	**G**
Manual scales	**H**
Customer-entered	**I**
Auto in-line dimensioning devices	**J**
Call-center employee entered	**K**

Information to be gathered	Level 1 Index value *j*	Level 2 Index value j
Proof of possession	**1**	**11**
Needed Clearance paperwork	**2**	**12**
Duties-and-taxes monies required	**3**	**13**
Proof of delivery (time)	**4**	**14**
Proof of delivery (signature)	**5**	**15**
Status of package at each point in lifecycle	**6**	**16**
Package dimensions	**7**	**17**
Package weight	**8**	**18**
Location of containers	**9**	**19**
Quality status	**10**	**20**

With the adoption of this new indexing system, the mathematical model remains similar. The indexing *decision variables* will remain the same, except the index *j* now increments from 1 to 20:

x_{ij} where *i* is the type of technology and *j* is the required information to be gathered (1)

The dummy variable y_i which indicates whether the fixed charge should be added to a certain portion of the integer program remains unchanged, since the purchase of a technology type can be shared across days and times of day.

y_i = 0 when no data elements require the i^{th} technology
1 when any data element requires the i^{th} technology (2)

The constraints to regulate the type of data are unchanged:

x_{ij} is binary for all *i, j* (3)

The constraints which guarantee that every data element is satisfied by only one technology, is unchanged by the additional data elements required:

$$\sum_{i=0}^{n} x_{ij} = 1 \text{ for each data element } j \quad (4)$$

The constraints to properly assign the fixed charges are affected only in the fact that the index *j* now increments from 1 to 20:

$$\sum_{j=0}^{m} x_{ij} \leq M\, y_i \text{ for each technology } i \qquad (5)$$

5.1.2.4 Results of analyzing for unbalanced volumes

As seen in the sensitivity analysis section 4.5.1, the portfolio of technologies is robust against a ten-fold swing in total volumes. The import/export imbalance or the day-to-day variation of volumes for any likely country will be considerably less than this ten-fold difference. Therefore, it can be safely postulated that a single portfolio of technologies will remain intact for expanding air cargo networks.

5.1.3 Pace of Growth

The financial business case for network expansion will have an estimated pace of growth, in order to show the long-term value of the expansion. This allows for the technology planner to incorporate strategic thought regarding the ways in which uncertain operational parameters may unfold.

5.1.3.1 Limits of Lean techniques

The above sensitivity analysis finds that the mix of technologies remains unchanged for all of the tested scenarios. This is unexpected, due to the analyzed volume variation ranging from 50% to 500% of the case study shipping volume. Experience in Lean implementation reveals that visual management and Kanban have diminishing returns as throughput increases. The package sortation operations operate closer to a three-second takt time, rather than the ideal one-minute takt time espoused in the Toyota Production System.

5.1.3.2 Two-stage implementation to accommodate Variation

When a country's new air cargo network grows beyond the physical limits of Visual Management and Kanban systems, a second stage of technology solutions will be required. The model accommodates such variation in parameters by excluding the decision variables related to the two non-feasible technologies.

In this case, the decision variables X_{Fj} and X_{Gj} as well as the constraint variables Y_F and Y_G are set to null and excluded from the linear program. The result is a new set of technology solutions as shown below, in Table 27.

Costs for this non-Lean technology solution will vary, depending upon the volumes that are realized within this uncertain scenario.

5.2. Results of competing models

5.2.1 Comparison to Kengpol and O'Brien (2001)

As described above, Kengpol and O'Brien (2001) discuss the methods for selection of advanced technology. The authors make a case for simplifying the model to determine cost/benefit solely on an accumulation of profits over the first five years. The hypothesis is that a simple sum is adequate rather than resorting to the analytical calculation of present value.

The Kengpol and O'Brien technique is implemented alongside the model proposed in Chapter III for comparison. The implementation medium is through Microsoft Excel, just as the authors described.

Upon implementation, the results are that the estimated cost increases dramatically – from the $5,436,972 given in section 4.4.2 to a value of $10,888,430 in the Kengpol and O'Brien model – due to their less sophisticated treatment of recurring monthly expenses. The actual selection of technologies is given in Table 28, and is quite similar to the industry standard amounts described in Table 19.

5.2.2 Comparison to Yap and Souder (1993)

The approach by Yap and Souder (1993) which has been described above is to first filter the undesirable candidate technologies. The approach then reviews five characteristics of each technology: uncertainties of commercial success, funding history of the technologies, resource requirements to develop the technologies, the degree to which technologies contribute to the enterprise mission, and the current life-cycle stage of the technology.

The initial filtering stage for the proposed model was described briefly in section 3.6 of this paper. The second stage with five criteria has been replicated to compare this model with what Yap and Souder refer to as the Technology Selection Procedure.

This procedure is implemented as a scoring matrix with three criteria:

(1) Does the new technology fill immediate performance needs?
(2) Does the new technology advance the state of the art?
(3) Does the new technology improve long-term viability of the firm?

Each of these criteria, as well as supplied sub-criteria, is weighted for their desired impact upon the final technology selection. For purposes of comparing these models, the selected weights are highest on filling the immediate performance needs of the expanding air cargo network.

This model then supplies the proposed purchases shown in Table 29.

Table 27 Results of optimizing Modular Technology Model, excluding low-volume Lean methods

Data Requirement	Optimum Technology for Gathering Data
Proof of possession	Employee scan
Needed Clearance paperwork	Employee scan
Duties-and-taxes monies required	Employee-entered free-form text
Proof of delivery (time)	Employee scan
Proof of delivery (signature)	Employee-entered free-form text
Status of package at each point in lifecycle	Employee scan
Package dimensions	Auto in-line dimensioning system
Package weight	Auto in-line dimensioning system
Location of containers	Active RFID
Quality status	Employee scan

Table 28 Results of Kengpol and O'Brien model

Data Requirement	Optimum Technology for Gathering Data
Proof of possession	Employee scan
Needed Clearance paperwork	Employee scan
Duties-and-taxes monies required	Employee-entered free-form text
Proof of delivery (time)	Employee scan
Proof of delivery (signature)	Employee-entered free-form text
Status of package at each point in lifecycle	Employee scan
Package dimensions	Auto in-line dimensioning devices
Package weight	Auto in-line dimensioning devices
Location of containers	Active RFID
Quality status	Employee scan

Table 29 Results of Yap and Souder model

Data Requirement	Optimum Technology for Gathering Data
Proof of possession	Passive RFID
Needed Clearance paperwork	Visual Management
Duties-and-taxes monies required	Employee-entered free-form text
Proof of delivery (time)	Passive RFID
Proof of delivery (signature)	Employee-entered free-form text
Status of package at each point in lifecycle	Passive RFID
Package dimensions	Manual scales
Package weight	Manual scales
Location of containers	Active RFID
Quality status	Visual Management

These selections are quite different than the proposals offered in Table 20, both in terms of the variety of solutions and in terms of line-by-line differences from the model developed in Chapter III. The total cost to implement the technologies in Table 29 is $8,371,028, including the capital cost plus the present value of future expenses. This is significantly more than the model results in Table 20, costing $5,436,972.

5.2.3 Summary of comparisons

Throughout the literature review, the two papers above stood out as having the greatest commonality to the work undertaken here. Through the demonstrations in sections 5.2.1 and 5.2.2, it can be concluded that the models offer no advantages under the given circumstances of an air cargo network expansion. The first model shown in Table 28 suffers from a financially inaccurate portrayal of the investment impact to the expansion, and gains little time in the way of simplifying analysis. The second model shown in Table 29 allows for additional factors to be considered other than cost, but suffers from a materially worsened outcome.

5.3. Success toward guiding hypothesis

Section 1.3 provided a guiding hypothesis, that the information technology (IT) decisions supporting expansion of an air cargo network can be effectively modeled to reduce costs.

The results given in the above chapter illustrate the success of proving this hypothesis, particularly measured by the 34% improvement in overall technology infrastructure cost, when adopting the optimized results in Table 20 versus the typical technologies in Table 19.

Furthermore,

- The model is shown to be general enough to include upfront and ongoing costs, as shown in Tables 15 and 16
- The model is shown to be general enough to include high-technology and low-technology solutions, as shown in Table 18
- The IT expansion model can be optimized based upon cost while meeting a minimum established customer expectation, as shown in Table 20

The model is therefore shown to be cost effective, robust against information needs, and sufficiently easy to model. It provides a standardized method for technology evaluation during air cargo network expansion.

Chapter VI
Conclusions

6.1. Contributions to the State of the Art

This research benefits the state of the art through the development of a clear model to aid in selection of technology components for an expanding air cargo network.

The development of a broad understanding of the information requirements for international air cargo networks is newly proposed here. The careful establishment of 40 unique information fields, then the categorization into relevant buckets will provide a useful structure for future research.

The customizations of the Fixed Charge Network Problem have been shown to be a good fit for air cargo networks, in that they are easily defined and scalable for expanding networks. The customizations are also proved to be applicable to technology selections in the same manner that this problem has been traditionally applied to brick and mortar infrastructure expansions. Furthermore, the incorporation of present value calculations into the fixed charge model brings a broader understanding and more sophisticated treatment of ongoing maintenance costs than is currently seen in the literature.

6.2. Audiences for the Modular Technology Model

One originally intended audience for the Modular Technology model is Information Technology planners, who have broadly strategic purposes and will incorporate this model into long-term planning for data storage and bandwidth capacity, as well as supported technologies. A second intended audience Expansion/Acquisition project teams, who can apply this model on a country-by-country basis to immediately select the most appropriate technology for a given situation. They may also use the model to evaluate an acquisition target to determine how close the optimal that target is currently operating. A third intended audience is expansion Work Planners, who can leverage the output of the model to plan employee activities and work schedules as well as estimate labor demands.

Beyond the originally intended audiences, further analysis indicates opportunities to leverage this model in broader areas than originally designed.

For example, the Modular Technology Model can become a means for driving operational parameters through capacity controls. These findings regarding the costs associated with expansion are non-linear with regard to shipping volume. Additional research may indicate opportunities for pricing and market controls to maintain shipping volume at an optimum point within the new expanded network.

A second possible application is to leverage this model in the initial determination to expand into a country. This model may bring decision support even further in advance of that originally intended. In effect, it can become a strategic aid following its initial application as a purchasing aid.

A third avenue for exploration is to broaden the scenario for which the technology is being procured. The current scenario is for network expansion into a new country. A possible future scenario is innovation into a new package delivery technology, such as drones or driverless vehicles. This same model sets the stage for a methodical categorization of the data parameters and an optimized calculation of the ideal technology portfolio.

6.3. General conclusions

Electronic data forms the underpinning of any large transportation company. This model is robust for a number of different factors in selecting technology infrastructure. It can accommodate various financial requirements, such as the three complications mentioned above: ongoing expenses, fixed charges, and shared technology. This model is subject to a continuous improvement process, where more factors can be included — subject to data availability — to make the model more realistic. Some future factors that are often discussed are:

- Round-the-clock awareness of each shipment's global position, rather than just the periodic updates that a shipment has passed a certain checkpoint
- Environmental monitoring of the package to satisfy FDA requirements for temperature- and humidity-sensitive products, such as pharmaceuticals or medical tissues
- Handling monitoring of the package to satisfy customer concerns about theft or damage of high-value electronics

The model is robust. Gurobi drives to an optimal solution of these 35 decision variables quickly, requiring approximately four seconds on a typical business-grade laptop computer. Earlier research by Thomadsen and Stidsen (2007). and Ahmed et al. (2003) both highlight the tractability of the Fixed Charge Integer Program at this scale. They also illustrate the ability of branch-and-bound as well as linear relaxation techniques to reach a global optimum. This model should continue to be tractable and wholly solve-able up to approximately 300 technology options or data requirements. At that point, the model will continue to be useful when solved heuristically or in smaller portions.

The robustness of this model will be further proved following a rigorous study of interaction effects among the parameters and development of shadow prices. Certain data such as wage rates and freight volumes will vary for each country, perhaps in ways not tested in sensitivity analysis above. Other data will change through time as technologies mature and components are commoditized.

This research has effectively developed and tested a model to specify the information technologies needed for expansion of an air cargo network into another country, and has then leveraged that model to minimize costs.

List of References

Abdelwahab, Walid and Sargious, Michel. *Modelling the Demand for Freight Transport: A New Approach*. Journal of Transport Economics and Policy, 1992

Ahmed, Shabbir; King, Alan J., Parija, Gyana; *Multi-Stage Stochastic Integer Programming Approach for Capacity Expansion under Uncertainty;* Journal of Global Optimization 26: 3–24; 2003

Anderson, Eugene; *Customer Satisfaction, Productivity, and Profitability; Differences between Goods and Services.* Marketing Science Vol. 16, No. 2, 1997

Anderson, Eugene; Fornell, Claes; Lehmann, Donald; *Customer Satisfaction, Market Share, and Profitability: Findings from Sweden;* Journal of Marketing Vol. 58, No. 3, July 1994

Angeles, Rebecca; *RFID Technologies: Supply Chain applications and Implementation Issues,* Information Systems Management, pp 51-65, Winter 2005,

Angeles, Rebecca; *Anticipated IT infrastructure and supply chain integration capabilities for RFID and their associated deployment outcomes;* International Journal of Information Management 29, pp 219–231, 2009

Antesa, J.; Campena, L.; Derigsa, U.; Titzeb, C.; and Wolleb, G.D. *Synopse: A model-based decision support system for the evaluation of flight schedules for cargo airlines*. Decision Support Systems Volume 22, Issue 4, April 1998, Pages 307-323

Azadian, Farshid; Murat, Alper; Chinnam, Ratna Babu; *Dynamic routing of time-sensitive air cargo using real-time information,* Transportation Research Part E 48, pp 355–372, 2012

Baker, N.R., Freeland, J., 1975. *Recent advances in R&D benefit measurement and project selection methods*. Management Science 21 (10), 1164–1175.

Banker, Rajiv; Chang, Hsihui; Janakiraman, Surya; Konstans, Constantine; *A balanced scorecard analysis of performance metrics.* European Journal of Operational Research 154, pp 423–436, 2004

Bartodziej, P.; Derig, U.; and Zils, M.; *O&D revenue management in cargo airlines—a mathematical programming approach*. OR Spectrum Springer Berlin / Heidelberg, Volume 29, Number 1 / January, 2007, pp 105-121

Baumol, W. J. and Vinod, H. D., *An Inventory Theoretic Model of Freight Transport Demand.* Management Science, 1970

Cachon, Gerard and Fisher, Marshall. *Supply Chain Inventory Management and the Value of Shared Information,* Management Science, Vol. 46, No. 8, Aug 2000

Cao, Qing; Good, Brandon S.; DeRose, Lynn A.; *RFID for Air Cargo operations: return on investment analysis through Process Modeling and Simulation*; Proceedings of the 2011 Winter Simulation Conference

Chan, Chi-Kong; Chow, Harry; So, Sunny; Chan, Henry; *Agent-based flight planning system for enhancing the competitiveness of the air cargo industry;* Expert Systems with Applications 39, pp 11325–11334; 2012

Chan, Felix; Bhagwat, Rajat; Kumar, N.; Tiwari, M.; Lam, Philip; *Development of a decision support system for air-cargo pallets loading problem: A case study.* Expert Systems with Applications 31, pp 472–485, 2006

Chan, K.Y., Dillon, T., Chang E., Singh J., *Prediction of Short-term traffic variables using intelligent swarm-based neural networks.* IEEE Transactions on Control Systems Technology, Vol 21, No 1, January 2013, pp 263-274

Chang, Yoon Seok; Son, Min Gyu; Oh, Chang Heun; *Design and implementation of RFID based air-cargo monitoring system,* Advanced Engineering Informatics 25, pp41–52, 2011

Cheung, Raymond; Shi, Ning; Powell, Warren; Simao, Hugo; *An attribute–decision model for cross-border drayage problem.* Transportation Research Part E Volume 44, pp 217–234. 2008

Ching, Chee; Holsapple, Clyde; Whinston, Andrew; *Toward IT support for coordination in network organizations,* Information & Management 30, pp 179-199, 1996

Crainic, Teodor Gabriel: *Service network design in freight transportation;* European Journal of Operational Research, v 122, n 2, p 272-288, April 16, 2000

Crainic, T.G., Laporte, G. *Planning models for freight transportation*. European Journal of Operational Research 97, pp 409–438. 1997

Dougherty, M. *A review of Neural Networks applied to Transport*, Transportation Research C. Vol. 3, No. 4. pp. 247 260. 1995

Drucker, P.F. *The information executives truly need*, Harvard Business Review 73 (1) pp 54–62. January/February 1995

Dueker, Kenneth J., Butler, J. Allison. *A geographic information system framework for transportation data sharing.* Transportation Research Part C: Emerging Technologies, 2000

Dyer, Robert F. and Forman, Ernest H. *Group decision support with the Analytic Hierarchy Process*, Decision Support Systems 8 pp 99-124, 1992

Easwaran, Gopalakrishnan and Üster, Halit. *A closed-loop supply chain network design problem with integrated forward and reverse channel decisions*, IIE Transactions, Volume 42:11, pp 779-792, 2010

Evans, G.N.; Naim, M.M.; Towill, D.R.; *Dynamic Supply Chain Performance: Assessing the Impact of Information Systems*, Logistics Information Management, Vol. 6, Issue 4, pp.15–25, 1993

Forster, Paul W. and Regan, Amelia C. *Electronic Integration in the Air Cargo industry: an Information Processing Model of On-Time Performance.* Transportation Journal, pp 46-61, Summer 2001

Gallagher, Keith; Hatch, Andrew; Munro, Malcolm; *Software Architecture Visualization:An Evaluation Framework and Its Application,* IEEE Transactions on Software Engineering, Volume 34, No. 2, pp 260-270, March/April 2008

Gavirneni, Srinagesh; Kapuscinski, Roman; and Tayur Sridhar*. Value of Information in Capacitated Supply Chains,* Management Science, Vol. 45, No. 1, pp 16-24, Jan 1999

Geoffrion, A.M., and Powers, R.F. *Facility location analysis is just the beginning (if you do it right)*, Interfaces 10/2, pp 22-30. 1980

Geoffrion, A.M., and Powers, R.F. *Twenty years of strategic distribution system design: An evolutionary perspective. (Implementation in OR/MS: An evolutionary view),* Interfaces 25, pp 105-128, 1995

Goetschalckx, M., Vidal, C. J., & Dogan, K. (2002). *Modelling and design of global logistics systems: A review of integrated strategic and tactical models and design algorithms*. European Journal of Operational Research, 143, pp 1–18.

Goh, M., Lim, J. Y. S., & Meng, F. *A stochastic model for risk management in global supply chain networks.* European Journal of Operational Research, 182, pp 164–173. 2007

Grieger, Martin. *Electronic marketplaces: A literature review and a call for supply chain management research*.

European Journal of Operational Research, 144, pp 280–294, 2003

Guimerà, R. and Amaral, L.A.N.. *Modeling the world-wide airport network*. Eur. Phys. J. B , Volume 38, Number 2, March II, 2004; Applications of Networks

van Hee K., Huitink B., Leegwater D.K. *Portplan, decision support system for port terminals*, European Journal of Operations Research, 1987.

van Hee, K.M. and Lapinski, A. *OR and AI approaches to decision support systems*, Decision Support Systems 4, pp 447–459 1988

Holsapple, Clyde and Luo, Wenhong; *A framework for studying computer support of organizational infrastructure*, Information & Management 31, pp 13-24, 1996

Holsapple, C.W. and Sena, M.P. *ERP plans and decision-support benefits*, Decision Support Systems 38 (4) pp 575–590, 2005

Hui, George W.L.; Van Hui, Yer; Zhang, Anming; *Analyzing China's air cargo lows and data,* Journal of Air Transport Management 10, pp 125–135, 2004

Hsu, Chaug-Ing; Shih, Hsien-Hung; and Wang, Wei-Che; *Applying RFID to reduce delay in import cargo customs clearance process.* Computers & Industrial Engineering. Volume 57, Issue 2, September 2009, pp 506-519 Challenges for Advanced Technology

Iyer, Ganesh; Narasimhan, Chakravarthi; Niraj, Rakesh; *Information and Inventory in Distribution Channels,* Management Science; Vol. 53, No. 10, pp. 1551–1561, October 2007

Johnston, Robert, and Mak, Horiace Cheok. *An emerging vision of internet-enabled supply-chain electronic commerce*. International Journal of Electronic Commerce, 2000. online journal

Kendall, K. *The significance of information systems research on emerging technologies: seven information technologies that promise to improve managerial effectiveness,* Decision Sciences 28 (4), December 1997

Kengpol, Athakorn; Meethom, Warapoj; Tuominen, Markku. *The development of a decision support system in multi-modal transportation routing within Greater Mekong sub-region countries*. International Journal of Production Economics, Volume 140, pp 691–701, 2012

Kengpol, A., O'Brien, C. *The development of a decision support tool for the selection of advanced technology to achieve rapid product development*. International Journal of Production Economics 69, pp 177–191. 2001

Kengpol, A., Tuominen, M. *A framework for group decision support systems: an application in the evaluation of information technology for logistics firms.* International Journal of Production Economics 101, pp 159–171. 2006

Kim, Soo Wook and Narasimhan, Ram; *Information system utilization in supply chain integration efforts,* International Journal of Production Research vol. 40, no. 18, pp 4585-4609, 2002

Kohn, W., Brayman, V. and Littleton, J. *Repair-control of enterprise systems using RFID sensory data.* IIE Transactions, 37(4), pp 281–290; 2005

Kozan, Erhan and Liu, Shi Qiang; *A demand-responsive decision support system for coal transportation*. Decision Support Systems Issue 54, pp 665–680. 2012

Krejcie, Robert V. and Morgan, Daryle W.; *Determining sample size for research activities.* Educational and Psychological Measurement Issue 30, pp 607-610; 1970

Kritikos, Manolis and Ioannou, George; *The balanced cargo vehicle routing problem with time windows.* International Journal of Production Economics Volume 123, Issue 1, pp 42-51; January 2010

Kubya, Michael J. and Grayb, Robert Gordon. *The hub network design problem with stopovers and feeders: The case of Federal Express.* Transportation Research Part A: Policy and Practice, Volume 27, Issue 1, January 1993, Pages 1-12

Lai, Kee-Hung; Ngai E.W.T.; Cheng, T.C.E.; *Information Technology Adoption in Hong Kong's Logistics Industry;* Transportation Journal, Vol. 44, No. 4, pp. 1-9, Fall 2005

Lau, H.C.W. and Nakandala, Dilupa. *A pragmatic stochastic decision model for supporting goods trans-shipments in a supply chain environment.* Decision Support Systems Issue 54, pp 133–141. 2012

Lee, Hau; So, Kut; and Tang, Christopher; *The Value of Information Sharing in a Two-Level Supply Chain*: Management Science, Vol. 46, No. 5, pp. 626-643, May 2000

Lee, Hau L., Whang, Seungjin. *Information sharing in a supply chain.* International Journal of Manufacturing Technology and Management, 2000

Lee, H.L., Padmanabhan, V., and Whang, S. *Information distortion in a supply chain: the bullwhip effect.* Management Science, Vol. 43, No. 4, pp 546-558, 1997

Lee, Patrick and Vora, Gautam; *A two-stage approach to multi-period allocation of savings among investment plans;* Annals of Operations Research 45; pp 221-242; 1993

Leung, Stephen; Tsang, Sally; Ng W.L.; Wu, Yue. *A robust optimization model for multi-site production planning problem in an uncertain environment*. European Journal of Operational Research Volume 181, pp 224–238, 2007

Leung, Stephen; Wu, Yue; Lai, K.K. *Cross-border logistics with fleet management: A goal programming approach*. Computers & Industrial Engineering Volume 50, pp 263–272; 2006

Li, J.A., Liu, K., Leung, S.C., Lai, K.K. *Empty container management in a port with long-run average criterion*. Mathematical and Computer Modelling Volume 40, pp 85–100. 2004

Li, Jing-An; Leung, Stephen C.H.; Wu, Yue; Liu, Ke. *Allocation of empty containers between multi-ports.* European Journal of Operational Research, Volume 182, pp 400–412, 2007

Li, Qingwei and Savachkin, Alex; *A heuristic approach to the design of fortified distribution networks;* Transportation Research Part E 50; pp 138–148; 2013

Li, Sheng-Tun and Shue, Li-Yen; *A study of logistics infomediary in air cargo tracking;* Industrial Management and Data Systems; Volume 103, Issue 1; 2003

Liberatore, Matthew; *Toward a Framework for Developing Knowledge-Based Decision Support Systems for Customer Satisfaction Assessment: An Application in New Product Development;* Expert Systems With Applications, Vol. 8, No. 1, pp. 213-228, 1995

Limão, Nuno, and Venables, Anthony J., *Infrastructure, Geographical Disadvantage, Transport Costs, and Trade*, The World Band economic review, 2001

Lin, Pei-chun and Lee, Chia-hui, *How Online Vendors Select Parcel Delivery Carriers,* Transportation Journal, Vol. 48, No. 3, Greater China Region, pp. 20-31, summer 2009

Liu, Minhui; Srinivasan, Mandyam; Vepkhvadze, Nana; *What is the value of real-time shipment tracking information?* IIE Transactions, 41:12, pp 1019-1034, 2009

Mandakovic, Tomislav and Souder, Wm. E.; *A flexible hierarchical model for project selection and budget allocation,* R&D Management IS, l, pp 23-29, 1985

Manzini, Riccardo. *A top-down approach and a decision support system for the design and management of logistic networks.* Transportation Research Part E Volume 48, pp 1185–1204; 2012

March, S.T. and Hevner, A.R. *Integrated decision support systems: a data warehousing perspective,* Decision Support Systems 43 (3) pp 1031–1043, 2007

Meixell, J., & Gargeya, V. B. *Global supply chain design: A literature review and critique*; Transportation Research Part E, 41, pp531–550,2005

Narasimhan, R., and Mahapatra, S. *Decision models in global supply chain managemen*t. Industrial Marketing Management, 33, pp 21–27. 2004

Neo, B.S.; *Managing New Information Technologies: Lessons from Singapore's Experience with EDI,* Information & Management, Vol. 26, pp 317-326, 1994

Ngai, E.W.T., Lai, K.H., Chang, T.C.E., *Logistics information systems. The Hong Kong experience.* International Journal of Production Economics 113, pp 223–234, 2008

Park, Yonghwa; Choi, Jung Kyu; Zhang, Anming. *Evaluating competitiveness of air cargo express services .* Transportation Research Part E: Logistics and Transportation Review Volume 45, Issue 2, March 2009, Pages 321-334 Entry and Customer Choice in Air Transport

Ramani, K.V.; Yap, Robert; Pavri, Francis; *Case study: Information technology enables business process reengineering at YCH DistriPark (Singapore),* Journal of Strategic Information Systems 4(l) pp 81-88, 1995

Reinheimer, Stefan and Bodendorf, Freimut; *A Framework for Electronic Coordination in the Air Cargo Market,* The Information Society: An International Journal, 15:1, pp 51-55, 1999

Rickman, T D, Hallenbeck, M E, Schroeder, M. *Improved method for collecting travel time information*, Transportation Research Record 1990

Riddle, W.E., Williams, L.G. *Technology selection: an educational approach.* IEEE Transactions on Software Engineering SE 13 (11), 1199–1206. 1987

Root, Sarah and Cohn, Amy, *A Novel Modeling Approach for Express Package Carrier Planning.* Wiley InterScience online August 2008

Shen, W.S., Khoong, C.M. *A DSS for empty container distribution planning*. Decision Support Systems 15, pp 75–82, 1995

Southworth, F. and Peterson, B.E. *Intermodal and international freight network modelling.* Transportation Research Part C 8, pp 147–166; 2000

Southworth, Frank; Peters, Bruce E., *Intermodal and international freight network modeling*, Transportation Research Part C: Emerging Technologies; 2000

Sutton, John C., Data *attribution and network representation issues in GIS and transportation*. Transportation Planning and Technology; 1997

Sutton, John C., Wyman, Max M. *Dynamic location: an iconic model to synchronize temporal and spatial transportation data.* Transportation Research Part C: Emerging Technologies; 2000

Thomadsen, Tommy and Stidsen, Thomas; *The generalized fixed-charge network design problem;* Computers & Operations Research 34; pp 997–1007; 2007

Thomas, D.J. and Griffin, P.M., *Coordinated supply chain management*, European Journal of Operational Research 94 (1) pp 1–15; 1996

Vidal, C. J., & Goetschalckx, M. *Strategic production-distribution models: a critical review with emphasis on global supply chain models*. European Journal of Operational Research, 98, pp 1–18; 1997

Verwijmeren, Martin; *Software component architecture in supply chain management,* Computers in Industry 53, pp 165–178; 2004

Verwijmeren, M. and Tilanus, C.B. *Network planning for scheduling operations in air cargo handling: a tool in medium term goodsflow control*. European Journal of Operational Research, Volume 70, Issue 2, Pages 159-166; October 1993

Volonino, Linda; Watson, Hugh; Robinson, Stephen; *Using EIS to respond to dynamic business conditions;* Decision Support Systems 14, pp 105-116, 1995

Webster, Juliet*. Networks of collaboration or conflict? Electronic data interchange and power in the supply chain.* The Journal of Strategic Information Systems, Volume 4, Issue 1, pp 31-42 March 1995

Winston, Clifford. *The demand for freight transportation: models and applications*, Transportation Research Part A: General, 1982

Wixom, Barbara and Watson, Hugh; *An Empirical Investigation of the Factors Affecting Data Warehousing Success*; MIS Quarterly, Vol. 25, No. 1, pp 17-41, March 2001

Wu, Yue, *A time staged linear programming model for production loading problems with import quota limit in a global supply chain,* Computers & Industrial Engineering Issue 59, pp 520–529. 2010

Wu, Y. and Wu, Yue, *A dual-response forwarding approach for containerizing air cargo under uncertainty, based on stochastic mixed 0-1 programming.* European Journal of Operational Research, 207, 2010, pp 152-164.

Wu, Yue, *A dual-response strategy for global logistics under uncertainty: A case study of a third-party logistics company.* International Transportation in Operations Research, Volume 19, pp 397–419, 2012

Wu, Yue; *Linear robust models for international logistics and inventory problems under uncertainty*. International Journal of Computer Integrated Manufacturing, Volume 24, No. 4, pp 352–364, April 2011

Wu, Yue, *Global Logistics Road Planning: A Genetic Algorithm Approach*, The Sixth International Symposium on Operations Research and Its Applications (ISORA'06), Xinjiang, China, August 8–12, 2006

Yan, Shangyao and Chen, Chia-Hung. *Optimal flight scheduling models for cargo airlines under alliances.* Journal of Scheduling Volume 11, Number 3 / June, 2008. pp 175-186

Yan, Shangyao; Chena, Shin-Chin; and Chena, Chia-Hung. *Air cargo fleet routing and timetable setting with multiple on-time demands.* Transportation Research Part E: Logistics and Transportation Review Volume 42, Issue 5, September 2006, pp 409-430

Yan, Shangyao; Lai, Chun-Hung; and Chen, Chia-Hung. *A short-term flight scheduling model for international express package delivery.* Journal of Air Transport Management; Volume 11, Issue 6, November 2005, pp 368-374

Yan, Shangyao; Shiha, Yu-Lin; and Shiaoa, Fei-Yen. *Optimal cargo container loading plans under stochastic demands for air express carriers.* Transportation Research Part E: Logistics and Transportation Review Volume 44, Issue 3, May 2008, Pages 555-575

Yap, C.M. and Souder, W.E., *A Filter system for technology evaluation and selection,* Technovation 13 (7) pp 449-469. 1993

Zhang, Cheng; Tan, Gek-Woo; Robb, David J.; Zheng, Xin; *Sharing shipment quantity information in the supply chain*; Omega 34; pp 427–438; 2006

Vita

Grayson McClain is a registered professional engineer in the state of Tennessee. Grayson's work experience spans multiple industries and sectors, but all have a common focus upon improving processes.

Grayson has served the US Navy as a submarine officer and as a manpower analyst. He then worked at a Fortune 500 manufacturing facility in Georgia, progressing from Process Improvement engineer to Project Leader to Six Sigma Blackbelt. Grayson transitioned into the service sector by working at a Fortune 500 transportation company in Tennessee, progressing from Project Engineer to Quality Principal to Process Improvement manager.

Grayson earned his Bachelor of Engineering degree from Vanderbilt University majoring in Electrical Engineering and Mathematics. He then earned the Master of Science in Industrial Engineering degree from the Georgia Institute of Technology. He has now completed his Doctor of Philosophy degree in Industrial Engineering from the University of Tennessee.