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# **Electronic Integration in the Air Cargo Industry: An Information Processing Model of On-Time Performance**

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## **ABSTRACT**

This study examines electronic integration in logistics supply chains using the non-integrated US-international air cargo industry as a case study. We ask what impact electronic integration has on interorganizational task performance, and hypothesize about factors limiting the effectiveness of electronic integration. Surprisingly, our study does not find evidence of direct impacts of electronic integration on performance though it does find evidence of indirect impacts of information systems use and performance. The findings suggest that the use of electronic integration as a strategy to improve operational performance across firms is limited by the nature of the interorganizational task, environmental dynamism, and the power relationships between firms in the supply chain.

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## INTRODUCTION

On-time movement of materials across global supply chains is of grave economic importance to both producers and users of the transportation system. For transportation service providers, control of time throughout the supply chain can increase efficiency and create competitive advantage by turning coordination in the supply chain into a source of differentiation.

Where on-time performance demands of an interorganizational task are high, organizational structure shifts towards vertical integration in order to reduce uncertainty. For example, vertically integrated companies such as UPS and Federal Express dominate the high-end express delivery sector of the air cargo industry.

These vertically integrated express carriers - integrators - move 92% of all U.S. domestic shipments and account for over 60% of total domestic air cargo revenues. However, in the rapidly growing international air cargo market, the integrators have a much smaller 6% stake. As demands for international on-time delivery increase, forwarders and carriers are turning to an alternative to vertical integration to increase on-time performance – electronic integration. Electronic integration is an organizational structure that uses interorganizational information systems (IOS) such as EDI, proprietary systems, and internet applications to share information across organizations to achieve higher levels of coordination.

While vertical integration is the dominant organizational structure in high performance air cargo, it comes at a high cost. Asset specific investments, reduced organizational flexibility and market responsiveness are risks associated with vertical integration. Electronic integration can arguably provide the performance quality of vertical integration but without the risks.

In this paper we draw upon data from the US-international air cargo sector to investigate the limits of electronic integration. We ask: does electronic integration impact

performance of an interorganizational task such as air cargo delivery? What factors limit the effectiveness of electronic integration?

The study analyzes data from a comprehensive survey of the freight forwarding industry. We examine this segment of the third party logistics industry at a time of rapid change. Web based information technologies are transforming the industry as we write. Our study examines the industry poised to adopt new IOS in the form of e-commerce technologies. We seek to understand the factors that appear to impact the success and failure of IOS. This study comes at an opportune time. Many more business operations will be linked with such inter-operational systems in the near future. Collaborative environments are being built for all sectors of the freight transportation industry (see for example the Global Freight Exchange (GF-X), Reuters Air Cargo Service and RightFreight for air cargo and 3PLEX, Nistevo, Trantis and Transplace for other freight industry segments). This study of the air cargo industry should lend insight into the future of electronic commerce, collaborative commerce and interorganizational systems in freight transportation and logistics.

## **AIR CARGO OPERATIONS**

Since the first air cargo shipment in 1910, the U.S. air cargo industry has grown to an industry that moves approximately 56% of all worldwide air cargo shipments, making it the largest single air cargo market<sup>1</sup> in the world. Of the \$300 billion in world-wide airline revenues due to scheduled flights the air cargo industry accounts for an estimated \$40 billion (IATA, 1998). The global air cargo community comprises approximately 25,000 forwarders and 700 airlines operating worldwide<sup>2</sup>, with about 1500 forwarders and 100 airlines operating in the U.S.

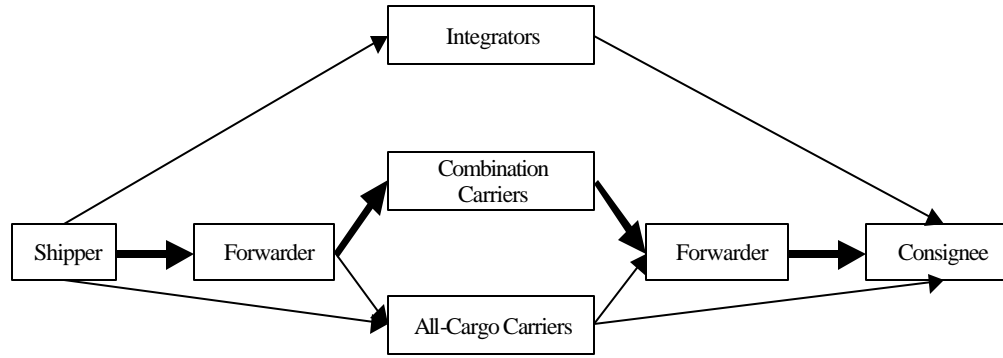


Figure 1 Alternative Organizational Structures for Air Cargo Delivery (Adapted from TIACA, 2000)

Two organizational structures dominate the provision of air cargo delivery. *Integrators*<sup>3</sup> own all assets of production from shipper to consignee. *Non-integrators* - forwarders and combination carriers<sup>4</sup> - provide air cargo delivery through their coordinated efforts (Figure 1).<sup>5</sup>

The integrators, such as FedEx and UPS, own all assets of production including physical assets such as trucks and airplanes, labor assets, and information assets. Emerging from the deregulation of 1978, integrators pursued innovative strategies for infrastructure, product and information technologies. The hub-and-spoke network was a radical change from the previous point-to-point network infrastructure increasing flexibility and capacity utilization. They pursued a product strategy that focused on high value business documents enabling standardized packaging, simplified pricing and documentation. Their technology strategy developed tracking and tracing technologies and internal information systems for monitoring system-wide performance. Using these strategies, in the U.S. domestic market, the integrators grew from 4% of air cargo revenue in 1977 to 61% in 1999, an average of 25% growth per year (Boeing, 2000). The integration strategy has proven highly successful in the domestic market.

In international markets, the integrators have a relatively small presence. In 1997 they held 6% of the international air cargo market, but they are expanding aggressively into

international markets and are close to reaching open skies agreements<sup>6</sup> in a number of key regions. They are forecast to grow at 25% per year, reaching almost 40% of the market by 2017 in contrast to the 6.4% forecasted growth for traditional air cargo (Boeing, 2000). However, as their core business comes under threat from electronic communications, the integrators are branching into more diverse markets such as industrial shipments in direct competition with forwarders and carriers. This places considerable pressure on forwarders and airlines to increase their on-time performance and overall responsiveness to customer needs.

Non-integrated air cargo delivery is provided through the coordinated efforts of forwarders and scheduled airlines<sup>7</sup>. Forwarders package, document, and surface transport shipments from shipper to scheduled airlines (e.g. Lufthansa, United) that transport cargo in the bellies of passenger aircraft. About half the world's air cargo travels in this manner.

This study focuses on the role of the forwarder in the provision of on-time services. In the eyes of the shipper or consignee<sup>8</sup>, the forwarder *is* the carrier and is held accountable for on-time performance. The forwarder typically selects an airline for transport, books the shipment, plans routing and transshipments, and plans the surface movement of the shipment at source and destination. The forwarder has the expertise to assist in the preparation of complicated documentation for specialized shipments and international transport. Forwarders can also provide expertise in the areas of packaging, insurance, customs clearance and international payments. When shipments are consolidated with other shipments with a common destination, the forwarder assumes the identity of indirect carrier, accepting legal responsibility for shipments.

### ***The Interorganizational Task of Air Cargo Delivery***

As noted earlier, in great part the success of the integrators came from their ability to standardize and simplify the types of goods that they ship, thereby reducing uncertainty and the opportunity for exceptions during task execution. Complex goods were left to the

non-integrators to transport. Perishable goods, live shipments, valuables, oversize shipments, dangerous goods, and so on are “routine” shipments in non-integrated air cargo.

The heterogeneity of inputs influences the shipment task in two ways. First, they increase complexity of operations because of the diversity of procedures and practices that must be maintained in order to handle the different types of shipments (e.g. dangerous goods, live animals, valuables). Second, heterogeneous shipments increase the amount and complexity of information required to satisfy regulatory restrictions.

The heterogeneity of general air cargo is a counterpoint to the homogeneity of integrated express delivery. The complexity of non-integrated air cargo delivery is reflected in the number of steps it takes to get a shipment to its destination. An industry study found that the forwarder-airline operations took 40 steps in the delivery cycle compared to only 11 steps by integrated carriers (Hamoen, 2001). The complexity in the non-integrated process is also reflected in unplanned delays that result in lower on-time performance. Fast and high quality exchange of information between forwarders and airlines is anticipated to reduce delays in air cargo operations and improve overall on-time performance.

### ***Electronic Integration of Forwarders and Airlines***

The success of the airline passenger reservation systems such as Sabre and Apollo (Copeland and McKenney, 1988) led to the expectation of similar competitive advantages in the cargo industry. Interorganizational information systems (IOS), systems that share information electronically across organizational boundaries, are expected to electronically integrate the industry, lower costs and yield higher on-time performance. A flurry of Cargo Community Systems (CCS) were developed during the 1980's and 1990's by carriers (e.g. Encompass), airport authorities (e.g. Cargonaut), industry associations (e.g. SITA) and third-party systems providers (e.g. SNS). CCS enable transmission of

documentation and tracking information among forwarders, carriers, consignees and shippers. Valued-added networks (VAN) emerged in the 1990s to provide a more general trade network with additional services such as currency exchange services as well as control and data integrity services.

Despite decades of investments in IOS by airlines, forwarders and industry associations, a recent industry survey by Unisys found that over the last 20 years international air cargo shipments have improved from 6.25 days to 6.0 days (Cargo Facts, 1997). This is a counterintuitive finding given the apparent incentives to the industry to improve on-time performance, and the expectation of the impact of electronic integration.

### ***Forwarder-Airline Relations***

Relationships between airlines and forwarders are complex. Many of the institutions of air cargo emerged during the period in which forwarders acted as licensed agents selling space for only particular airlines. While this arrangement has changed, airlines have long looked upon forwarders as direct agents and have a paternalistic attitude toward the forwarding industry. Some airlines see forwarders as purely consolidators adding no other value to the air cargo products, and compete head-to-head with forwarders for the business of shippers.

While forwarders are generally dwarfed in size by their airline partners, they can also have considerable sway with airlines. First, forwarders make their money on the difference between the price they receive from the shipper or consignee and the cost of cargo space paid to airlines. Forwarders tender most of the international air cargo moved by the scheduled airlines and play one airline against another for the lowest price. Second, the attitude of many airlines towards cargo as incremental revenue has given the forwarders an upper hand in extracting low rates from airlines. Third, in the scheduled carriers, passenger service requirements constrain cargo operations. This weakens the ability of cargo operations to create differentiated services and compete on a basis other



than price. Despite their size, as suppliers of air cargo space, the supplier power of airlines is low, while the buyer power of forwarders is high.

As a result of these factors the relationship between forwarders and airlines can be characterized as traditionally distrustful and uncooperative. We will argue that the nature of the forwarder-carrier relationship inhibits the impact of IOS applications on on-time performance.

### **AN INFORMATION PROCESSING MODEL FOR IOS IMPACTS**

In this section we propose an information processing model of the impact of IOS on the performance of an interorganizational task. The model is based on an organizational design framework of Galbraith (1973, 1977) and the work of Bensaou and Venkatramen (1995) who extended this framework to the interorganizational level.

The model assumes that a key function of organizations is the processing of information in order to coordinate the execution of a task. Any task can be decomposed into a series of coordinated subtasks. Interorganizational tasks require effective sharing of information within and between organizations. The more complex the overall task, the greater the problem of coordinating the subtasks. The problem of coordination is a problem of information; how to communicate information between decision-makers involved in the performance of interdependent subtasks.

Information processing requirements of a task derive from uncertainty. Uncertainty is the difference between the information required to perform a task at a desired level of performance and the amount of information available to the organization. Where all required information is known before task execution, the task can be preplanned (preprocessed) and no information needs to be exchanged between decision-makers during task execution. Where information is not available prior to task execution

information must be exchanged during execution. The greater the degree of uncertainty, the greater the information processing requirements.

Information processing capacity is provided by coordination mechanisms that share information across organizational boundaries. In this study we focus on the use of IOS as a means of sharing information between organizations to coordinate an interorganizational task.

The model asserts that the performance of an interorganizational task is determined by the “fit” between the information processing capacity afforded by IOS and the information processing requirements arising from uncertainty in the task environment. “Fit” can be interpreted as a match between the requirements and capacity (Tushman and Nadler, 1978). High information processing requirements must be matched with high information processing capacity in order to achieve performance goals.

In the model presented in Figure 2 there are four dimensions of information processing requirements, and six dimensions of information processing capacity.

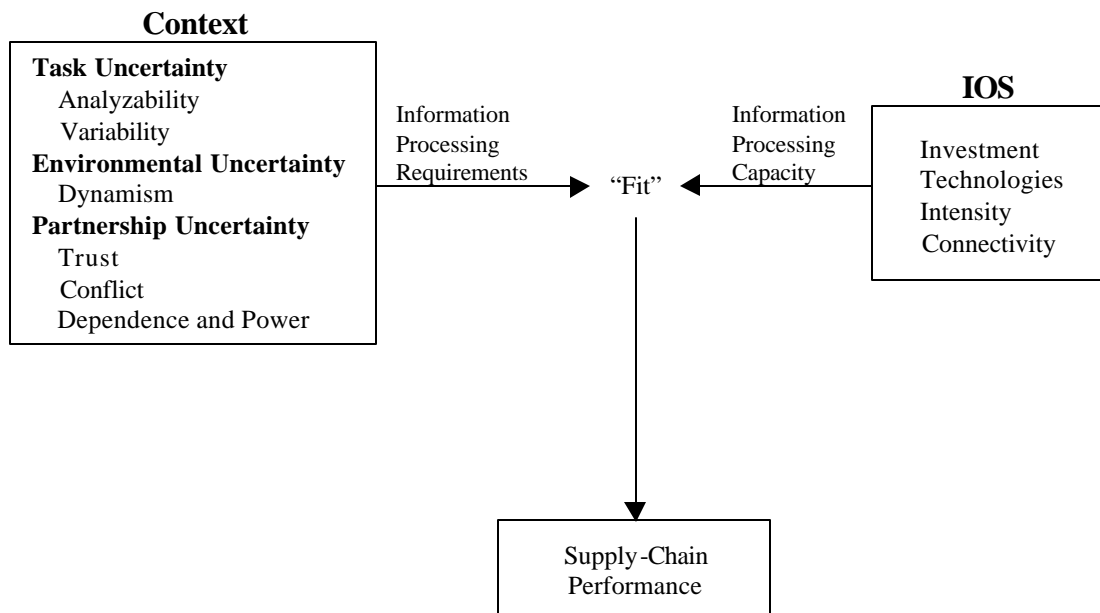
Information processing requirements increase as a function of task, environmental, and interfirm relationship uncertainty. Task uncertainty arises from the analyzability and variability of a supply-chain task. Environmental uncertainty arises from the degree of change in the interorganizational environment. Partnership uncertainty arises from distrust, conflict, and dependence between supply chain partners. Organizations concerned with supply chain performance are continually facing situations of increasing processing requirements.

The match of requirements and capacity determines performance. Faced with an information processing deficit, organizations must choose between two basic strategies: reduce information processing requirements or increase information processing capacity. The default do-nothing strategy results in compromising performance.

In the context of air cargo the model might be interpreted as follows. The interorganizational task is the coordinated movement of shipments from origin to destination coordinated across forwarders and airlines. Uncertainty, the source of information processing requirements, arises from exceptions in the shipment process. Simple tasks in a stable environment and forwarder-airline relations characterized by low conflict, high trust, and balanced power give rise to few exceptions during task execution. Complex tasks in dynamic environments with forwarder-airline relations characterized by high conflict, low trust and unbalanced power give rise to many exceptions during the shipment process. Exceptions create delays and reduce overall task performance.

### ***Dimensions of Information Processing Capacity***

IOS provide information processing capacity by sharing information between decision-makers in different organizations throughout the supply chain. We hypothesize that the level of investment in IOS, type of IOS, intensity of use of the IOS, and the degree of electronic connectivity with other organizations will affect the overall information processing capacity.



**Figure 2 Information Processing Model for IOS Impacts**

Information processing capacity is provided by IOS such as EDI, Cargo Community Systems, or web-based systems that provide processing capacity in the form of electronic document exchange and tracking information. Document exchange allows critical shipment information to be transmitted downstream in advance of shipment arrival. Tracking and tracing technologies can provide in-transit visibility of shipments and an early warning system to reduce their impact of delays on performance, and as systems to exchange information once delays occur.

Information processing capacity in this study is the product of 1) IT investment, 2) IOS technologies, 3) intensity of use, and 4) connectivity.

*IOS investment* reflects the level of expenditures on IOS. On a practical level, separating IOS expenditures from total information technologies expenditures is problematic.

*IOS technologies.* The type of IOS technology can affect what information is shared, how it is shared, and the accessibility of the information. In the context of air cargo we identify EDI, Cargo Community Systems, and tracking and tracing technologies as the most significant IOS technologies available for coordinating supply chain operations.

*IOS intensity.* IOS can be used at varying levels of *intensity*, reflecting usage and integration of the IOS into task operations. Higher intensity provides greater exchange of information between organizations.

*IOS connectivity* is the proportion of other organizations with which an organization maintains electronic links. Firms that have high connectivity have greater capacity to share information with their partners than those firms with lower connectivity.

### ***Dimensions of Information Processing Requirements***

Uncertainty, as manifested through exceptions arising in the execution of an interorganizational task, is the source of information processing requirements.

The model identifies three general sources of uncertainty in the interorganizational task environment: 1) task uncertainty, 2) environmental uncertainty and 3) uncertainty in the interfirm relationships.

#### **Task Uncertainty**

Our model identifies task variability and task analyzability as two sources of task uncertainty. These types of uncertainty influence the amount of information required to perform a supply chain task by affecting task complexity and the amount of information a decision-maker must consider during task execution.

### **Task Variability**

*Task variability* refers to the frequency with which unanticipated events occur during the execution of the interorganizational task requiring non-routine procedures to be used in the execution of the task. Tasks that are unpredictable have greater uncertainty and a greater number of exceptions and information processing needs during task execution (Galbraith, 1977).

As task variability increases, the behavior of critical elements of the task become increasingly unpredictable and information requirements between decision-makers in the supply chain increase in order to coordinate the task at the desired level of performance. Task variability is reflected in the number and complexity of decisions that arise during task execution. Where there are a wide variety of exceptions to manage, decision-makers are faced with more complex decision tasks.

### **Task Analyzability**

*Task analyzability* is the extent to which there is a “known procedure that specifies the sequence of steps to be followed in performing a task” (Bensaou and Venkatramen, 1995:1475).

The analyzability of an interorganizational task reflects the level of understanding of all the steps required to execute the task. Tasks that are analyzable lend themselves to preplanning. Highly analyzable tasks have fewer exceptions that occur during task execution and thus have lower processing requirements. Tasks that are not analyzable cannot be preplanned but require constant management during execution.

### **Environmental Uncertainty**

Lawrence and Lorsch (1967) observe that firms do not operate in isolation from their environments, and that environmental complexity influences internal uncertainty. The greater the instability of the general environment, the greater the uncertainty facing decision-makers (Tushman and Nadler, 1978). When the environment is stable, firms can

preplan and reduce much of the information that is required during task execution. When the environment is unstable it will result in more exceptions during task execution.

There are many potential sources of environmental uncertainty, however we center our attention on examine environmental dynamism. Dynamism reflects the extent to which task-relevant characteristics of the environment are changing. Where the environment is changing, cause-and-effect relationships between the environment and the firm become unclear (Daft and Lengel, 1986).

### **Interfirm Relationships**

The relationship between organizations involved in the performance of an interorganizational task is a source of uncertainty and information processing requirements. As organizations become more interdependent, interfirm relations increase in their significance as a source of uncertainty. Kumar and van Dissell (1996:283) argue “the closer the coupling or interdependency, the greater the intentional or accidental harm one unit can inflict upon the other”. We argue that the greater the interdependency between firms, the greater the potential for issues of power, trust and conflict between partners to create uncertainty about the execution of a interorganizational task.

### **Power and Dependence**

Emerson (1962:32) argues that one party’s power “resides implicitly in the other’s dependency”. The power of one party to control or influence another resides in the control the first has over things the second values. He defines power as potential influence, where the power of party A over party B is equal to the dependence of B on A.

Unbalanced power relations lead to uncertainty through coercive actions, opportunistic behavior, or instability. Where there is a power imbalance, one firm has the ability to influence how another uses its resources to perform an interorganizational task. The

power imbalance may provide the more powerful firm the ability to take advantage of the less powerful firm. Emerson asserts that where one party has greater power than the other, the situation is unstable, and sets in motion processes which attempt to reduce the costs of meeting the more powerful party's demands and "balancing operations".

A powerful firm may lead to anti-information sharing behaviors towards the less powerful firm such as reducing visibility into its operations or denying information to the less powerful firm. Such behaviors can create uncertainty for both parties during task execution. "Access to or control over information flows and power are two sides of the same coin" (Huigen, 1993).

Relationships between dependency and the use of IOS have been established in prior studies. Hart and Saunders (1997) argue that firms with greater power can influence their trading partners to adopt and EDI. However, when firms use coercive power to force use, the less powerful partners may be left vulnerable. Clemons and Row (1993) argue that where bargaining power is low between partners, less powerful firms will be resistant to adoption despite apparent benefits of IT.

The relationship between power and supply chain performance has been explored in a recent study by Maloni and Benton (2000). They find that different sources of power influence the interfirm relationships in the supply chain. The interfirm relationships, in turn, influence supply chain performance. The information processing model suggests that the relationship between power and performance is moderated by information processing capacity.

## **Trust**

Interorganizational trust is defined by Zaheer et al. (1998) as "the extent of trust placed in the partner organization by the members of a focal organization" (p. 142). They define trust itself as the expectation that an actor (1) can be relied on to fulfill obligations, (2)



will behave in a predictable manner, and (3) will act and negotiate fairly when the possibility for opportunism is present.

From a transaction perspective, trust reflects a calculated decision by a party to the transaction about the risks of opportunism. From an institutional perspective, institutional arrangements (e.g. regulations, professions, laws, rules) produce the trust that supports complex economic systems. Distrust leaves a party vulnerable, requiring more information to mitigate their uncertainty about the behavior of their partners. The exchange of reliable and accurate information is one facet of trusting relationships, in which partners share rather than withhold information (Mishra, 1996). Malone and Rockart (1993) asserts that IOS can mitigate the uncertainty created in low trust situations by:

- Making remote decision makers more effective
- Controlling and monitoring remote decision makers
- Socializing remote decision makers and building loyalty

### **Interorganizational Conflict**

Conflict is defined as a situation in which one member of the supply chain “perceives another member as engaging in behavior designed to injure, thwart, or gain resources at its expense” (Bowersox and Closs, 1996:324-325). Conflict between supply chain partners arises from incompatible goals, institutional differences, breakdowns in communication, and differing perceptions of appropriate roles (Taylor and Jackson, 2000).

### **Performance**

The model asserts a relationship between IOS use, uncertainty, and performance of an interorganizational task. This study of air cargo delivery focuses on a single measure of performance: on-time delivery. The significance of on-time delivery to the air cargo

industry has been discussed earlier, but we note that it is only one measure of performance relevant to the supply chain.

## **RESEARCH HYPOTHESES**

“Fit” has been variously interpreted in studies of the information processing model. In this study we pursue an *interaction* interpretation of fit. This approach argues that the variation in performance is the result of the interaction between sources of information processing requirements and information processing capacity. The strength of this interpretation of fit is its specificity, identifying interactions between specific sources of information processing requirements and capacity. Statistically, the interaction is usually represented as a product term in a regression equation. A “pure interaction” interpretation asserts that there will be a purely interactive effect of IOS and uncertainty on performance. Our first hypothesis:

*There is a direct relationship between IOS use and performance of the interorganizational task.*

Consistent with the interaction approach, we must specify hypotheses for each interaction of requirements and capacity:

*H<sub>Variability</sub>: Interorganizational task variability will moderate the relationship between IOS use and supply chain performance*

*H<sub>Analyze</sub>: Interorganizational task analyzability will moderate the relationship between IOS use and supply chain performance.*

*H<sub>Dynamism</sub>: Environmental dynamism will moderate the relationship between IOS use and supply chain performance.*

*H<sub>Trust</sub>: Interorganizational trust will moderate the relationship between IOS use and supply chain performance.*

*H<sub>Conflict</sub>: Interorganizational conflict will moderate the relationship between IOS use and supply chain performance.*

*H<sub>Power</sub>: Interorganizational power will moderate the relationship between IOS use and supply chain performance.*

## **METHODS**

### **Research Design**

The data for this study were collected from senior executives in charge of air cargo operations in forwarding organizations. The fieldwork proceeded in two stages. First, a series of semi-structured interviews were conducted with forwarders, carriers, associations and information systems providers. These interviews were complemented by observation of air cargo operations in the hub of a large international carrier. The interviews were focused on clarifying how IOS were being used, their effectiveness, and the issues facing the use of IOS in air cargo.

In the second stage we designed a structured questionnaire for freight forwarders. Two pretests of the instruments were conducted with a senior executive from each of seven companies in a first pretest and eight companies in a second. Pretest participants were senior executives in forwarding companies, airlines, and third party information system providers.

Sampling proceeded as follows. The survey was mailed to senior executives in 1,490 forwarding firms operating in the U.S. and U.S. territories.<sup>9</sup> Three reminders were sent to respondents. Responses were received from 195 forwarders with one unusable response, representing an effective response rate of 13.1%.

The response rate reflects the length of the questionnaire<sup>10</sup>, the pre-Winter Holiday timing of the survey, and the fact that in many forwarding companies air cargo constitutes a small percent of their business. However, this response rate falls within the 10 to 20% expected response rate for national surveys of top managers (Hambrick et al, 1993). ). Non-response bias occurs when non-respondents differ systematically from

respondents on key characteristics and is a threat to external validity. Because late respondents have been shown to resemble non-respondents more than they resemble early respondents (Kanuk and Berenson, 1975) correlations between response order and several key constructs (revenues, tonnage, shipments, IT expenditures) were examined. There were no statistically significant differences between the demographic characteristics of the respondents between the first wave and the last wave of respondents.

### **Operationalization of the Model Variables**

Validated measures were used where they were available from previous studies. For variables unique to this study content validity was assessed using data from the qualitative phase and through interviews with senior executives. The measures for each construct are given in Tables 1, 2, and 3 with a description of the indicators and their scales. Construct validity was tested using common factor analysis with maximum likelihood extraction and varimax rotation. The reliability of the seven multi-item constructs ranged from .58 to .80. Given the exploratory nature of this research it was decided to retain the constructs with the two lowest reliabilities: task variability (.58) and environmental dynamism (.67).

**Table 1 Measures of Information Processing Capacity**

Information Processing Capacity		
	Items	Description
Investment	1	Percent of gross revenue spent on information technology
Technologies	1	Dichotomous item (use/don't use) for electronic data interchange (EDI).
	1	Dichotomous item (use/don't use) for Cargo Community Systems (CCS).
Intensity	1	Percent of outbound shipments with electronic AWB <sup>11</sup> .
	1	Percent of outbound shipments with complete electronic documentation
	1	Percent of shipments electronically tracked or traced at least once during transport.
Connectivity	1	Percent of shipping, trucking, forwarder, airline, customs, and consignee relationships that are primarily electronic

**Table 2 Measures of Information Processing Requirements**

Information Processing Requirements		
	Items (reliability)	Description
Task Variability	3 (.58)	<i>Frequency of exceptional and novel events which require different methods for performing the task.</i> The extent to which 1) operational problems frequently arise for which there are no standard solutions, 2) the extent to which operational problems are routine and have routine solutions, 3) the extent to which the number of exceptional problems are rising. The indicator is measured using a 5-point interval scale ranging from “to no extent” to “very great extent”.
Task Analyzability	2 (.72)	<i>Extent to which there is a known procedure that specifies the sequence of steps to be followed in performing the task.</i> The indicator is composed of three items. The extent to which 1) there are clearly established procedures and practices to guide agents in planning and following shipments, and 2) operational performance is easy to measure. The indicator is measured using a 5-point interval scale.
Environmental Dynamism	3 (.67)	<i>Degree of change in the firm’s environment.</i> The extent to which 1) our firm must change its business practices frequently, 2) changes in the products offered by competitors are hard to predict, 3) product demand is hard to predict. The indicator is measured using a 5-point interval scale.
Trust	3 (.72)	<i>Degree of trust that exists between firms.</i> The indicator is composed of three items. The extent to which 1) The airlines we deal with adhere to agreements, verbal and written, 2) our information relationship with airlines is open and sharing, 3) airlines are well known for their fair dealing. The indicator is measured using a 5-point interval scale.
Conflict	1 (na)	<i>Degree of disagreements between parties.</i> Extent of frequent disagreements with airline. The indicator is measured using a 5-point interval scale.
Supplier Power	1 (na)	<i>The extent to which the supplier (airline) has influence over the buyer’s (forwarder) operational practices.</i> The indicator is measured using a 5-point interval scale.
Buyer Power	1 (na)	<i>The extent to which the buyer (forwarder) has influence over the supplier’s (airline) operational practices.</i> The indicator is measured using a 5-point interval scale.

**Table 3 Measures of Performance<sup>12</sup>**

Performance		
	Items	Description
Domestic On-Time	1 (na)	<i>Percent of shipments available to the consignee at the destination airport: Just before or just at the scheduled delivery time/ Within 4 hours of the scheduled delivery time/ Within 12 hours/ Within 24 hours/ Within 48 hours/ Within 72 hours. The items were reduced to a single measure by using a weighted average.</i>
International On-Time	1 (na)	<i>Percent of shipments available to the consignee at the destination airport: Just before or just at the scheduled delivery time/ Within 4 hours of the scheduled delivery time/ Within 12 hours/ Within 24 hours/ Within 48 hours/ Within 72 hours. The items were reduced to a single measure by using a weighted average.</i>

## **FINDINGS**

Basic descriptive statistics are displayed in Tables 4 and 5. Prior to analysis we performed data screening activities. Several firms were contacted for their revenue and tonnage data and seriously non-normal distributions were transformed before final analysis.<sup>13</sup>

**Table 4 Descriptive Statistics**

	N <sup>14</sup>	Min.	Max.	Mean	S.D.	Skewness <sup>15</sup>	Kurtosis <sup>16</sup>
<b>IOS</b>							
IT Investment	169	0.000	1.491	0.743	0.345	0.146	-0.525
EDI Use	179	0.000	1.000	0.358	0.481	0.600	-1.659
CCS Use	195	0.000	1.000	0.262	0.441	1.094	-0.812
Electronic Air Waybills	166	0.000	100.000	27.21	41.394	0.980	-0.927
Electronic Documentation	158	0.000	100.000	17.01	34.781	1.785	1.421
Tracking	172	0.000	100.000	47.55	41.187	0.087	-1.684
Connectivity	140	0.000	10.000	3.795	2.653	0.357	-0.564
<b>Sources of Uncertainty</b>							
Task Variability	180	-1.488	2.162	0.000	0.773	0.331	0.030
Task Analyzability	184	1.000	5.000	3.840	0.796	-0.356	-0.127
Environmental Dynamism	182	-1.662	2.167	0.000	0.856	0.184	-0.135
Trust	187	-2.169	1.730	0.000	0.861	0.082	-0.282
Conflict	186	1.000	5.000	2.339	1.039	0.540	-0.332
Buyer Power	184	1.000	5.000	1.870	1.053	1.059	0.433
Supplier Power	180	1.000	5.000	2.833	1.275	0.023	-1.029

**Table 5 Descriptive Statistics**

	N	Min.	Max.	Mean	S.D.	Skewness	Kurtosis
<b>Dependent Variables</b>							
Domestic Performance	74	0.000	1.690	1.052	0.451	-0.452	-0.451
International Performance	158	0.005	1.790	0.909	0.471	0.137	-0.780
<b>Controls</b>							
Revenue	195	0.477	6.141	3.107	0.955	0.245	1.025
Shipments – U.S.	195	0.000	1.982	0.542	0.709	0.920	-0.737
Shipments - Canada	195	0.000	1.695	0.356	0.402	0.773	-0.426
Shipments - Western Europe	195	0.000	1.959	0.963	0.671	-0.284	-1.310
Shipments - Eastern Europe	195	0.000	2.004	0.414	0.505	1.111	0.289
Shipments - Middle East	195	0.000	2.004	0.504	0.564	0.801	-0.489
Shipments - Far East	195	0.000	2.004	1.049	0.655	-0.266	-1.017
Shipments – Latin America	195	0.000	2.004	0.727	0.613	0.425	-0.812

In the first stage of the analysis, correlation analysis is used to assess the direct impact of IOS use on international on-time performance. In the second stage of the analysis,



moderated multiple regression analysis (MMR) is used to assess the interaction of sources of uncertainty and IOS on on-time performance. A description of the MMR technique is found in Appendix I. The control variables in all regressions are the air cargo revenues and the percent of the firm’s shipments destined for key international geographic regions. The log of the dependent and all control variables are used in the analysis.

***Direct Impacts of IOS on Logistics Supply Chain Performance***

Our first hypothesis is that there is a direct relationship between IOS and performance. Examining the correlations<sup>17</sup> between IOS dimensions and domestic and international on-time performance we find only one significant correlation. Connectivity and international on-time performance were negatively correlated at  $\alpha < .05$ . Connectivity is a measure of the penetration of IOS into the forwarder’s network of partnerships. The other measures of IOS were not significantly correlated with performance including key measures of IOS investment and EDI measures. We conclude that there is no support for the hypothesis that there is a direct impact of IOS on performance.

The absence of a direct relationship between IOS use and performance could mean that there is no impact at all of IOS on performance. To determine if there is an interaction effect present we proceed to the interaction analysis.

**Table 6 Correlations Between IOS Use and Performance**

On-Time Performance (p<.05; 2-tailed).	IT Investment	EDI Use	CCS Use	Electronic AWB	Electronic Doc	Tracking	Connectivity
Domestic	-0.036	-0.153	0.001	0.018	0.054	0.059	-0.137
International	-0.032	-0.003	0.048	0.080	-0.007	-0.021	-0.193

## **CORRELATIONS BETWEEN IOS AND PERFORMANCE MEASURES**

### *Interaction Effects of Uncertainty and IOS on Performance*

Table 7 provides the basic details of the MMR analysis for the twelve significant interactions. The table provides the adjusted squared multiple correlations for the full regression model including the interaction term, the change in squared multiple correlation, and the full model significance. The adjusted squared multiple correlation indicates the percent of variance in the dependent variable accounted for by the model. The change in squared multiple correlation indicates the additional variance explained by the interaction term. Significance is provided for the interaction term and the model.

We find evidence of significant relationships between interactions of dimensions of uncertainty and IOS and supply chain performance. Ten interactions were found on international on-time performance and two for domestic on-time performance. Summarizing the findings, we find evidence of interactions of task, environment, and partnership uncertainty with dimensions of IOS use to affect on-time performance. For the construct of task, interaction effects of task variability and analyzability with IOS are found. For environment, dynamism is found to interact with IOS. For partnerships, conflict, supplier dependence and supplier power are found to interact. We find support for the hypotheses that uncertainty dimensions of task, environment and partnership interact with dimensions of IOS to impact logistics supply chain performance.

**Table 7 Summary of the MMR Analysis**

<b>Uncertainty Dimensions</b>	<b>IOS Dimensions</b>	<b>N<sup>18</sup></b>	<b>Adj. R<sup>2</sup></b>	<b>?R<sup>2</sup></b>	<b>Interaction Sig. (p&lt;)</b>	<b>Model Sig. (p&lt;)</b>
Task Variability	EDI (D)	66	.098	.048	.10	.05
	Connectivity(I)	111	.183	.024	.10	.001
Task Analyzability	IT Investment (D)	66	.092	.086	.05	.10
	EDI (I)	137	.197	.020	.10	.001
Interorganizational Conflict	IT investment (I)	122	.120	.019	.10	.01
Supplier Power	EDI (I)	132	.184	.023	.10	.001
	Connectivity (I)	107	.196	.029	.10	.001

(D) = Domestic on-time performance; (I) = International on-time performance

## **DISCUSSION**

### ***Support for the Information Processing Model***

The study found seven interactions between dimensions of information processing capacity and dimensions of information processing requirements. The detection of the interactions supports our hypotheses that dimensions of task, environment and partnership uncertainty interact with dimensions of IOS to predict on-time performance. From the information processing view these findings support the argument that the level of performance depends on the fit between information processing requirements arising from contextual uncertainty and information processing capacity provided by IOS.

### *The Significance of Context*

The absence of direct effects of IOS on performance<sup>19</sup> combined with the detection of interactions suggests that the effect of IOS on operational performance can only be seen in the presence of a third moderating variable. This reinforces the significance of including context in models of operational impacts of IOS. This might also explain the difference in findings between studies that have not found a direct effect (e.g. Powell and Dent-Micallef, 1997; Venkatramen and Zaheer, 1990), and those that have (e.g. Hart and Estrin, 1991, Kekre and Mukopadhyay, 1992).

The findings demonstrate the benefits of a socio-technical approach towards understanding IOS impacts on supply chain performance (e.g. Kling and Iacono, 1989). The study demonstrates that a technologically deterministic perspective of IOS impacts, ignoring contextual influence, is naïve in its assumptions. In the context of the supply chain literature, the discussion of interfirm relationships is often characterized by language of cooperation and joint coordination that smooth the transfer of information. The findings suggest that electronic integration must also contend with issues of power and conflict that influence the amount of information that needs to be exchanged between organizations.

The significance of the findings for the development of IOS for electronic integration are that design, adoption and implementation of systems should consider the impact of relevant task, environmental and partnership factors in the supply chain context in order to increase the likelihood of positive impacts of IOS on performance.

### *Granularity of Models*

The findings of the study indicate that it is possible to take a fine-grained approach to the study of the role of information technologies in electronic integration. The twelve interactions between distinct dimensions of IOS and particular dimensions of context

suggest that models of effective use of IOS in supply chains can be extended to reflect the subtlety and complexity of the use of IOS for electronic integration.

The fact that all these moderating factors are operating simultaneously within a single industry and a single supply chain task underscores the complexity of IOS impacts. Any single factor may be responsible for only a small portion of variance in supply chain performance. A more holistic approach toward modeling performance impacts of electronic integration is required.

## **CONCLUSION**

This study examines the impact of electronic integration of the logistics supply chain and attempts to identify limits of this integration. We point out, that as technologies evolve that these limits may well change. Nonetheless, identifying these could influence future information systems development. Our study finds that dimensions of task, environment and partnership interact with dimensions of interorganizational information processing capacity to predict supply chain performance. What this suggests is that the use of electronic integration as a strategy to improve operational performance is limited by the nature of the particular task, the supply chain environment, and the quality of the partnership between firms in the supply chain.

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## APPENDIX I: MODERATED MULTIPLE REGRESSION

Moderated multiple regression (MMR) seeks to identify a moderated causal relationship in which the relationship between an independent variable  $X$  and a dependent variable  $Y$  is moderated by a third variable  $Z$ . The relationship between  $X$  and  $Y$  varies depending on the value of  $Z$ . The interaction between independent variables  $X$  and  $Z$  models can be interpreted as both the moderating effect of  $Z$  on the relationship between  $X$  and  $Y$  and the moderating effect of  $X$  on the relationship between  $Z$  and  $Y$ . In this study the moderator  $Z$  is the sources of uncertainty.

The MMR procedure requires testing interactions between each of the uncertainty variables and each of the IOS variables. With two performance measures as our dependent variables this results in examining  $X$  regression equations for significant interactions.

MMR uses standard hierarchical regression techniques to detect moderator effects. We use a regression strategy recommended by Cohen and Cohen (1983) and Jaccard et al. (1990) that uses a product term  $X*Z$  to model the interaction between independent variables  $X$  and  $Z$ , where  $Z$  is the hypothesized moderator. If a moderator effect is present, then the coefficient of the product term will be significantly different from zero, and the difference in squared multiple correlation between the main effects model (1) and the interaction model (2) will be significant.<sup>20</sup>

$$Y_i = b_0 + (Controls) + b_X X_i + b_Z Z_i + e_i \quad (1)$$

$$Y_i = b_0 + (\text{Controls}) + b_X X_i + b_Z Z_i + b_{XZ} X_i Z_i + e_i \quad (2)$$

The regression coefficient of the interaction term in (2) is interpreted as:

$b_{XZ}$  = the number of units that the slope of  $Y$  on  $X$  changes given a one-unit change in  $Z$ .

Or, for every unit increase in  $Z$ , the slope of  $Y$  on  $X$  changes by  $b_{XZ}$ .

The test of the null hypothesis,  $H_0: b_{XZ} = 0$ , is a test for a reliable moderating effect of  $Z$  on the  $X$ - $Y$  relationship (McClelland and Judd, 1993). If the F-test is significant we can reject the null hypothesis in favor of the alternative hypothesis that an interaction is present.

The strength of the moderator effect is indicated by the size of the change in squared multiple correlation between the main effects model and the interaction model. The change indicates the percent of variance in the dependent variable accounted for by the interaction effect.

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<sup>1</sup> 31% of world air metric tonnage is moved in the domestic U.S., U.S.-International air freight accounts for another 25% (Boeing, 1998). This includes both U.S. and non-U.S. airlines and forwarders.

<sup>2</sup> This number includes all scheduled and non-scheduled national and regional airlines.

<sup>3</sup> The largest integrators are FedEx and UPS which carried 70% of shipments in 1992. Forwarders and airlines moved approximately 20% of shipments. In weight FedEx and UPS moved 30% of the weight while forwarders and carriers moved 50%. In revenue, FedEx and UPS had a 50% share of air cargo while the forwarders and airlines had 25%. This emphasizes some distinctions between integrated and forwarder-airline operations.

<sup>4</sup> Combination carriers are scheduled airlines that carry a combination of both passengers and cargo.

<sup>5</sup> All-cargo carriers can be organized as integrators or non-integrators but are not included in the current study

<sup>6</sup> Open sky agreements provide airlines access to regional air cargo markets to offer services without restrictions.

<sup>7</sup> These airlines are often called combination-carriers as they carry both passengers and cargo.

<sup>8</sup> The consignee is usually the party paying for the shipment in commercial transactions.

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<sup>9</sup> Cargo Network Services, a wholly owned non-profit subsidiary of the International Air Transport Association (IATA) provided the mailing list for the survey. Its membership accounts for 90-95% of all air cargo revenues from shipments on scheduled air carriers in the United States. CNS provided support for the survey mailout and for faxing reminder letters. Returned surveys were mailed directly to the researchers in prepaid envelopes.

<sup>10</sup> The full survey contained 50 questions.

<sup>11</sup> The air waybill (AWB) provides administrative, financial and operational information critical to the shipment process.

<sup>12</sup> Clearly there are many other important measures of performance. The integrators began competing on this measure with guaranteed delivery times. Therefore, it seems a reasonable measure to examine, when examining the impact of IT (IOS) in the non-integrated sector.

<sup>13</sup> Screening continuous variables for normality increases the quality of the multiple regression and potentially can reduce the number of cases required to detect an interaction. Although normality of variables is not a requirement for regression, the sensitivity of the analysis can be greatly improved if variables are all normally distributed (Tabachnick and Fidell, 1996). In particular, the transformation of a skewed dependent variable can dramatically improve results.

<sup>14</sup> N varies due to missing values.

<sup>15</sup> Skewness reflects symmetry of a distribution. Positive skewness indicates a distribution where the bulk of the cases are to the left and with a long right tail. A normal distribution has skewness of zero.

<sup>16</sup> Kurtosis is a measure of the peakedness of a distribution. Positive kurtosis indicates a peaked distribution with long tails. A negative kurtosis indicates a flat distribution. A normal distribution has skewness of zero.

<sup>17</sup> Correlations were performed using both Pearson product-moment parametric and Spearman rank nonparametric measures of correlations.

<sup>18</sup> N for domestic performance ranges from 56 to 74; N for international ranges from 115 to 158. N for each variable included in the analysis varies according to the number of missing responses. Missing values were not included in the regression analysis. The one exception is that missing value replacement was used for the revenue control variable to increase the number of usable cases. We used mean substitution from the transformed population as the original transformation was highly skewed. Thirty-five missing values were replaced in this way.

<sup>19</sup> Of the eleven dimensions of IOS, only the measure of connectivity was significantly correlated to international on-time performance. This is not a measure of IOS adoption per se, but a reflection of the penetration of IOS into the forwarder's network of partnerships.

<sup>20</sup> Some authors have suggested centering variables prior to MMR analysis to avoid problems of multicollinearity (e.g. Jaccard et al, 1990; Cohen and Cohen, 1983). However, it has been demonstrated by Kromrey and Foster-Johnson (1998) that MMR using centered and uncentered variables yield functionally equivalent results. Therefore uncentered variables will be used in our analysis.