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An Application of ANP to Strategic Analysis of Modern Logistics Systems[1]

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ABSTRACT: This paper develops and illustrates an analytical framework to assess enterprise logistics strategy. Logistics can be defined to include the management of materials, information and financial flows. The "principles of logistics" which consist of selective risk, information selectivity, information substitution, transaction simplification, variance reduction, inventory velocity, postponement, and shared/shifted risk are used as the foundation for an analytical framework. The principles of logistics are defined and developed as strategies for achieving coordination and integration of the logistics network and supply chain. The analytic network process, a systemic analytical model, will be utilized to evaluate logistics strategies for an enterprise or supply chain that seeks to be adaptive to dynamic competitive environments.

INTRODUCTION

The strategic management of logistics is a critical aspect of a successful competitive enterprise and supply chain. Managing logistics activities across traditional boundaries is essential for integrating the supply chain. The basic mission of logistics is to provide goods and services to customers according to their needs and requirements in the most efficient manner possible (Ballou, 1992). Logistics emphasizes both internal and external customers in the production of goods and services. Logistics is "the heat that forges the supply chain" (Harrington, 1995) and helps to facilitate the migration of an organization towards optimal performance. The integration and coordination of the materials, information and financial flows across the supply chain are critical for an organization to be adaptive to dynamic competitive environments.

Logistics plays an increasingly important strategic role for organizations that strive to keep pace with market changes and supply chain integration. Traditionally, supply management and logistics have been delegated to operational level personnel in purchasing and distribution departments. Logistics and supply management are currently evolving due to external factors such as the high cost of money, technological changes, and the increasing competitive environment. There have also been changing internal factors such as the implementation of decision support systems, information systems integration, spanning of logistics to impact

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traditional functional areas, and increasing performance expectations (LaLonde and Mason, 1993). These factors are influencing a new management style in the logistics field leading to well-defined actions or strategies defined by LaLonde and Mason (1993) as the "Principles of Logistics." These principles including, Selective Risk, Information Selectivity, Information Substitution, Transaction Simplification, Variance Reduction, Inventory Velocity, Postponement, and Shared/Shifted Risk are used to develop a foundation for an analytical strategic decision making framework for identification of appropriate logistics technology, operations, or systems strategies. The complexity of logistics strategic decisions and choices has increased with the number of dimensions that need to be considered. A summary of these many dimensions is presented later in the discussion on the principles of logistics and in the development of the strategic analytical framework. A systemic multiattribute analytical technique, defined as the analytical network process (ANP), is used for evaluating alternative logistics strategies. An illustrative example provides additional insights for research and practical applications. First, a review of some analytical models for strategy development and decision making in logistics is presented.

ANALYTICAL MODELS FOR LOGISTICS STRATEGY ANALYSIS

As in most strategic management literature, analytical models that incorporate the many dimensions of a logistics strategy are rare. Analytical models that do exist, typically focus on one dimension of the logistics strategy or are static in their approaches (Davis, 1994; Johnson and Wood, 1993; LaLonde and Masters, 1994; Lee and Billington, 1994; Wilson, 1992).

Part of the difficulty in analytically modeling strategic decisions is their basis on qualitative information. A quantitative model that can be used to transform qualitative information to quantitative values and analysis is the Analytical Hierarchy Process (AHP). This technique has been effectively used for logistics applications such as the analysis of international consolidation terminals (Minn, 1994b), determining what to benchmark (Partovi, 1994), the allocation of contract incentives based on schedule, quality, radiation exposure, and safety (Thompson, 1994), and locating airports (Minn, 1994a). AHP is a relatively popular tool for modeling strategic decisions, but a primary limitation is its basic relationships do not allow for an integrated dynamic modeling of the environment.

AHP assumes the system elements are uncorrelated and are unidirectionally influenced by a hierarchical relationship. A more general evaluation approach defined as the Analytical Network Process (ANP), or systems with feedback approach, with may be used to assume a multi-directional relationship among decision attributes (Hamalainen and Seppalainen, 1986; Saaty, 1988; Saaty and Takizawz, 1986). Due to its complex relationships, ANP's application has been very limited. One of the few strategic applications of ANP includes an evaluation of a multi-attribute, multi-year decision process applied to an equipment replacement decision (Azhar and Leung, 1993). The ANP approach has been defined as a non-linear, network relationship among various factors. It allows for the capability to model more complex and dynamic environments, environments that are more evident at strategic planning levels.

THE PRINCIPLES OF LOGISTICS

The principles of logistics, identified by LaLonde and Mason (1993) provide a foundation for consistent evaluation of logistics activities and strategies. The three main areas of logistics; inbound logistics, materials management, and outbound logistics are all influenced by the principles of logistics. These principles will also impact and be impacted by the logistics environment of the firm (e.g. supply chain strategies and product life cycle strategies). Example attributes, which form another level within the analysis framework, are based on expert opinion and literature; they are not exhaustive. Table 1 summarizes the nine principles of logistics along with the supporting attributes for their effective management. This tabular relationship can also be viewed as a hierarchical linkage, as will be shown in the analysis framework.

PRINCIPLE OF LOGISTICS	*Attributes for Management of Logistics Principle*
Selective Risk	Knowledge About Customers (KACU) Knowledge About Competition (KACO) Service Range Capabilities (SRC) Inventory Management System Flexibility (IMSF)
Information Selectivity	Flexibility of Data Linkages (FDL) Accuracy of Data (AOD) Accuracy of Data Needs (ADN) Data Search Capability (DSC)
Information Substitution	Coverage of Information Linkages (CIL) Accuracy of Data (AOD) Level of Systems Integration (LSI) Forecasting Capabilities (FC)
Transaction Simplification	User-Interface Friendliness (UIF) Data Available to User (DAU) Level of Systems Integration (LSI) Suppliers Access to Information (SAI)
Variance Reduction	Demand Forecasting Tools (DFT) Communication with Customer/Supplier (CCS) Statistical Process Control (SPC) Internal Systems Integration (ISI)
Inventory Velocity	Efficient Third Party Relationships (ETPR) Just-In-Time Support (JITS) Flexible Manufacturing Operations (FMO) Flexible Distribution Options (FDO)
Postponement	Modular Product Design (MPD) Flexible Packaging Design (FPD) Retail/Distribution Site Data (RDSD)
Shared/Shifted Risk	Creation of Standards (COS) Outsourcing Agreements (OA) Supplier Customization (SC)

Table 1: Principles of Logistics and Attributes of Systems for Management of Logistics Principles.

A Network Framework for Assessing Logistics Strategies and Systems

The discussion on logistics strategies, environments, and principles provides the elements for the development of a strategic assessment framework. This framework is summarized in Figure 1. The framework is presented through a network of decision model relationships. The levels of the network framework include the organizational/supply chain relationships, the principles of logistics level, the attributes level, and the alternative selection level. These levels impact the overall goal of maintaining a competitive logistics/supply chain strategy. This framework is only one general set of relationships that can exist, some variations on this framework are discussed in the final section.

The four components of the *organizational/supply chain relationships* (we shall define these as organizational relationships), are commodity, partnership, strategic alliance, and virtual enterprise. The strategic alignment of an organization's logistics network needs to be synchronized with the demands of the competitive environment. As a system, an enterprise that fails to respond to environmental demands is placed at a disadvantage relative to competing firms. Some of the characteristics of the supply chain relationship spectrum are defined below. This spectrum will comprise the strategic dynamic environment elements in the strategic analysis model.

Commodity relationships among enterprises focus on customers choosing suppliers based on price, quality, and reliability. The relevant business processes will be sparsely linked compared with the linkages to be found at the virtual relationship end of the spectrum, and the financia/legal relationships will be less strongly coupled.

Partnering's goal is to provide benefits to all sides of the relationship. Moody (1994), Schonberger (1990) and others advocate long term, selective partnerships. Cost and time reductions are tangible benefits, whereas flexibility and customer satisfaction are intangible benefits of partnering.

Strategic alliances are more strategically oriented than partnerships. The organization develops a relationship with a specific goal in mind. The supplier adds value to the customer's business processes as purchases become more unique and customized.

Virtual relationships focus more on satisfying the customer than on maintaining the relationship. The concept of the "Virtual Enterprise" (Iacocca Institute, 1994) has become more evident in recent years. Based on this concept, several independent enterprises join together emphasizing their particular core competencies to form a Virtual Enterprise that is able to compete in a given arena for a given product or service. Without this merger of resources, the separate companies may be unable to successfully compete in a given market niche. The competitive advantage that can be achieved by a virtual enterprise depends on how well the individual firms complement each other and their ability to integrate with one another.

Even at the supply chain strategy level a dynamic environment with various choices exist. Supply chain strategies include a continuum extending from commodity providers to virtual enterprise membership. Commodity, partnering, strategic alliances and virtual enterprises form a spectrum of relationships that may exist among enterprises, with the relations of the inter-enterprise business processes becoming more unified and integrated along this spectrum.

The *principles level* contains the eight principles of logistics discussed earlier. The *attributes level* is composed of the components which help monitor the deployment and management of these principles. For the illustrative example and for maintaining simplicity in its presentation, three logistics systems are considered, the Current (incumbent) System, System A and System B. The goal of this model is to select the most appropriate logistics system for a given enterprise operating to maintain a competitive logistics strategy.

Similar to the traditional AHP approach a hierarchical relationship exists within the network model. A major difference is the existence of a feedback relationship among the levels within this framework. In this example, a two way impact relationship exists between the *organizational relationships* and *principles of logistics* levels of analysis. The principles of logistics effect the organizational relationship selected (or in practice) and the organizational strategy selected determines the roles of the principles. For example, in a commodity relationship, the selective risk principle may play a larger role then in a strategic alliance relationship (where shared/shifted risk would become a more critical principle). In addition, the focus on a certain principle would impact the development on these relationships. If there is a higher priority set on shared/shifted risk a commodity relationship may be forced to evolve into a partnership oriented relationship.

The Analytical Network Process

ANP is a more general form of AHP. Whereas AHP models a decision making framework using a uni-directional hierarchical relationship among decision levels, ANP allows for more complex interrelationships among the decision levels and attributes. Typically, in AHP the top element of the hierarchy is the overall goal for the decision model. The hierarchy decomposes from the general to a more specific attribute until a level of manageable decision criteria is met. ANP does not require this strictly hierarchical structure. Interdependencies may be represented by two way arrows (or arcs) among levels, or if within the same level of analysis, a looped arc. The directions of the arcs signify dependence, arcs emanate from an attribute to other attributes that may influence it. The relative importance or strength of the impacts on a given element is measured on a ratio scale similar to AHP. A priority vector may be determined by asking the decision maker for his numerical weight directly, but there may be less consistency, since part of the process of decomposing the hierarchy is to provide better definitions of higher level attributes.

The ANP approach is capable of handling interdependence among elements by obtaining the composite weights through the development of a "supermatrix". Saaty (1988) explains the supermatrix concept as a parallel to the Markov chain process. The supermatrix development is shown in the steps for assessing the model. In this example, the only interdependencies that are identified, and will form the supermatrix, are the organizational relationships and principles of logistics components levels. The methodology for building and analyzing the logistics strategy model is now detailed in a series of steps with a parallel illustrative example provided. The values used in this example are assumed. In an actual application of this model a complex iterative approach is recommended, one designed to elicit the data from the "minds" of one or more strategic planners who have a stake in the final decision. This may include input from sources outside the immediate enterprise, to include customers and suppliers.

ANP Analysis and Solution Methodology

STEP 1: *Model Construction and Problem Structuring:* The first step is to construct a model to be evaluated. The illustrative example will use the model that was developed earlier in the paper and summarized in Figure 1. The relevant criteria and alternatives are structured in the form of a hierarchy where the higher the level, the more "strategic" the decision. The topmost elements are decomposed into sub-components and attributes. The model development will require the development of attributes at each level and a definition of their relationships. In this example, the only interdependence or feedback occurs between the organizational relationships level and the principles of logistics level of attributes.

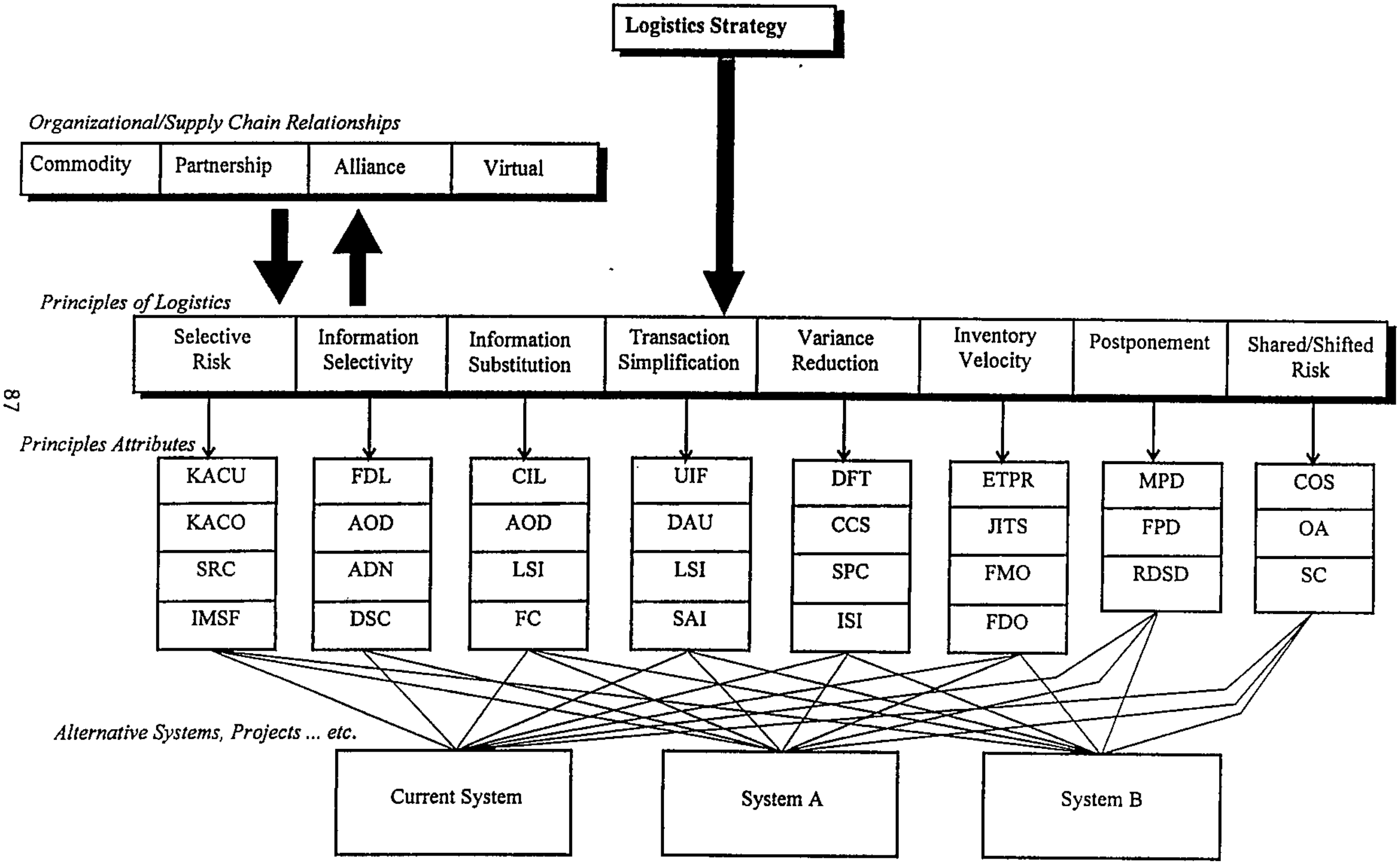
STEP 2: *Pairwise Comparisons Matrices of Interdependent Component Levels*: Eliciting preferences of various components and attributes will require a series of pairwise comparisons where the decision maker will compare two components at a time with respect to an upper level "control" criterion. In ANP, like AHP, pairwise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion.

Saaty (1988) has suggested a scale of 1 to 9 while comparing two components, with a score of 1 representing indifference between the two components and 9 being overwhelming dominance of the component under consideration (row component) over the comparison component (column component). If a component has some level of weaker impact the range of scores will be from 1 to 1/9, where 1 represents indifference and 1/9 being an overwhelming dominance by a column element over the row element. When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix. That is, if a_{ij} is a matrix value assigned to the relationship of component i to component j, then a_{ji} is equal to $\frac{1}{a_{ij}}$ (or $a_{ij}\, a_{ji} = 1$). Since many of these values are strategic, additional strategic group decision making tools such as scenario planning or the Delphi approach can be utilized to assign meaningful values to these pairwise comparisons. Especially, when determining the relative impact of various logistics principles within a given organizational relationship.

Within this illustrative example the relative importance of the system attributes with respect to a specific organizational relationship selected (i.e. Commodity to Virtual Enterprise) is first determined. A pairwise comparison matrix will be required for each of the four major organizational relationships for calculation of impacts of each of the logistics principles. In addition, eight pairwise comparison matrices will need to be determined for calculation of the relative impacts of the organizational relationship on a specific logistics principle. To fully describe these two-way relationships, 12 pairwise comparison matrices will be required.

Once the pairwise comparisons are completed, the local priority vector w (defined as the eVector in the example figures) is computed as the unique solution to:

$$Aw = \lambda_{\max} w, \qquad (1)$$



Logistics Strategy
Organizational/Supply Chain Relationships
Commodity
Partnership
Alliance
Virtual
Principles of Logistics
Selective Risk
Information Selectivity
Information Substitution
Transaction Simplification
Variance Reduction
Inventory Velocity
Postponement
Shared/Shifted Risk
Principles Attributes
KACU
KACO
SRC
IMSF
FDL
AOD
ADN
DSC
CIL
AOD
LSI
FC
UIF
DAU
LSI
SAI
DFT
CCS
SPC
ISI
ETPR
JITS
FMO
FDO
MPD
FPD
RDSD
COS
OA
SC
Alternative Systems, Projects ... etc.
Current System
System A
System B

where λ_{max} is the largest eigenvalue of A. Saaty [24] provides several algorithms for approximating w. In this paper a two-stage algorithm that involved forming a new n x n matrix by dividing each element in a column by the sum of the column elements and then summing the elements in each row of the resultant matrix and dividing by the n elements in the row. This is referred to as the process of averaging over normalized columns. This is represented as:

$$w_i = \frac{\sum_{i=1}^{I}\left(\frac{a_{ij}}{\sum_{j=1}^{J} a_{ij}}\right)}{J} \quad (2)$$

where:

w_i = the weighted priority for component i

J = index number of columns (components)

I = index number of rows (components)

In the assessment process there may occur a problem in the transitivity or consistency of the pairwise comparisons. For an explanation on inconsistencies in relationships and their calculations see Saaty (1988). It is assumed that the pairwise comparisons are consistent in these examples.

An example of the logistics principles pairwise comparison matrix within a *commodity* organizational relationship environment is presented in Figure 2. In the *commodity* environment, the *selective risk* principle is viewed as being slightly more important (a_{12} = 3) then the *information selectivity* principle. The weighted priorities for this matrix is shown as the last column in Figure 2. The weighted priorities for each of the organizational relationships matrices (four in all) are combined to create a matrix **A** with four columns and eight rows (see Figure 3).

COMMODITY	Sel Risk	Info Sel	Info Sub	Tran Simp	Var Red	Inv Vel	Pp	S/sh Risk	eVector
Sel Risk	1.000	3.000	3.000	0.333	0.500	0.250	2.000	3.000	0.109
Info Sel	0.333	1.000	3.000	1.000	0.250	3.000	3.000	3.000	0.136
Info Sub	0.333	0.333	1.000	3.000	0.333	3.000	2.000	3.000	0.107
Tran Simp	3.003	1.000	0.333	1.000	3.000	5.000	3.000	2.000	0.228
Var Red	2.000	4.000	3.003	0.333	1.000	5.000	3.000	3	0.301
Inv Vel	4.000	0.333	0.333	0.200	0.200	1.000	2.000	2.000	0.055
Pp	0.500	0.333	0.500	0.333	0.333	0.500	1.000	5.000	0.044
S/sh Risk	0.333	0.333	0.333	0.500	0.333	0.500	0.200	1.000	0.021

Figure 2: Logistics Principles Pairwise Comparison Matrix for Commodity Organizational Relationship Environment and Eigenvector (Relative Importance/Impact Weights).

A MATRIX	COMMODITY	PARTNERSHIP	STRAT ALL	VIRTUAL
Sel Risk	0.109	0.193	0.254	0.127
Info Sel	0.136	0.135	0.188	0.102
Info Sub	0.107	0.135	0.100	0.120
Trans Simp	0.228	0.273	0.146	0.125
Vari Red	0.301	0.140	0.131	0.050
Inv Vel	0.055	0.078	0.056	0.045
Pp	0.044	0.028	0.020	0.285
S/sh Risk	0.021	0.018	0.104	0.147

Figure 3: The A Matrix Formed from Eigenvectors (Relative Importance Weights) for Organizational Relationship Implications on Logistics Principles.

STEP 3: *Supermatrix Formation:* The supermatrix allows a resolution of the effects of interdependence that exists between the elements of the system. The supermatrix is a partitioned matrix, where each submatrix is composed of a set of relationships between two levels in the graphical model. Three types of relationships may be encountered in this model: 1) independence from succeeding components, 2) interdependence among components, and 3) interdependence between levels of components.

The two compiled matrices A and B, are now combined to form the supermatrix M shown in Figure 4. Raising the supermatrix to the power 2k+1, where k is an arbitrarily large number, allows convergence of the interdependent relationships between enterprise strategies and principles of logistics. In this example, convergence is reached at M^{31}. The "long term" stable weighted values to be used in the analysis are shown in Figure 5.

STEP 4: *Analyze Principles of Logistics Attributes*: In this illustration no interdependence between the principles level and the attributes level is assumed to exist. A similar pairwise comparison that was made in Step 2 is made for the attributes level for relative importance weight calculation (or eigenvector determination). There are eight separate pairwise comparison matrices that have to be developed for this step in the analysis.

STEP 5: *Alternative Evaluations*: Each alternative will need to be evaluated on each of the principle attributes or management decision categories. This is completed by making a pairwise comparison of the performance of each alternative on each attributes. Since there are 30 attributes, an additional 30 3x3 pairwise comparison matrices will be needed for evaluation. The size of the pairwise matrices is dependent on the number of systems alternatives that are to be evaluated. This illustration includes three alternatives, a current logistics (incumbent) system that is to be evaluated against two new alternatives. The pairwise comparisons are completed by asking the relative impact of one system on a logistics principle attribute. For example, the first attribute "knowledge about customer" (KACU), is compared between the current system and alternatives "A" and "B". The current system is assumed to perform better on the KACU attribute than system "A" and "B", since it already tracks sales and length of time company has been a customer.

STEP 6: *Selection of Best Alternative:* The selection of the best alternative depends on the calculation of the "desirability index" for an alternative i (D_i). The equation for D_i is defined by:

$$D_i = \sum_{j=1}^{J} \sum_{k=1}^{K_j} P_j A_{kj} S_{ikj} \qquad (3)$$

where:

P_j is the relative importance weight of principle j,

A_{kj} is the relative importance weight for attribute k of principle j, and

S_{ikj} is the relative impact of alternative i on attribute k of principle j.

K_j is the index set of attributes for principle j.

J is the index set of principles.

The alternative with the largest desirability index should be the one selected. In the illustrative example the results of the logistics strategic analysis (see Figure 6) point to selection of Alternative System A, which has the largest desirability index of 0.438.

SUPER MATRIX	Commodity	Partner	Strat All	Virtual	Sel Risk	Info Sel	Info Sub	Tran Simp	Var Red	Inv Vel	Pp	S/sh Risk
Commodity	0	0	0	0	0.411	0.476	0.484	0.436	0.303	0.192	0.102	0.137
Partner	0	0	0	0	0.265	0.241	0.245	0.275	0.160	0.212	0.225	0.272
Strat All	0	0	0	0	0.185	0.198	0.162	0.177	0.258	0.255	0.311	0.332
Virtual	0	0	0	0	0.140	0.085	0.108	0.112	0.279	0.341	0.362	0.259
Sel Risk	0.109	0.193	0.254	0.127	0	0	0	0	0	0	0	0
Info Sel	0.136	0.135	0.188	0.102	0	0	0	0	0	0	0	0
Info Sub	0.107	0.135	0.100	0.120	0	0	0	0	0	0	0	0
Trans Simp	0.228	0.273	0.146	0.125	0	0	0	0	0	0	0	0
Var Red	0.301	0.140	0.131	0.050	0	0	0	0	0	0	0	0
Inv Vel	0.055	0.078	0.056	0.045	0	0	0	0	0	0	0	0
Pp	0.044	0.028	0.020	0.285	0	0	0	0	0	0	0	0
S/sh Risk	0.021	0.018	0.104	0.147	0	0	0	0	0	0	0	0

Figure 4: Initial Supermatrix M Compiled from Matrices A and B for Organizational Relationships and Logistics Principles Linkages.

Converged Supermatrix	Commodity	Partner	Strat All	Virtual	Sel Risk	Info Sel	Info Sub	Trans Simp	Var Red	Inv Vel	Pp	S/sh Risk
Commodity	0	0	0	0	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359
Partner	0	0	0	0	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236
Strat All	0	0	0	0	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218
Virtual	0	0	0	0	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184
Sel Risk	0.164	0.164	0.164	0.164	0	0	0	0	0	0	0	0
Info Sel	0.140	0.140	0.140	0.140	0	0	0	0	0	0	0	0
Info Sub	0.114	0.114	0.114	0.114	0	0	0	0	0	0	0	0
Trans Simp	0.201	0.201	0.201	0.201	0	0	0	0	0	0	0	0
Var Red	0.179	0.179	0.179	0.179	0	0	0	0	0	0	0	0
Inv Vel	0.058	0.058	0.058	0.058	0	0	0	0	0	0	0	0
Pp	0.079	0.079	0.079	0.079	0	0	0	0	0	0	0	0
S/sh Risk	0.062	0.062	0.062	0.062	0	0	0	0	0	0	0	0

Figure 5: Supermatrix Convergence to "Long Term" Weights at M^{31}.

PRINCIPLES	WEIGHT	ATTRIBUTE	WEIGHT	WEIGHT	INCUMBENT SCORE	WEIGHT	SYSTEM A SCORE	WEIGHT	SYSTEM B SCORE
Selective Risk	0.164	KACU	0.373	0.5	0.031	0.2	0.012	0.3	0.018
		KACO	0.241	0.4	0.016	0.4	0.016	0.2	0.008
		SRC	0.193	0.6	0.019	0.2	0.006	0.2	0.006
		IMSF	0.193	0.5	0.016	0.2	0.006	0.3	0.010
Information Selectivity	0.140	FDL	0.248	0.6	0.022	0.2	0.007	0.2	0.007
		AOD	0.269	0.3	0.012	0.2	0.008	0.5	0.020
		ADN	1.431	0.3	0.064	0.3	0.064	0.4	0.085
		DSC	0.199	0.4	0.012	0.3	0.009	0.3	0.009
Information Substitution	0.114	CIL	0.266	0.3	0.009	0.2	0.006	0.5	0.015
		AOD	0.214	0.3	0.007	0.3	0.007	0.4	0.010
		LSI	0.324	0.3	0.014	0.1	0.005	0.6	0.027
		SAI	0.197	0.3	0.007	0.1	0.002	0.6	0.013
Trans. Simplification	0.201	UIF	0.256	0.2	0.010	0.7	0.036	0.1	0.005
		DAU	0.25	0.1	0.005	0.7	0.035	0.2	0.010
		LSI	0.264	0.1	0.011	0.6	0.004	0.3	0.022
		SAI	0.23	0.2	0.009	0.7	0.032	0.1	0.005
Variance Reduction	0.179	DFT	0.384	0.2	0.014	0.6	0.041	0.2	0.014
		CCS	0.215	0.3	0.012	0.6	0.023	0.1	0.004
		SPC	0.173	0.2	0.006	0.4	0.012	0.4	0.012
		ISI	0.228	0.1	0.004	0.3	0.012	0.6	0.024
Inventory Velocity	0.058	ETPR	0.348	0.4	0.008	0.2	0.004	0.4	0.008
		JITS	0.229	0.4	0.005	0.4	0.005	0.2	0.003
		FMO	0.18	0.3	0.003	0.3	0.003	0.4	0.004
		FDO	0.243	0.3	0.004	0.4	0.006	0.3	0.004
Postponement	0.079	MPD	0.486	0.1	0.004	0.4	0.015	0.5	0.019
		FPD	0.313	0.2	0.005	0.5	0.012	0.3	0.007
		RDSD	0.202	0.1	0.002	0.4	0.006	0.5	0.008
Shared/Shifted Risk	0.062	COS	0.359	0.4	0.009	0.3	0.007	0.3	0.007
		OA	0.359	0.6	0.013	0.2	0.004	0.2	0.004
		SC	0.282	0.4	0.007	0.3	0.005	0.3	0.005
Desirability Index					**0.350**		**0.441**		**0.384**

Figure 9: Desirability Index Calculation for Logistics Systems Alternatives.

Discussion and Conclusions

The framework that was used in this example should serve as one of the tools for making a strategic decision. The criteria and attributes that were used in the model focused on logistics strategy and requirements. Since any logistics system that is selected will impact other functional strategies, this framework requires integration with other models for strategic decision making. For example, in the model there was no consideration of costs, revenues and profits associated with the system. These financial measures need to be considered in a more complete analysis. The final values that are determined should be critically analyzed. The use of auditing and iterative approaches with this model should be pursued in an actual presentation.

The framework represents only one set of possible relationships. A variation in the attributes or organizational strategies can also be made to this model. The attributes selected for this model were not justified, primarily due to space requirements. In an actual implementation of this framework, the number of attributes will be specific to the organization that uses this model. Additionally, the organizational strategies may not be limited to whether the organization practices one of the supply chain relationships mentioned earlier, a cross-sectional look at supply chain strategies. Enhancements to the model will increase the amount of analysis that needs to be completed. The use of ANP and AHP should also be critically observed since there are problems with "rank reversal." Currently, techniques exist to help reduce the occurrence of this event (Salo and Hamalainen, 1992). In addition, since the application of AHP requires qualitative assessment, fuzzy set theory has been looked at to improve analysis of the problem. The use of fuzzy set approaches in the ANP approach require development and research.

In conclusion, this paper has set the foundation for a systemic framework that can be used for selection or justification of various logistics strategies and systems. The contribution of the paper is through the linkage of disparate strategic logistics and systems issues in a single systemic framework. The paper also provides an analytical approach for managerial decision making through a modeling technique that has not been fully explored by researchers or practitioners.

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