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Supply Chain Collaboration: Information Sharing in a Tactical Operating Environment

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Supply Chain Collaboration: Information Sharing in a Tactical Operating Environment

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ABSTRACT: The operational availability of any equipment depends on its supply chain. In a tactical environment, logistics are complex and dynamic. If the elements of a supply chain are poorly integrated and collaborated on, supply can be unstable and inefficient. This study uses system theory to understand how collaboration on logistics information affects the supply chains among companies and military organizations in a tactical operating environment. The paper reviews the literature and designs an experimentation campaign to address the suggested hypothesis. This experiment seeks to increase the effectiveness and efficiency among the elements of a supply chain to increase the readiness of equipment in a operating environment.

KEY WORDS AND PHRASES: System Thinking, Feedback Loop, Collaboration, Supply Chain and System Dynamics

1 INTRODUCTION

The militaries face many logistical challenges to support their increasingly widespread missions. The supply chain channel has to attend the needs has thousands of suppliers and manufacturing. But in a conflict, the logistics group coordinates every supplier to maintain and make available the equipment ready for use.

In a joint operation among Navy, Army and the Air Force, each branch has to plan its needing; to coordinate tons of material to transport, to maintain all equipment and to coordinate the needs that rapidly changing in time.

This environment is complex due to many variables involved to be analyzed and make decisions about. Each environment has its own database, system and network. The logistics information is not available on time, and the logistics structure causes delays in answering the needs.

It becomes difficult to coordinate all elements of such tactical supply chain. These are serious problems because without accurate information and coordination, the goods could not arrive on time and to the right place. Besides the organization has to maintain a high inventory to compensate for uncertainty.

In the supply chain literature, there are many examples in collaboration on supply chain information. Luh, Wang, & Chen (2007) studied an example of automotive industries. X. Wang, (2011) presented how it can integrate the information across standard protocol. Papazoglou & Ribbers, (2006) showed the e-commerce history and show the definition of Electronic Data interchange –EDI. EDI integrate the information among different systems. Mukhopadhyay, Kekre, & Kalathur (1995), Anderson & Nanen (2002) and Iacovou, Benbasat, & Dexter (1995) explore the use of EDI. But the literature doesn’t present collaboration with use of EDI concepts in Tactical Military Environment.

Nowadays, e-Commerce is used in many companies and grows each year because the companies need to collaborate information to enhance their supply chain management. Collaborative system thinking is a new organizational behavior of resulting in broad information sharing (Lamb & Rhodes, 2008).

The purpose of this study is to design the experiment for understanding how collaboration on supply chain information sharing with EDI, based system-thinking theory, affects the supply chain among companies and military organizations in a tactical environment. The supply chain will be formed of five organizations that close the cycle of order the material to manufactory the material to delivery. The research is also limited to peace regular time, not focusing in other adhoc situations or war time to avoid increasing the complexity of the study and brings uncertainty and/or ambiguity to the findings.

The study is based on the literature review and systems theory based experiment design.

2 LITERATURE REVIEW

2.1 System Thinking

In Nielsen's book, there is an example of mathematicians working together on an unsolved mathematical problem in a virtual network, the Polymath problem. These mathematicians were connected and shared information on-line to solve a problem of significant complexity (Nielsen, 2012). This experience demonstrates how mathematicians in a virtual network can build knowledge. They worked as a system, or like Von Bertalanffy defines, they were as elements in a standing relationship (Capra, 1996). The example demonstrates an important property of the system that the whole is greater than the sum of the parts (Capra, 1996). This is an example of where knowledge collaboration solved a complex problem that could have taken a mathematician working independently dozens of years.

During the 20th century, many authors inspired researchers to seek a greater understanding of the systems and concepts about system thinking. (Capra, 1996) discusses an example where a living systems is network, "the web of life consists of network within networks." Other thinkers, like the biologist Ludwin von Bertalanffy, formulated that general system theory "*is a general science of wholeness*" (Capra, 1996), and that living systems have the property the open systems (Von Bertalanffy, 1950). The cyberneticist's community continued the research from the second half of XX Century. They developed the concepts of feedback loop and networks (Capra, 1996). Nobert Wiener et al defined that feedback is a mechanism that organisms use to maintain a state of dynamic balance (Rosenblueth, Wiener, & Bigelow, 1943). The cybernetics community introduced self-balancing and self-reinforcing feedback loop concepts as well. All these concepts were important for the creation of digital computers (Capra, 1996).

With the evolution of digital computers, John von Neumann started to study the analogy between computer and brain functioning to describe the brain function in formal logical terms. This study help the developed of the field of Artificial Intelligence (AI). AI fascinated scientists but some critics argued that the brain "*is not a central logical processor, information is not stored locally and the brain shows a manifesting self-organizer capacity that computers don't have*" (Capra, 1996). From this research, a new concept has emerged, self-organization.

Self-Organization – S-0 is a "spontaneous emergence of new structures and new forms of behavior in open systems far from equilibrium characterized by internal feedback loops and non-linear equation" (Capra, 1996). This way, "every dynamic system generates its own form of intelligent life"(Ashby, 1947). If each system is connected, the life is a big dynamic system network.

2.2 Feedback Loop

To understand the Self-Organization, feedback loop has to be define better. Thesaurus dictionary define feedback as "return of information". The feedback loop concept started in observations between organisms and machines. A Feedback loop " *is a circular arrangement of causally connected elements, in which an initial cause propagates around the links of the loop*" (Capra, 1996). (Senge, 1990) explained the concept of the feedback loop with an example illustrating the relationship between the thirst in a human and a glass of water. He explained that when an individual's desire for water ceases, they stop ingesting water. The action to stop ingesting water is enabled by the existence of a feedback loop in a living organism.(Senge, 1990)

All dynamic situations arise from the interaction of two types of feedback loops, positive or self-reinforcing and negative or self-balancing loops. Positive loops tend to amplify what happens in a situation. Negative loops oppose changing. It means if there is a high positive loop, on the other hang, there will be high negative loop. (Sterman, 2000).

In the problem of research, there are material orders among organizations of supply chains to resupply of stock. Without the collaborative information many problems occur in the supply chain. Senge (1990) described this problem through archetype: Balancing Process with Delay – BPD. Archetypes can be defined as system templates, it means, these processes happen many times in other real situations (Senge, 1990).

BPD happens because a person or organization wants to create goals. However, those goals may be based on a static environment. When a situation changes, the person or organization tends to overreact. If this situation has many degrees of separation, we have the bullwhip effects. In the use case for this paper, when there is a variation of demand, the forecaster requests material from the supplier. They tend to ask for more than is required due to the potential for having a shortage. The Suppliers behave in a similar manner. At the end of the process, the manufacturer produces a lot, and there are big quantities of material associated with this lot in the supply chain. When this situation emerges, forecasters try to correct the situation by issuing requests for a low quantity. The lower demand signal from the forecasters to the manufacturers initiates a process of lower production, which creates a shortage.

Senge (1990) explains that three causes for the bullwhip effect. First, the organizations in the supply chain don't know the real demand, so the empirical data is lost and organizations make misinformed decisions in the absence of critical data regarding the whole supply chain. Second, the supply chain structure where we have many elements and delays cause the bullwhip effect because the feedback information has a delay. The length of the chain directly impacts the reaction; specifically, the information and material delivery times. Third, the lack of collaboration means unnecessary redundancy as different elements in the chain attempt to independently solve the problem(Senge, 1990).

The literature review presents many examples of this problem. Lee et al. (2004) defined the bullwhip effect as a phenomenon that has large variance, orders of magnitude, and effect of stock is amplified. They argue that accurate information on demand and inventory can improve coordination across the chain and decrease variation(Lee, Padmanabhan, & Whang, 2004).

(Lee, So, & Tang, 2000)suggests that the value of demand information sharing can be quite high, especially when demands are significantly correlated over time. They did an experimentation between two-level with non-stationary end demands (Lee, So, & Tang, 2000). In addition, Chen (1999) suggests that each organization is divisions of the same firm. He showed that the owner could manage the divisions as cost centers and the divisions could work as a team. This action can improve lead-times and decrease delays(Chen, 1999).

Steckel et al(2004) did an interesting experiment.. They shared the demand information among organizations and studied how these demands produced effects within the supply chain efficiency. They used three patterns of demands. They found if the demand follows a S-shape, the information sharing decreased the performance (bullwhip continues). They suggest a systematic laboratory to explore this issue (Steckel, Gupta, & Banerji, 2004). Other research done per Raghunathan (2001) shows that when the organization shared the information the benefit is insignificant, he arrived at this result because the organization used the order history to make the prediction (Raghunathan, 2001).

Furthermore, within the military environment, (Li & Ling, 2008) showed that the supplier manages the inventory that the supplier is responsible for. Using this approach, the suppliers have access to all required information. They suggest that this approach enables the supplier to create more value demand and value support.

The literature review doesn't explore information collaboration among military organizations, suppliers and manufactories in a tactical environment. The researchers explore more the private supply chain. On the other hand, in the tactical military environment is difficult to make some logistics experiment. So, this experiment comes to fill this lack.

2.3 Collaborative System Thinking

Reflecting on the Polymath problem example, Nielsen (2012) presented a good example of how mathematicians used collaboration to solve a complex problem. (Lamb & Rhodes, 2008) define the collaboration within live systems as:

> *"An emergent behavior of teams resulting from the interactions of team members and utilizing a variety of thinking styles, design processes, tools, and communication media to consider them system, its components, interrelationships, context and dynamics toward executing systems design"* (Lamb & Rhodes, 2008).

Collaborative systems thinking incorporates five key systems thinking themes. These themes include: component complexity, interrelationships, context, emergence, wholes (Lamb & Rhodes, 2008). Lamb & Rhodes, (2010) complete that clear communication and having a transparent process are more important indicators of collaborative systems thinking(Lamb & Rhodes, 2010)

When Lamb & Rhodes write about clear of communication, they reveal the underlying concept of degree of separation. Barabási (2003) shows an example wherein everyone is connected with six degrees of separation. He defines clusters as strong connections. That weak tie connects many clusters. Many clusters and weak ties connected form a network(Barabási, 2003). With the introduction of the Internet, the world has changed. Now, everyone can connect to volumes of information with just a few clicks. More information is available for the purposes of consulting, analysis and research. The network is the best form of information collaboration across an extensive supply chain. In logistics management, Buchanas

(2002) cites Peter Drucker that "e-Commerce is to Information Revolution what the rail-road was to the Industrial Revolution." E-commerce is one of the principal examples of collaboration in supply chain(Buchanas, 2002).

E-commerce is growing fair in logistic environment. (Papazoglou & Ribbers, 2006) explained that this collaboration example started with the requirement of companies to integrate with logistics information. Basically, there are two types of E-commerce : Electronic Market or E-Business. Electronic Market matches buyers and sellers to find the best price and provide our support for purchase like Ebay, Amazon. E-Business is different in that it is relationship between two companies. They share information about logistics transaction as such purchase order, number of track delivery or material orders, i.e. (Papazoglou & Ribbers, 2006).

A example about specific e-commerce, Luh et al. (2007) explained that in the automobile industry it is essential to build a collaborative model to exchange information among whole industries. They argued that this process could enhance the efficiency of the automobile industry(Luh et al., 2007). Other study showed that collaboration in supply chain can bring many benefits and suggested strategies for information collaboration (X. Wang, 2011). He suggested the construction of standard, application of the standard and IT support, and incentives to adopt the solution and create a secure environment. (Madlberger, 2008) explained that the companies share the information if the firms will benefit financially.

To enable companies to share information, the E-business architecture was developed. The E-business architecture has standardized protocols between companies. Within the E-business architecture, there are four tiers: Client (Web Application Clients), Presentation (Web-Server), Processing (Application-Server), Data (Database & Systems Legacy)(Papazoglou & Ribbers, 2006). The standard protocol for E-business architecture is Electronic Data Interchange – EDI. EDI is defined as the transfer of structured data by agreed message standards between computer applications. EDI performs the follows transaction: research on item, negotiate the purchase, order, deliver, invoice, payment, after sales, and other logistics data. EDI uses the body of Extensible Markup Language (XML) to transmit logistics information. Fundamentally, EDI used XML to exchange information between application(Papazoglou & Ribbers, 2006).

To share the information, there are business standards that manage the structure for defining form, fit, and function of products or services, regardless of the industry(Papazoglou & Ribbers, 2006). They provide a definition of common business processes, definition of common data-interchange formats, definition of a security & reliability framework and other logistics information. The business protocol captures the information and exchange requirements, identifying the timing, sequence and purpose of each business collaboration and information exchange. There two big standard to EDI: Rosettanet and ebXML. But there are some problems in these protocols, as the transactions don't reflect all business rules, delay to create or change some protocols, and different standards(Papazoglou & Ribbers, 2006). This problem can delay some change of information among companies.

The adoption of EDI can be problematic for a supplier. Wang & Seidmann (2012) affirm if buyers can subsidize the implementation of EDI, the EDI reduces the transaction costs of the buyers, and buyers tend to reduce the supplier base too(E. T. G. Wang & Seidmann, 2012). To quantify the benefits the EDI, research by Mukhopadhyay et al.(1995) showed that Chrysler could save $220 million (usd) per year with EDI(Mukhopadhyay et al., 1995).

Another study by (Anderson & Nanen, 2002) showed that EDI "improves the efficiency of accounting transactions. Although the benefits are immense, some suppliers, predominantly small suppliers, have struggle to adopt the technology due to extensive IT support requirements and they don't see the real benefit in collaboration (Iacovou et al., 1995). To provide an incentive for small business collaboration, Iacovou et al. (1995) suggest development of "*a long-term EDI partner expansion plan from the very beginning, the individual assessment of each partner's EDI preparedness level, and the selection of appropriate influence tactics to expedite adoption by small partners"* (Iacovou et al., 1995). So, the agreement among companies is very important.

3 EXPERIMENT DESIGN

3.1 Collaborative System Thinking

The experiment uses the concept of collaborative system thinking. The experiment will share the information about material demand of each element of the supply chain. This information can be shared using EDI or whatever other kind of communication.

When the elements are connected, a new collaborative tactical network topology is created. The organizations can share information, knowledge, and decision between nodes via use of technology. Now the hubs are connected, and this new network works as a systems.

The evolution of this network will take a long time and this task is not easy(E. T. G. Wang & Seidmann, 2012),(Mukhopadhyay et al., 1995),(Anderson & Nanen, 2002). Sometimes, companies spend months to develop and integrate their systems. In this experiment, the time to integrate the information does not be taken into consideration.

In this environment, hubs are the organizations (CSS-Maintenance, CSS-Supply, Depot, Supplier, Manufacturing). Theses elements use connectors to communicate: internet and EDI protocol. Without sharing information, there are 2 to 4 degrees of separation among organizations.

Analyzing Technology ties; there are strong ties when EDI is used. There are weak when the EDI is not used or the organizations don't share the information. This way, they have to connect systems and networks manually.

Analyzing Social Relationship ties; there are weak ties when there are many degrees of separation. This way the information spends a long time to be available. There are strong ties when there are low degrees of separation. The table below summarizes the analysis.

<u>Hubs & Connectors</u>

CSS- Maintenance– Hub
CSS- Supply– Hub
Depot- Hub
Supplier – Hub
Manufacturing- Hub

EDI– Connector
INTERNET- Connector

<u>Degrees of Separation</u>

CSS-Maintenance-Manufacturing-4
CSS-Maintenance-Supplier – 3
CSS-Supply-Manufacturing-3
CSS-Maintenance-Depot - 2
CSS-Supply-Supplier - 2
Depot-Manufacturing-2

<u>Weak and Strong Ties: Technology</u>

Strong: EDI
Weak:
Network Separated
Database System Different

<u>Weak and Strong Ties: Social Relationship</u>

Strong: Low degree of separation
Weak: High degree of separation

Figure 1: Hubs, Connectors, Weak and Strong ties

The experiment suggests that networks form when the elements of supply chain share information using EDI or other kind of communication. When Organizations stabilize an effective network, the oscillation of stock and average and lack of material decrease. The new collaborative environment emerges.

"Research Design is the plan and structure of investigation, conceived so as to obtain answers to research question" (Kerlinger & Lee, 1999). Churchman (1971) complements that "a system is designed to perform better than we can, it can legitimately tell us what to do"(Churchman, 1971). This chapter describes the procedures of experiment "in a logical way to move from a idea or concept to some demonstrated military capability" (Alberts & Hayes, 2009).

3.2 Campaign of Experimentation

This experiment proposes to measure the performance of stock among organizations in tactical network logistics environment. More precisely, this paper is restricted to build a preliminary model that measures the stock level as an effect of changes in the level of collaboration caused by changes the degree of separation through EDI.

The campaign of this experiment is to organize the procedure to test the experiment (Alberts & Hayes, 2009). The first procedures of the experiment are the discovery experiments. This step seeks to find if the new way of logistics information collaboration will be useful for military environment (Alberts & Hayes, 2005). This phase will use simulation and empirical experiment to generate promising approach to the other phase (Alberts & Hayes, 2009), the Hypothesis Testing Experiment (HTE).

HTE tries to falsify specific hypothesis to form new knowledge. In the last phase, this paper shows the steps that are needed to do the demonstration phase of the experiment that are used to "convince, educate, and train"(Alberts & Hayes, 2005).

For each phase of the experimentation, this research will show the infrastructure of the experiment, scenario, the team responsible, procedure of collection of data and analysis, and describe the experiment evolution.

3.2.1 Discovering Experiment

The discovery experiment stimulates creativity to bring new ideas(Alberts & Hayes, 2005). This experiment intends to discover if collaboration of information among organizations makes the stock of supply chain more stable.

This experiment will use dynamic simulation using Stella Software.

a) Objectives: The objectives of this experiment are to simulate and analyze if a computational environment without the human interaction, the stock in the organizations will be more stable.

b) Schedule/Tasks: the schedule and tasks are controlled by Project Microsoft Software.

c) Scenario- this experiment will be of simulation. The supply chain will be modeled in Stella Software. In this software, it will simulate the orders of material, stocks and delivery of material of each organization. The Stella Model is in appendix 1.

d) Infra-structure – We need a computer and Stella software to model the supply chain.

e) Setup Experiment: This experiment will be specific for a material. His demand will be stochastic and follow the Poisson distribution with mean of 100 for a week. The stock of each organization starts with 100 units. The unit of time will be “week”.

f) Team - this phase will have only the research team. The research team has a Professor Coordinator, PhD Student and Auxiliary.

The PhD Student is responsible to design the model and coordinate all events.

Professor works as a advisor to validate the model, planning and reports

The auxiliary helps in the experiments.

g) Experiment Procedure: The simulation follows these steps. Each week, organizations will receive incoming orders, receive incoming deliveries, send out deliveries, and finally, ask on the amount to be ordered.

The first step will simulate without shared the information. In the end of each round, the software take record all events, and after 40 rounds the experiments finish. We will do again this experiment changing the constraint (Delivery time will be 2 weeks, and Quantity material in stock will be 50)

After this step, we do the same thing but the demand information will be shared among organizations.

h) Collect of Date: The software records the stock of each organization in each period. This data will be collected to analyze.

i) Analyses and Validation: We will do a statistics test in this data, Pareto analyses and preliminary hypothesis.

3.2.2 Hypothesis Testing Experiment

(Alberts & Hayes, 2009) explain when discovery experiment can process hypothesis, the experiment can move to the hypothesis testing stage. Hypothesis testing experiments refines or builds the knowledge about the designed system.

For this experiment the primary hypothesis – H1 is:

H1: In Tactical Network environment, the decrease of degree of separation among organizations with different demand behaviors affects efficiency and stability of the stock under the same delivery time and same quantity initial of the material in stock.

To test the H1, the science tries to "obtain evidence to disprove the null hypothesis"-Ho(Alberts & Hayes, 2009):

H0: In Tactical Network environment, the decrease of degree of separation among organizations with different demand behaviors doesn't affect efficiency and stability of the stock under the same delivery time and same quantity initial of the material in stock.

The objective of this experiment is to prove that Ho is not true.

a) Objectives: The objective of this experiment is to prove that Ho is not true.

b) Schedule/Tasks: the schedule, tasks and responsible are controlled by Project Microsoft Software.

c) Scenario: The experiment will be in a classroom with four tables. Each table represents an organization of supply chain. This scenario tries to simulate a real situation.

d) Infra-structure: The experiment will be conducted in a Class Room. In this class we will need four tables and pieces that represent the unit of material. Each table will connect with others to facilitate the movements. This scenario will have a representative of each of supply chain. In each table, elements will see the stocks, the order, and the delivery material to conform figure 2:

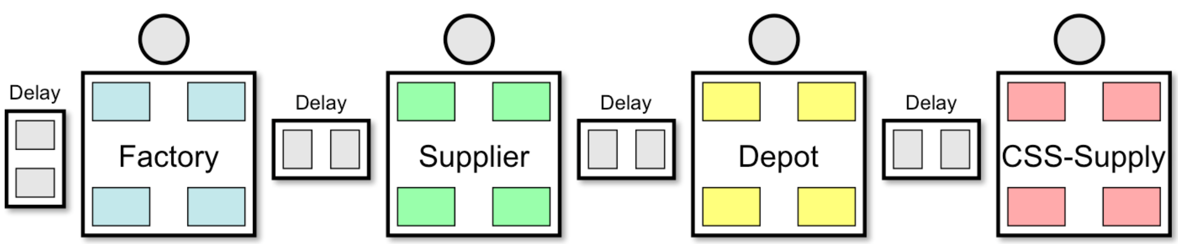

Figure 2: Device Experiment

e) Setup Experiment: This experiment will be specific for a material. His demand will be stochastic and follow the Poisson distribution with mean of 100 for the week. The stock of each organization starts with 100 units and delivery time will be a week. The unit of time will be a week.

f) Team: The experiment is composed of Research Team and a supplier of each unit of supply chain.

The Research team is responsible to coordinate, analyze and report the experiment.

Supplier representative is responsible to plan, order and control the stock as they do in their organizations.

g) Experiment Procedure: Each week, organizations will receive incoming orders, receive incoming deliveries, update play sheets (outstanding deliveries and inventory), send out deliveries, and finally decide on the amount to be ordered.

The first step will simulate without sharing the information. In the end of each played, the auxiliary or research take the note of stock, and after 40 rounds the experiments finish.

We will do again this experiment changing the constraint (Delivery time will be 2 weeks, and Quantity material in stock will be 50)

After this step, we will do the same procedures but the information will be shared among organizations.

h) Collect of Date: Each unit of the experiment will take sheets notes, outstanding deliveries, and inventory.

i) Analyses and Validation: We will do a statistics test in this data, Pareto analyses and confirmation of hypothesis to each result.

3.2.3 Demonstration Experimentation

In this step, the finding must demonstrate their utility in a specific operation. The benefits have to be demonstrated. Inappropriate setting will fail to achieve the desired result (Alberts & Hayes, 2009), (Alberts & Hayes, 2005).

a) Objectives: the objectives of this experiment are to verify and analyze if a real environment with the human interaction, the stock of supply chain will be more stable and efficient.

b) Schedule/Tasks: the schedule, tasks and those responsible are be controlled by Project Microsoft Software.

c) Network Tactical Logistical Scenario

This scenario will be a logistics tactical network. In this environment the Combat Service Support -CSS is created. The CSS is under control of the Task Force and is responsible to support logistics, personnel and health services(Army-USA, n.d.). This experiment studies the small supply chain in combat to understand the phenomenon. The elements are in table 1.

CSS - Maintenance	This section keeps equipment and weapons in a serviceable, operational condition and conducts battle damage assessment and repair as necessary. (Army-USA, n.d.).
CSS-Supply	This section acquires, receives, and issues all classes of supply required by the task force. (Army-USA, n.d.).
Depot	Organization the provide material to the Task Force and other Units. Each branch has its structure.
Supplier	They sell goods to Depot. They buy material from manufacturing.
Manufacturing	They produce goods for sale.

Table 1-Elements of logistics tactical network

In a real scenario there are thousands of materials in stock on CSS. Many of these items are used in the maintenance. CSS-Supply asks the Depot to resupply. Depot orders the purchase to the supplier. And the supplier orders to manufacturing. In real situations, we have many Depots and hundreds of suppliers and manufacturing.

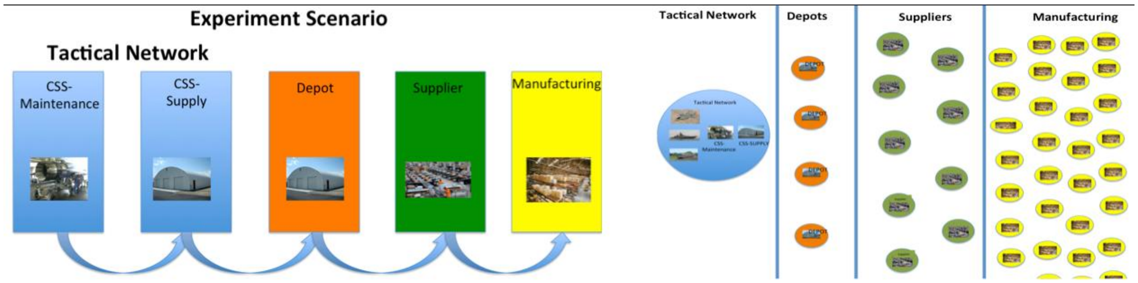

Fig 3 Experiment Scenario and Real Logistics Environment

d) EDI Development: Each element of the supply chain has to develop the EDI Protocols. EDI exchanges the information among organizations. These are the following tasks to develop EDI: protocol definition, data mapping, development, system test, and production phase.

e) Setup Experiment: This experiment will be specific for <u>a material</u>. For this experiment each element of supply chain plans the stock. This stock will be used in the Operation Theater.

f) Infra-structure: For this experiment, each element of supply chain and research teams needs Internet to change information. Each organization will use own system to control its material. The communication must be available 24h.

g) Team: Logistic Team, Research Team, IT Team, and Coordination.

h) Experiment Procedure: The experiment starts together with the operation. This time, the research team will take the stock level of each unit by EDI. After this, each information order will be available for all organizations. The experiment will finish when the operation will finish or after 24 weeks.

i) Collect of Data: The research team takes and records the information order and the stock level and material order by EDI protocols.

j) Analyses and Validation: We will do a statistics test in this data, Pareto analyses and confirmation of hypothesis.

<u>3-3 Construction and Variables</u>

<u>3.3.1 Variables</u>

The research variables must define the constraints that will lead to a feasible solution. They are the design variables constraints, functional constraints and criteria constraints.

Design variables are those that are under the immediate control of the system architect, this variable can be manipulated as an independent variable.

Design Variable	Representation/ Design Space -
Material Order Demand	-Deterministic - Stochastic (know the distribution)
Degrees of separation of information	0- the same actual situation 1- degree separation
Communication	0-without EDI 1-EDI

Table 2 - Design Variables

A functional constraint is a variable that is assigned by the user of the system or environmental factors.

Functional	Representation
Delivery Time	This numbers will be set
Quantity of Material in Stock	This numbers will be set

Table-3 Functional Constraints

Criteria space variable are in essence of the dependents variable, are the outcome of the experiment.

Criteria	Representation/Criteria Space
Amplitude	Scale 1-5 Represent the perception information collaboration among organizations of Supply Chain. This measure will get the min and max quantity in stock in the period. We transform the numbers in scale 1 to 5, 1 low amplitude – 5 very high amplitude
Frequency	Scale 1-5 Represent the perception information collaboration among organizations of Supply Chain. Counting the number of times that event occurs within a specific time period, then dividing the count by the length of the time period. We transform the numbers in scale 1 to 5, 1 low frequency – 5 very high frequency
Average of Stock	Scale 1-5 Represent the perception information collaboration among organizations of Supply Chain. This measure will get the average of stock in the period. We transform the numbers in scale 1 to 5, 1 low average of stock – 5 very high average of stock
Average of Lack of Material	Scale 1-5 Represent the perception information collaboration among organizations of Supply Chain. This measure will get the sum of lack stock in the period. We transform the numbers in scale 1 to 5, 1 low average of lack– 5 very high average of lack

Table 4- Criteria Space Variable

The scale 1-5 represents the follows values: 1-low, 2-moderate, 3- medium, 4-high, 5- very high.

3.3.2 Relationship among constructs

Below, there is a proposal of relationship between variables:

- Deterministic demand variation and 1 degree of separation and EDI use, we have low amplitude and frequency of stock.
- Stochastic demand variation and 1 degree of separation and EDI use, we have moderate amplitude and frequency of stock.
- Deterministic demand variation and 1 degree of separation and EDI use, we have low average of quantity and lack of stock.
- Stochastic demand variation and 1 degree of separation and EDI use, we have moderate average of quantity and lack of stock.
- Deterministic demand variation and 1 degree of separation and without EDI, we have moderate amplitude and frequency of stock.

- Stochastic demand variation and 1 degree of separation and without EDI, we have medium amplitude and frequency of stock.
- Deterministic demand variation and 1 degree of separation and without EDI, we have moderate average of quantity and lack of stock.
- Stochastic demand variation and the 1 degree of separation and without EDI EDI use, we have medium average of quantity and lack of stock.
- Deterministic demand variation and actual degree of separation and without EDI, we have high amplitude and frequency of stock.
- Stochastic demand variation and actual degree of separation and without EDI, we have very high amplitude and frequency of stock.
- Deterministic demand variation and actual degree of separation and without EDI, we have high average of quantity and lack of stock.
- Stochastic demand variation and actual degree of separation and without EDI, we have very high average of quantity and lack of stock.

3.3.3 Pareto Set

An effective way to assess a process model is to examine how well it simultaneously satisfies multiple criteria (Reynolds, Ford, & Eynolds, 1999). This study hypothesizes that the increase of collaboration will affect the oscillation and average of the material in stock. If the oscillation of stock is low and the average of stock is bigger, the efficient isn't good. At the same time, if the average of stock is low but oscillation is big, the stability isn't good.

The best solution for this experiment is to have a low amplitude and low frequency, and these factors have to be associated with other sets, low average of stock and lack of material. So the best way to Pareto set is low oscillation and low average of stock.

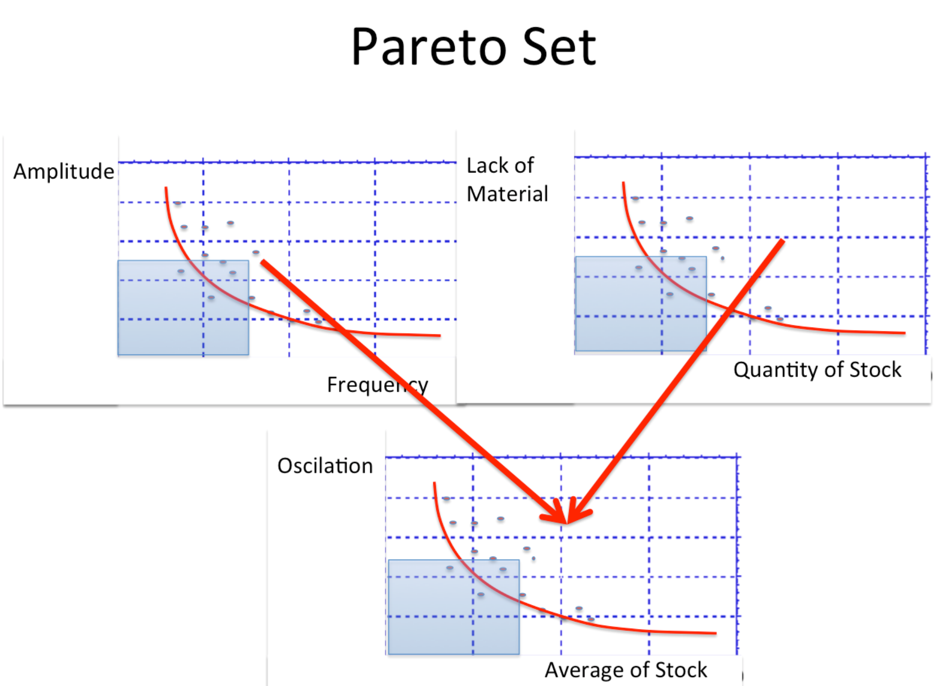

Figure 4 –Pareto Set

3.4 Experiment Evolution
3.4.1 Evolution

A campaign of an experiment has many activities that differ in the phases in fidelity and control. Each phase of campaign fidelity and control have different levels. In this campaign, the discovering experiment used modeling and simulation to do the preliminary hypothesis, because this approach provides great control over variables and is easy to replicate(Alberts & Hayes, 2005). In the next step this experiment inputs the human decision and tests in the classroom to simulate a real situation. This is good to refine the hypothesis and see alternative contexts on performance (Alberts & Hayes, 2005). In the demonstration, the experiment is more difficult to control all variables but the research question has to be answered, and the researcher has to control all variables. "For this reason, reality is the best for confirming something that has been suggested(Alberts & Hayes, 2005)". In the picture below is the proposal of the evolution of campaign and knowledge in this experiment.

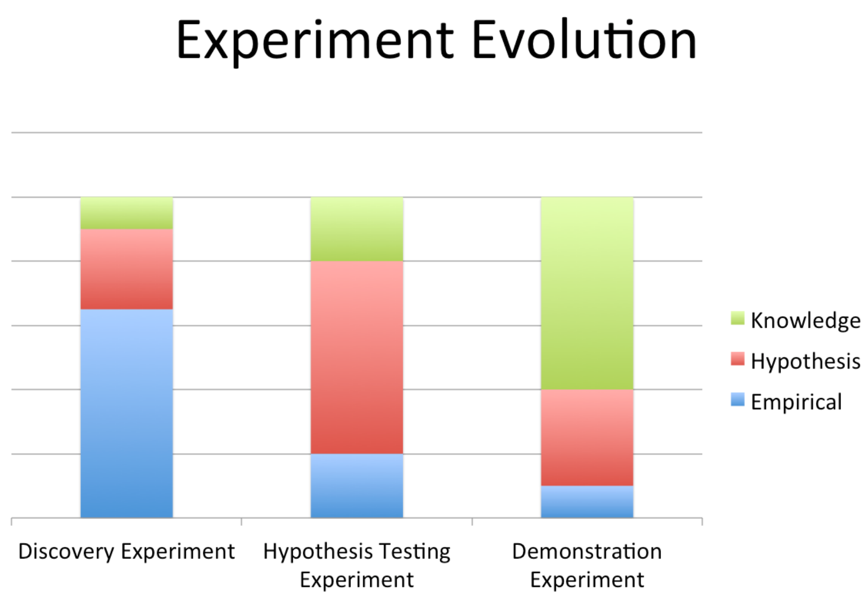

Figure 5 - Experiment Evolution

3.4.1 Limitation and Suggestions

This paper investigates only a type of material in demonstration experiment. Other materials can have different behavior that influence the research result.

As suggestion, others researches can explore more materials simultaneous during the demonstration experiment.

4. Conclusion

This paper describes a campaign of experimentation designed to analyze how collaboration on supply chain information, based system-thinking theory, affects the supply chain among companies and military organizations in a tactical environment.

This research draws on general system theory, in particular the concept of collaboration to describe how the degree of separation among organizations with different demand behaviors affects efficiency and stability of the stock under the same delivery time and same quantity initial of the material in stock in a Tactical Network environment.

The experiment merges to reveal a new comprehension about the supply chain network. With the analysis of more formal hypotheses about information collaboration among elements within a supply chain, this paper demonstrates how information collaboration affects the stock level in an operation. As a result, the experiment answers the call to better understand how an increase in supply chain collaboration can increase the overall effectiveness of supply chain in a tactical environment.

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Appendix 1– The Discovering Experiment Stella Model