Smart and Sustainable Logistics Ecosystem of Panama: A Conceptual Model

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Abstract

Greta Thunberg highlighted in her speech during the COP 2019 the lack of integrity about the goals of the countries in emission reduction when vessel and aircraft transportation has a great impact over pollution and none of them were addressed, that is the case of multimodal logistics systems in the world wide world.

The question is What is Latin-American multimodal Logistics systems doing about it?

Latin America has a great model in Pollution reduction and optimization of operations because Panama is working for decades to reduce emissions in the Panama Logistic ecosystem. For example, Panama Canal expansion increased the efficiency of movements in global commerce while reducing the impact in emissions. During the decade of 2010s the Panama Canal took the risk to expand the canal to a third set of Locks and a new type of vessel arrived, the Neo-Panamax, which increased the capacity per vessel from 8,000 TEUS to 15,000 TEUs. Panama is increasing the awareness about the logistics impact over the emissions, but there are still challenges because of the increment of 87.5% of the load movement into the Logistic hub of Panama, and there is a need to address real time information about the performance of the Distribution Centres, the ports, and the interaction with the Logistic ecosystem to increase efficiency and reduce CO2 emissions.

Thus, the main objective of this research is to summarize the journey of the Panama Logistic Innovation path that results in a conceptual model of Smart and Sustainable Logistic Ecosystem (SSLE).

Keywords: Traceability, Internet of Things (IoT), Smart and Sustainable Logistic Ecosystem (SSLE), CO2 emissions, and Efficiency.

I. INTRODUCTION

This research presents an innovation path, the Panama Logistic innovation path and it is unique. The journey started in 2013 with a diagnostic of the logistic main node processes and interactions. Then, it includes RFID, Internet of Things and other traceability technology evaluation from 2015 to 2018 while supporting the Panama Logistic Strategic Plan for 2030 and the Panama Canal master plan. Finally, all these studies merged in two goals, efficiency and CO2 emissions reduction in the Panama Logistic Ecosystem using smart technologies. The Smart and Sustainable Logistic Ecosystem has several challenges since in 2018 Panama imports grew 4% more than 2017 and Panama exports grew 1.9% more than the previous year [1]. The trends in international commerce shows a continuous growth [2, 3, 4] that directly affects the CO2 emissions [5], in other words growth without tracking of metrics can lead to not liable development. The lack of efficiency of moving goods in the Panama Logistics Ecosystem increases the congestion in the transportation of trucks and their interaction with the ports increasing the emissions in the waiting lines [6]. It is important to mention that the journey since 2013 collecting time has a significant impact in the suggestion of a real time tracking system because the validation with the transportation agents presents that the time studies does not reflect all the variabilities in the multimodal interactions. Vande Vorst, et. al. (2013) found that after several surveys about what drives sustainable strategies the more ranked was cost savings [7], similar argument that Yossi Sheffi presented in 2018 about the green initiatives must be related with corporate economic goals [8]. Therefore, if we can make a diagnostic on CO2 emissions, we can address transportation savings reducing those emissions, and if we address efficiency in the Logistics system it leads to more volume in the operations per day, which increases profit. This paper starts with a brief summary of the journey of research in Smart Systems, Sustainable Operations and the merge of both in section II, then goes forward in section III with previous studies trying to understand the operation of the multimodal nodes of Panama, then it continues with the CO2 emissions calculations in section IV, then in section V an economic, technical and qualitative analysis of the alternatives to track the performance of the logistics ecosystem, and the last part of the paper, in section VI, it is presented the conceptual model of Smart and Sustainable Logistic Ecosystem (SSLE). Thus, the SSLE objective is to balance the necessity of track lead time to calculate CO2 emissions in the multimodal system of Panama.

II. LITERATURE REVIEW

There is ample academic literature with focus on environmental sustainability in the manufacturing industry, and the supply chain, but there is small academic literature in the logistics and service industry. [9]

In addition, the literature in 3PL environmental sustainability from 2000 to 2016 just relate 4.6% of the papers with Information and Communication Technology affecting reduction of emission with third party logistics services providers. [10]. The environmental sustainability is being translated into indicators, since it is becoming more important for the logistic companies to reduce cost (e.g. Access to financial incentives, energy efficiency, tax relief), and increase sales (e.g. customer demand for green products/services, improvement of customer relations, participation in sustainability programs). [11]

Consequently, the availability of current and accurate information is essential for environmental sustainability, and the Information and Communication Technologies are increasingly gaining preference amongst management and researchers, who identify its potential to support sustainable road freight across social, environmental, and economic frameworks. [12] The problem of cost reduction in hub systems will drives logistics organizations towards efficiency. This focus on efficiency will expand along the multimodal linkages across the globe affecting other Logistics hubs [13].

In other words, if Panama Logistic hub focuses on fourth industrial revolution technologies to address Sustainable Development it supposes to affect other Logistic Hubs in Latin-America, and other logistics ecosystems around the world. Specifically, Internet of Things applications with Artificial Intelligence may increase competitiveness and sustainable development.

However, it is important to start from the beginning for a better understanding of Smart and Sustainable Logistics Ecosystems. So, let's start with Smart with the ubiquitous computing concept by Wiser in 1996 [14] to understand the technology that enhances smart systems. This was the start of the discussion about smart products and services that have the main purpose to deliver the humanity of unnecessary work. There is some mention that those concepts were based on just one on one relationships and not complex systems such as Artificial Intelligence (AI) and Internet of Things (IoT). The reality is that in the past 20 years the inclusion of AI and IoT is directly connected when the Logistics experts describe the future of Smart Logistics or Logistics 4.0.

Smart Logistics Setup (SLS) was presented in 2007 by Stefansson and Sternberg as a proposed model to understand Smart Logistics. [15]. The discussion about Smart Logistics continued by Uckelmann (2008) when he presented the concept of Smart Logistics in his documentation and the actual definition of it. Smart Logistics is defined by: *“Smart Logistics (SL) embraces smart services and smart products within Logistics, SL is derived from technology driven approach, and thereby subject to change”.* [16]

In addition, Smart Logistics can help with traceability of load, cargo, movements, and products, but what is Traceability? Traceability stands for the ability to identify and trace the history, distribution, location and application of products, parts, materials, and services (ISO 9000), but why is traceability important in the multimodal operations? One of the suggestions to address efficiency is the traceability offered by RFID technology applied in Supply Chain justified by Operation Reference and ROI over the labour reduction and efficiency in a hub system [17]. Furthermore, an adequate combination of RFID, geographic information system (GIS) and mobile communication like GSM (Global System for mobile Communication) could offer an interesting solution. This kind of system is a web-based solution with client-server architecture. GSM and GIS are chosen for the communication between the tracking unit and the server and vehicle position tracking [18]. Consequently, the traceability can be directly related to Information and Communication technologies, such as RFID, GPS with the goal to reduce environmental impact of the operations while there are several benefits in cost reduction and revenue.

In Contrast, there are other factors than just technology to address traceability for sustainability in the Global Supply Chain such as governance and collaboration [19]. The implementation of all new technologies in a Logistic system will require collaboration, and some level of governance guidelines for the access of the data and the data security, based on the Edge Conference of the CSCMP of 2018 and the audience commentaries.

As part of the other factors to consider in Smart and Sustainable in Logistics Ecosystems are the important discussion about Ecosystems in Business, starting from the Basole, et. al, (2016) construction uses biological/ecological sciences to describe industries working as co-dependents for survival [20] Following by the Lenton et. al. (2000) biological ecosystem definition where the system combined forces that interact and change [21]. Then, business ecosystem definition by Moore (1998) describes business ecosystem results as production of goods, services and coevolving capabilities. [22]

Furthermore, Logistics ecosystem is not complete without the definition of the term Logistics by Lummus et. al. after the analysis of several historical definitions where Logistic stands for *"the movement and transmittal of goods, services and information"* [23]. The following topic to describe is Logistics hub or cluster, well defined by Sheffi, et. al. (2013) as follows: *"Logistics intensive clusters are agglomerations of several types of firms and operations."* [24]

Thus, the literature review can help us to identify a preliminary term for Smart and Sustainable Logistic Ecosystem which is ***the community of organizations from end to end of the global supply chain collaborating to move and transmit goods, services and information to address environmental, social and economic sustainability making decisions in real time without human interaction or with minimum human interaction.*** Why so many terms in one statement? The reality is complex, and we are limited as humans. As mankind the simplification is the best way for learning and understanding, however the beauty of the Multimodal system is the complexity of addressing the old challenges plus technology and sustainability in the new area post-COVID 19.

III. PANAMA MULTIMODAL NODES PREVIOUS STUDIES

The type of operations evaluated were import, export, transshipment, and the kind of movements or transportation studied were trucking and railroad. There is a strong interaction with shipping operations and air cargo, and some the times contemplate those, but the efficiency study and the CO2 emissions preliminary results are mainly focused in ground movements across the Country.

Figure1. Map of the Logistics movement in Panama. [25]

A. Data Collection

The sample was done defining the real population of stakeholders that develop a role into the PLE, that number in 2013 to 2014 was 587.

$$n = \frac{N}{1 + \frac{e^2(N-1)}{Z^2 pq}}$$

Equation 1. Sample Estimation

N= Total population = 587 stakeholders [1-8]
E= error = 0.03
Z= confidence level of 70% = 0.524401

Figure 2. Variables definition of the Sample Estimation

The sample was defined by the equation 1 and the variables definition in figure 2, where 'n' is the sample, 'N' is the population, the 'e' is the margin of error, and Z is the confidence level, 'p' percentage picking a choice, and 'q' is '100 -p' or the percentage of not picking a choice. The interviews were made in three layers per each type of stakeholder, executive profile, middle management profile, and operations profile. In addition, there was some level of redundancy for any type of issue with internet connection with the tablets used to gather the data. Consequently, we used some hard copies of the interview instruments and we tried to obtain more than the minimum statistically significant sample of 67, and we interviewed 83 stakeholders. As validation of cross checking of the information gathered, some of the data gathered includes other data sources such as consulting documents, Georgia Tech Logistics centre, and Government Reports.

B. Time study

There was a direct observation of the operations in Paso Canoas, the border between Costa Rica and Panama, and Balboa and Manzanillo seaports. The data gathering was 100 data points collected in 15 days randomly selected. The data gathered was from the port enter gate to the gate exit gate. The classification of the operations was imports, exports and transhipment.

The validation of time study was made with focus groups with agents from the Governments, that includes Customs, Ministry of Commerce and Industry, the Airport, and the Maritime Authority of Panama. The Colon Free Freight Zone was a key area to understand which takes from 30 minutes to 1 hours and 30 minutes to move the load. Based on the observation, the bottleneck was the customs which in average was 23 minutes.

As a summary the export takes on average 1 hour and 30 minutes, imports take 2 hours and 9 minutes, and transhipment takes 32 minutes. In addition, the trucks usually take between 2 hours to 4 hours in line in the pick season, which lies between November to December, to access the port for imports, for exports or for transhipment. This is not the case of the railroad time or the service offered by The Manzanillo International Terminal (MIT) to move the container through a direct gate to the Colon Free Freight zone.

C. Process Study of the Logistics System

The optimization of the processes of commerce between Logistics nodes in Panama increases the movement of load and generates efficiency and effectiveness in the operations.

The analysis is based on the three main operations related to the movement of loads, and the interaction between the four Logistics nodes, Atlantic, Pacific, Border with Costa Rica and Air cargo at the Tocumen International Airport.

a. Transhipment

There are three types of transhipment in the International movement of goods in Panama. Transhipment by railroad, transhipment by truck, and transhipment using the seaport as a depot, mainly containers.

a.1 Railroad Transhipment

The time is set as the worst-case scenario, with the objective to make a point about full capacity or full utilization of the system. The total time of transshipments is 40 hours and 30 minutes. The bottleneck of the process is the Crane loading to the ship, then the download from the ship, and the third bottleneck is the transportation. However, if we take out the interaction with the vessels, and the transit time, which is fixed. The next main bottleneck is the paperwork, which can be changed to a digital workflow.

a.2 Truck Transhipment

The transhipment by truck is like the transhipment by railroad, but the railroad can move more volume than the truck, and the truck can address less time of the process. The bottlenecks of the process take out the vessel interaction and focus on the transportation time with 2 hours in the road, the paperwork, and the waiting time to load the container. These three bottlenecks can be changed, the road time with better scheduling, the paperwork with a digital workflow and the waiting time with better identification of the container. The total time of truck transhipment is 30 hours and 43 minutes. The time of truck transhipment takes 13 minutes more than railroad per container, because of the time on the road, the paperwork, and waiting time. In addition, the waiting time, usually is time with the truck on and consuming fuel.

b. Imports

There are different agents that inspect the load to enter the country, the ministry of health, the Agriculture Ministry, the firefighter's department, and the department of Pharmacy and Drugs.

The pre-import process starts when the buyer makes the transaction and notifies the customs broker about the transaction and the load arriving information. Then, the custom broker coordinates with the transportation agency (shipment agency, airline and/or truck company), then the broker sends the origin certification, the bill, and the rest of the information to the freight agent 48 hours before the arrival of the load. Then the broker makes the payment and the release of the load. The range in Costa Rica border and seaports depends on the type of merchandise, since the control of containers and trucks is more severe than the control from airport and Colon Free freight zone.

c. Exports

The export follows the regulations depending on the country of destination. There is no control from the Panama side, except for the sender.

However, the colon free zone (CFZ) is the one that does several exports that are affected by the procedures. There are two types of export that have some delays to take in consideration. The CFZ to Airport and the CFZ to Costa Rica border (Border).

C.1 Colon Free Freight Zone Export to Airport.

The total time of this process is 98 hours. However, the time of transportation of 24 hours seems to be too much, because the waiting time that usually happens in the airport increases the uncertainty. The bottleneck is the third step.

C.2 Colon Free Freight Zone Export to Border

The Export using the border to Costa Rica requires around 72 hours of volunteer waiting before moving the load out of Colon Free Freight Zone, this time the truck is not on, but the load is delayed, and affects the movement of goods, especially time sensitive items. The total minimum time of this export is 90 hours and 39 minutes, and the maximum time is 110 hours and 39 minutes. In this case, the bottleneck is the consolidation which takes 72 hours.

IV. CO2 EMISSIONS STUDY

The emissions of CO_2 to the air is mainly based on the movement to the border as table 1 presents. However, the movements to the border represent just 1.66% of the movements, and the train represents 0.2% of the volume of the movements. Consequently, the trucking movement for import, export, and transhipment is responsible for many of the emissions, because the study does not include the emissions from the vessels.

Table 1. Comparison of process time vs CO2 emissions time

Logistics action	Process Time (hours)	Emission time (hours)
Transhipment Railroad	40.5	3.5
Transhipment Trucking	30.72	3.72
Exports by airport	98	3.5
Exports by border	110.65	11

Based on Netherlands cargo report, 90% of the containers managed by the seaports is transhipment [26], so in 2017 the seaports managed 6.89 million TEU [27], so 6.201 million TEU were transhipment. In addition, 10% of the transhipment is by truck and 24% of the transhipment is by train. [28] However, the study includes all kinds of movement between the main nodes of internal and international commerce for Logistics of goods. In other words, the trucking address mainly imports and exports, while maritime transportation addresses most of the transhipment, and the crossing of the canal.

The calculation of CO2 is based in the following equation 1. This formula is mainly for truck calculations, but it can be used for railroad emissions too.

$$CO_2EMISSIONS = (D * W * EF)/1{,}000{,}000$$

Equation 2. [29]

The EF factor or the modes specific emissions factor used is 99.8 grams of CO2 per ton-mile based on ECTA average estimation for CO2 emissions [30,31], the W is the weight and the D is the distance in Km or miles. The movements used were the 96% of the movement presented in statistics from Customs in 2012. Therefore, the total of CO2 emissions in metric tons of the 96% of trucking is 40,090. The emissions of trains using the same equation 1, and 35.4 g of CO2/ton-mile was a total of 13,297 metric tons of CO2.

However, the EF factor in trucking can drastically change the gas emission estimation, since the controls in emissions in US and Europe are greater, for two reasons, first the control in the truck systems to reduce emissions, and the use of Diesel in all the trucks in Panama.

The CO2 emissions using 161.8 grams of CO2/ton-mile as EF from the Green Freight handbook [32] of U.S. Environmental Protection Agency (EPA) increment the emissions by 62%. In other words, 65,009 metric tons of CO_2 for trucking and 21,563.6 metric tons of CO_2. To this research the US emission factor is more suitable since most of the trucks are from the US.

V. Technology evaluation

This research aims to evaluate economically different alternatives of tracking the movements, so the CO_2 emissions can be better calculated. The first option is Passive RFID, the second is OCR, the third one is GPS. After an evaluation of several academic documents [12, 17, 18, 19, 32, 33, 34, 35, 36, 37], and commercial descriptions of the apparatus and labour requirements for an implementation of a tracking system [38, 39, 40, 41].

For the evaluation of technologies, there is a suggestion of a hybrid of the three of them in different layers of implementation. Although, the engineering economic comparison seems to start any conversation about technology implementation just as previous works in water ports [42]. The main assumptions for this comparison will be 1,000 trucks, 24 gates systems, 2% rate [43], 5 years' timeline, and 25% of the initial cost in tracking equipment for case of repair or replacement per year as maintenance cost, since usually the warranty of hardware is one year. The Net Present value will be used as an Engineering Economic tool.

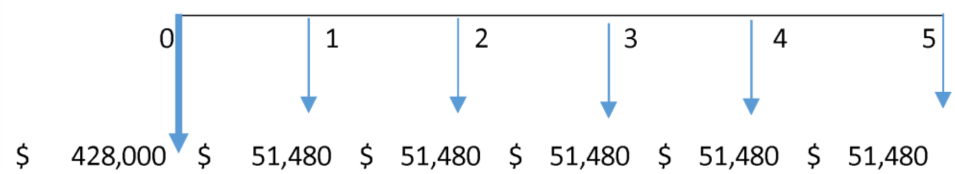

Figure 3. GPS investment timeline

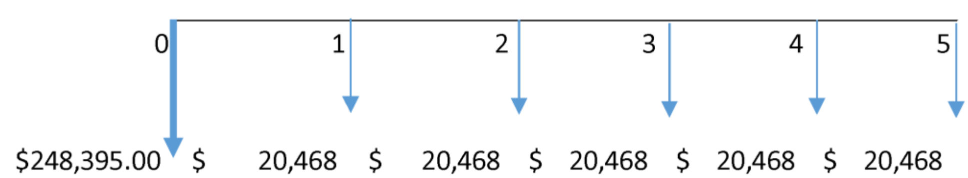

Figure 4. RFID investment timeline

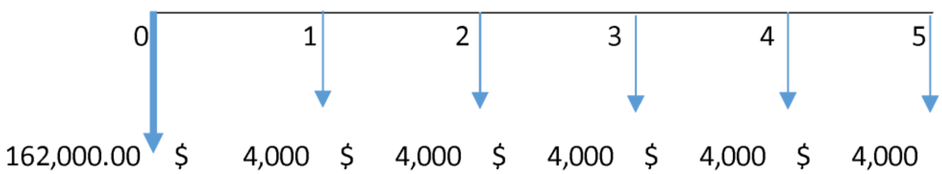

Figure 5. OCR investment timeline

Thus, from the economic perspective the NPV from higher to lower is GPS with $453,634, RFID with $258,587, and the OCR $163,992. In other words, the less expensive alternative as the all the timelines and NPV shows is the OCR. However, there are two qualitative pros that RFID has over OCR. First, the OCR can be intimidating to the truck drivers, since it has face recognition, and the toll system of the turnpikes already has RFID systems.

VI. Proposed Smart and Sustainable Logistics Ecosystem Model

The Logistic Ecosystem is presented in two ways going in and out of the logistics services or commerce areas. From the entry ports moving them by the transportation system and arriving to the logistics hubs, free zones and cities. There are some areas that just import, others that just export and others that import and re-export.

In addition, some of the re-export is Value Added Logistics Services (VALS) [44], and some of them are consolidation of load, especially in free tax zones like Colon Free Zone or Panama Pacific hub. The key areas for CO_2 evaluation of this research are the transportation by truck and by train in transhipment, import and export of goods. The main areas are shown in figure 6 with the 6 areas of transhipment from origin to destination.

Figure 6. Sustainable and Smart Logistics Ecosystem Value Stream Mapping

The minimization of CO2 emissions is the main goal of this design while there is minimization of the lead time in the import, export and transhipment operations.

The proposed model integrates cloud base storage with RFID and OCR systems to trace the flow of the ports and Logistics hubs and the CO2 emissions. The cloud storage will have direct access to the Logistics Government agency, and other government agencies, like the Agriculture Ministry and Customs to link their systems to increase efficiency in the system and reduce paperwork. The red electric line shapes represent the direction of the data to the main computer to data mine the Big Data and send just relevant information.

The system includes trucking and turnpikes for traceability, and it is focused on the containers and loads that enter the Country by sea.

VII. Conclusions and Future Research

The definition and the conceptual model of a Smart Logistics Ecosystem is the main focus of this research paper, the explanation of a system that can grow as a life form, using the logistics of goods to include devices that can communicate between each other to increment efficiency and to reduce the deterioration of the environment. RFID technologies seems to be a suitable way to address that from the qualitative standpoint, and from the quantitative standpoint a mix between OCR systems seems to have a lower initial investment and lower Net Present Value. However, starting with RFID, followed by OCR systems can be less traumatic for the Logistic community.

In addition, the bottlenecks in the system that affect efficiency, and include hours of congestion and CO2 emissions in the short distant may require attention to be tested in the future. The movements in the interactions between the seaports, the Free Zones, the Logistics hubs, and the cities are relatively the great focus of emissions.

After this research there are still several aspects to cover in future, but the main one is the actual test of the model vs the Manzanillo International Terminal system that includes Active RFID tags for people and trucks, and GPS and Visual Recognition for the robotic cranes.

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