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Optimization of the air cargo supply chain

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Abstract

Purpose: This paper aims to evaluate and optimize the various operations within the air cargo chain. It pursues to improve the efficiency of the air cargo supply chain and to provide more information to the decision-makers to optimize their fields.

Design/methodology/approach: The method used is a process simulation modelling software, WITNESS, which provides information to the decision-makers about the most relevant parameters subject to optimization. The input for the simulation is obtained from a qualitative analysis of the air cargo supply chain with the involved agents and from a study of the external trade by air mode, given that their behaviour depend on the location. The case study is focused on a particular location, the Case of Zaragoza Airport (Spain).

Findings: This paper demonstrates that efficiency of the air cargo supply chain can increase by leveraging several parameters such as bottlenecks, resources or warehouses.

Originality/value: It explores the use of a simulation modeling software originally intended for manufacturing processes and extended to support decision making processes in the area of air cargo.

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1. Introduction

The importance of air cargo industry has increased in the global economy, in spite of passengers taking precedence over cargo, which impacts on the volume of this business. This fact is due to the dynamism and flexibility that it provides to the supply chain. Nevertheless, the use of conventional modes of transport is still higher, positioning air cargo as an alternative mode under certain conditions. Besides, the knowledge of this mean is rather short, that is the reason for attempting to analyze the operation of air cargo, as well as the agents who take part in the air chain and identify factors that influence on their behavior.

The complexity of air mode and the high costs associated to it in comparison with other means limit air cargo to a narrow market niche.

Furthermore, the impact on the total cost or total time of each operation from origin to destination is difficult to evaluate, as well as the decisions of each agent and the relation among them.

Having a better knowledge of the operations, processes and the interrelations would enable evaluating and optimizing the supply chain, allowing other market niche markets entering.

The objective of this research is to evaluate and optimize the different operations within the air cargo chain. Results are obtained from qualitative and quantitative analyses using different sources. The qualitative analysis intents to determine the agents involved in the air cargo supply chain and the parameters that affect their behavior. Operations could vary from one airport to another. In order to understand their performance depending on the location it is crucial to study the external trade by air mode.

Once the air cargo supply chain is defined, in order to analyze it quantitatively, the research will be focus on the simulation of the air logistics chain from the general to particular. This simulation follows the business intelligence methodology, using real data to provide information to the decision-makers about the strategies to pursue.

The outstanding parameters will be used in a sensitivity analysis with the object of optimizing the whole chain in terms of efficiency and in monetary terms, by means

of identifying and removing bottlenecks, improving operations, and assigning, eliminating or reallocating resources.

The assumptions taken in the simulation will cover all operations of the air cargo supply chain from origin to destination on pure cargo aircrafts with a constant fuselage. To simplify the model, slots will be assumed to be huge enough to not constraint and with no delays in flights. Couriers will not be included in the analysis, whose operations are already integrated. The simulation will be run for a particular supply chain case to show easily an example of the possibilities that this tool would offer for helping the decision-makers. Although it will be run for a certain case, the tool is versatile enough to be extended to all kind of chains, products and scenarios.

The object to study the particular case is Zaragoza Airport (Spain).

Nowadays, Zaragoza Airport is achieving an excellent position in terms of volume in cargo. Indeed, it has reached the third place within Spain, just after Madrid and Barcelona Airports in the first quarter of 2009.

The influence area of Zaragoza represents the highest Gross Domestic Product and Gross Domestic Product by Person within Spain. This influence area has been considered with a 300 kilometers of radius; the maximum a driver can make a return route within a working day. This fact, together with its exceptional geographic location in the Iberian Peninsula, place Zaragoza as an important logistics area, with a high potential to develop.

Regarding logistics through air mode, 80% of freight summing up exports and imports in Zaragoza by air is apparel from and to Middle East and Asian Southeast. The main import is fish coming from South Africa. In addition, courier companies also operate in Zaragoza Airport.

2. Objectives

The general goal of this paper is to evaluate and provide more information to the decision-makers to optimize their fields within the air cargo supply chain.

Particular objectives to support the global purpose are:

- Determine the variables that impact on the behavior and decisions of the agents involved in air cargo.

- Deduce the pattern of external trade.

- Provide evidence of the simulation modeling software for the optimization and support for decision-making processes in the air cargo supply chain.

3. Literature review

Research by Larrodé et al (2007) studied the airport of Zaragoza. The influence area was analyzed, including locations, industries, accesses, foreign trade and the capacity of the airport with the purpose of determining the potential markets. Also, some studies of airports in Spain have been carried out, analyzing the infrastructures (Campos et al, 2002), capacities (Vázquez, 2005), intermodal transportation (Maeso González & Maeso Escudero, 2004) and the viability of new airlines of low cost and long range (Torres, 2005), although more oriented to the passengers transportation.

Several papers have developed this thematic, approaching the liberalization of the commerce (Inglada et al, 2006), airport management (Fernándes & Rodrigues-Pacheco, 2007), operations on airports (Sarkis & Talluri, 2004), international hubs (Matsumoto,2007), the intermodal transport between railway or maritime modes and road (Ruesch, 2001) and the diagnosis of the air cargo in other countries (Herrera et al, 2005), although none has been focused on the characterization of the air chain nor of the agents.

Reviewing the literature, at national and international level in the fields of logistics and transportation, it could be noticed the poor number of studies focus on air cargo. Comparing among modes, air cargo is not significant in terms of volume. This fact is due to its high costs, which limited this mode mainly to express, valuable or perishable goods.

Therefore, the characterization of the agents and their operations is fundamental, in terms of interactions among them, aiming to make the chain more efficient and, consequently, reducing associated costs.

Up to now, simulation tools have been used to optimize production processes (Barcia, 2005) and storage (Laney & Mayer, 1997). WITNESS has also been implemented to improve some capabilities combining the simulation with other system (Robinson, Edwards & Yongfa, 2003), which linked the tool with an expert system software to include decision-making processes.

This research implements the simulation of an air cargo supply chain, integrating all the operations and processes, as well as storage during the route. This is an

innovated usage of simulation tools, which provides information from analyzing the impact on the efficiency of the whole chain for an agent decision.

4. Methodology

The methodology applied in this research is explained in the following steps:

Characterization of the air cargo supply chain: qualitative analysis

In order to define the air cargo supply chain the first step is to identify the agents involved. Once the agents are known, their operations, behavior and relation among them must be identified besides the outstanding parameters. This information is provided by previous researches, literature (Aran, 2003) and (Villa, 2004) and interviews to a sample of agents in different provinces within Spain.

Assumptions

The design of the questionnaire for the interviews covers fifty five questions and is based on four types of variables: numeric, categorical single-answered, categorical multi-answered and text.

The selection of the interviewers is driven by the representative areas for air commerce in Spain and the type of agent.

The agents interviewed are airport manages, airlines, custom officers, forwarders, forwarding agents, handling agents, couriers and airport facilities managers.

The representative areas chosen are Madrid, Barcelona, Zaragoza and Vitoria for the high volume in air cargo.

The results from the interviews are analyzed statistically to identify trends and relevant factors that affect their behaviors.

The quality of the information gathered is satisfactory as it meets the purpose of the interviews.

Variables

Within the four types of variables, sorting out by the classification, the variables considered are:

- Numeric: time for operations and storage, companies in the area of influence, origins/destinations of the airport, airlines, fleet, fuselage, capacity, volume, value and growth percentage of exports/imports.

- Categorical single-answered: import/export growth forecast, knowledge of air cargo management, expedition management, storage, level of service.

- Categorical multi-answered: import and export products, origin, destination, agents, freight characteristics, special freight conditions, intermodal modes of transport, reasons for air cargo choice, consolidation/deconsolidation type, incoterms, traceability and information interchange systems, facilities, air service modality, freight type, seasonality, risks, obstacles and opportunities for the air cargo growth.

- Text: process for receiving, handling, warehouse distribution, hubs, flows.

External trade pattern: Quantitative analysis

To determine the products subject to study, as well as their distribution among origins and destinations, we execute a quantitative study analyzing data for external trade, sourced from the Spanish tax office (2008).

Assumptions

Although the model could be extended to any supply chain with any product, airport or agent, in order to illustrate the versatility of this tool, a particular case has been studied, the case of Zaragoza Airport (Spain).

The first step is to analyze the external trade of the airport. This data is provided by the Tributary Agency (2008), which captures products imported/exported from/to countries from records of the origin/destination custom office and province.

Origin and destination custom office or province can be distribution hubs or final locations.

Consolidation will be carried out by destination. Therefore, data will be filter by this variable. For Zaragoza airport, there are five destinations that highlight in export, of which their monthly evolutions by tones and their monthly number of orders per destination are estimated.

Actual and potential demand of an airport is estimated from the air commerce from/to the airport, its customs office and its area of influence, given by external trade data.

As an assumption, local and domestic market is not significant and subject to consideration for air trade so only foreign commerce is measured.

Variables

Input variables used for the external trade study are products, volume and value, import and export countries and origin/destination regions.

The outcome defines some factors to measure the trends and behavior:

- Inter arrival time per order.

- Volume per order, which will be useful to calculate the packages in each load device given its capacity.

- Volume and orders frequency.

- Volume in terms of destination.

- Order contribution.

Simulation of the supply chain: General case

Beginning with the general flow diagram, a simulation was developed from forwarder to consignee, through all links in the chain.

Assumptions

The model was carried out with WITNESS, a process simulation modeling software used by professionals to validate a proposed facility or business process as well as to support process improvement activities. The model is built up for any kind of product or supply chain. Subsequently, it has been particularized to the case of the Zaragoza Airport. The purpose of showing a specific scenario is to calibrate the relevant parameters to use in the what-if analysis afterwards.

Demand for the chosen products is known by the data of export and import for Spain, of which source is the Tributary Agency (2008).

Timing, resources and operations are obtained by interviewing several agents within the provinces subjected to study.

The simulation covers all operations of the air cargo supply chain from origin to destination on pure cargo aircrafts with a constant fuselage. Carrying capacity of trucks, vans and forklifts are also constant. Slots are assumed to be huge enough to not have constraints in that sense and with no delays in flights. Couriers are not included in the analysis, whose operations are already integrated.

Variables

The variables and assumptions that have been taken into consideration are mentioned below.

The chain represents all the links from the forwarder to the consignee. The defined elements are classified in buffers, machines, vehicles, labor, tracks, paths and parts. Each element has several variables to define, which would influence in the outcomes of the integrated process and also of itself.

One of the most relevant variables for buffers is the capacity, which will be able to be adjusted to the demand, in order to be well-measured. In addition, output and input rules, as well as output direction are significant, which describe the way the warehouse is managed. For instance, the depot could be managed as a FIFO or LIFO, or it could need a different output rule if it is required to output elements with same characteristics. In this simulation, delays are not taken into consideration in buffers.

On the other hand, machines are active elements that execute operations. For machines, input and output rules are programmed, as well as operations, their cycle time and the labor that carry them out. Operations include consolidation and deconsolidation. Setups, breakdowns and repair operations are not taken into consideration in the model.

Labor is one of the resources to optimize. The relevant factor is the quantity of each kind of labor. Shifts are not considered and it is assumed that they are always available.

Vehicles are the other type of resource subjected to optimization. Trucks and vans are considered as vehicles for the routes between forwarder and airport facilities and, analogously, from the destiny airport to the consignee. Movements within the airport facilities are done with forklifts. The significant variables are quantity of each kind of vehicles in each stretch and when to push the vehicle to the respective track to have it ready to load when the freight and the labor are already prepared.

Capacity of the vehicle and speed when loaded or unloaded are given by the specifications of itself. Delays are not considered in this model.

These vehicles cover their respective tracks. Tracks are used to load, unload or just as paths through which vehicles go. In any of these cases, it is needed to specify whether the vehicle is called for a specific action or it is always moving along the track. For loading/unloading, the quantity and the time to load/unload must be indicated, as well as in which track or element the load will be pushed and the route the vehicle has to follow, considering also the return. Each track has a length and a defined speed, which determine the time covering the distance. Moreover, depending on the traffic of that road or path, the capacity of the track varies.

While tracks are defined for being used by vehicles, paths are just ways that do not need vehicles, just labor. The most relevant variable for paths is the traverse time, which depends on their distance.

Finally, parts are the demanded products in the chain, which could be turned into other kind of parts, if they are assembled or produced in the cases of consolidation and deconsolidation, respectively. For parts, the distribution must be defined and their attributes detailed. Inter arrival time and the distributions referred to the attribute indicate the flow of parts. Lot size for arrivals influences in the quantity to load according to the capacity of the vehicles. There is no constraint with the maximum number of arrivals.

Simulation of the supply chain: Particular case (Zaragoza Airport)

Once the model is defined and the relevant variables and results are known, we simulate a particular case to calibrate the parameters and evaluate the impact on a what-if analysis afterwards.

Assumptions

This integrated model is an approximation of the real case of Zaragoza Airport.

The model focuses on exports, splitting the products by destination. The distribution of the demand has been estimated by orders and by volume.

The capacity of the truck is assumed to be constant and it can load 30 packages. Each forklift truck can load 5 packages and its capacity is also constant. Speed of vehicles is given by the characteristics of each kind of vehicle, and it varies whether

it is for loading or unloading. Paths and tracks are measured as estimation of the distances and times that they take, provided by the interviews.

Consolidation is assumed to be four packages per unit of consolidation, the number of packages that would fit on a pallet of approximated 100 kilograms. The Unit Load Device (ULD) for an aircraft has an approximated capacity of 2,500 kilograms, which would be translated in 25 units of consolidation.

Concerning agents, they are involved in their respective operations, and the number of each of them is proportional to the real one. Taking into consideration that the courier is the agent who deals with all activities in the supply chain, the model represents the case of forwarding agent in order to be able to analyze the performance of each agent. Times and resources assigned not only to paths and tracks but also to operations are proportional to those provided by the interviews.

The model has been run during 48 hours. Statistics for each element as tables or charts will be evidence for the need to improve any variable considered significant.

For machines, as assumptions, it was mentioned before that there are not any breakdown neither, subsequently, setups.

Regarding labor, the fact that operations and resources at the destination site are fewer than at the origin site in the short term is evident, because the flow that arrives from the air mode is less the inflow for the forwarder. Moreover, demand at destination site for imports is unknown, then, the optimization will be focused on the origin site.

As vehicles, the defined fleet of trucks consists of 12 trucks in each site and the one of forklift is composed of 5 each. For planes, the quantity is also 5. Trucks at origin cover the route between the forwarder and the airport facility. For trucks, the main part of the time has been demanded, which represents the time since a truck is called. It includes the return time and the time waiting to be loaded again. Transfer time is the spent time in loading and unloading.

The aim of this project is not to optimize the fleet of aircrafts, thus it has been considered that there are no delays neither slots that restrict the performance of planes. Hence, the fleet has been defined such that there is always a plane available. Resources at destination are not considered in the optimization analysis because they must have enough capacity to stand for the demand of other origins.

Vehicles travel by tracks. For each path covered by vehicles, three tracks have been defined. The first track, called track to load, is a short path where the vehicle is called under certain conditions and it is placed waiting to be loaded. The second goes to the destination and there it unloads. Finally, the third is the return way. Tracks and paths are not subjected to optimization in this study.

Optimization: Sensitivity analysis for a particular case (Zaragoza Airport)

The influence of each outstanding parameter in the chain efficiency has been measured. This efficiency is evaluated in terms of volume, inflows and outflows for a given capacity or resources, or by measuring yields of resource utilization.

Assumptions

Machinery, labor and vehicles constitute the relevant resources in the simulation. Furthermore, resources for a given volume and capacity can be optimized, reallocating them, removing unnecessary resources or assigning new to speed up processes. Additionally, bottlenecks are identified and reduced or even removed.

Finally, efficiency has also been considered as capacity utilization for given volume and resources. As a result, efficiency is translated in cost reduction, associated to resource optimization and to capacity utilization for a certain demand.

5. Model results

Characterization of the air cargo supply chain

The air cargo supply chain consists of the physical and documentary flow of freight from origin to destination. The flows are always identical, although the agents who take part could be different. In the following Figure 1 both flows and the agents are showed.
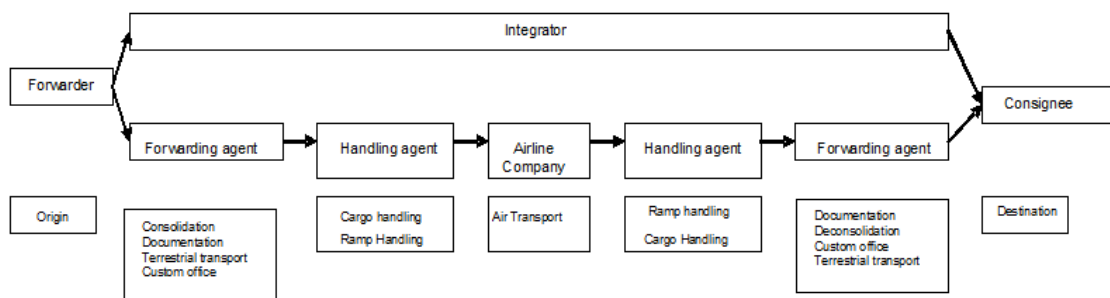

Figure 1. Air Cargo Supply Chain

The result extracted from the information obtained in the interviews is a description of their behavior and the variables that have influence on their decision-making processes, explained below:

Forwarder: Company that outsource to a third party the freight management from origin to destination.

The decision variables for this agent are:

- Product life time, which imposes the maximum available time for the shipment.

- Product density of value, which gives a measure of the total economic cost of the route that the product can bear.

- Product requirements in terms of temperature, humidity or any other condition that requires a specific treatment.

- Seasonality level of the product, measurement of the shipping frequency of that product.

- Economic cost of the air and freight forwarding routes, which determines the total economic cost of transport.

Forwarding agent: Intermediary who makes the required arrangements and/or provides complementary services for the freight transportation and other services on behalf of the forwarder and/or consignee.

The decision variables for this agent are:

- Security level required by the product, which sets transport conditions.

- Level of dangerous goods that is willing to admit, which needs specific safety measures.

- Specific temperature that is able to have under control during transportation.

- Relative humidity willing to provide to the freight.

- Special conditions in terms of special chambers, dry ice or any other requirements that they would want to meet.

- Intermodal level at origin and destination, which determines the reliability to meet the route.

- Consolidation, technique the forwarding agent wants to manage it.

- Documentation, depending whether it is sent with the freight or by other mode.

- Customs dispatch, decision of offering this additional service.

Customs Agent: Real or legal person, authorized by Customs Office to process the required documentation at export and import dispatches, as well as to make payments of tariffs and duties. This agent does not contribute to the decision-making process, although his good performance adds agility in the process, which helps companies to decide where to set up.

Handling Agent: Airport service rendered of cargo handling which uses available resources and facilities for the treatment of passenger, luggage and cargo flows.

The decision variables for this agent are:

- Required facilities list for the product, which sets constraints for the storage and handling.

- Offered facilities list at origin and destination airports, which sets constraints for the storage and handling.

- Consolidation, manner the agent wants to handle it.

- Additional service offered, such as road transport.

Airline: Real owner of the aircraft, who can operate or rent it.

The decision variables for this agent are:

- Route factors at origin and destination airports, which give a measurement of the potential capacity of the airport.

- Level of infrastructures at origin and destination airports that limits the number of travels and maximum size of aircrafts.

- Congestion level at origin and destination airports that set the possibility of delays.

- Fleet size, which contributes to increase the number and frequency of flights.

- Type of fuselage, which conditions the kind and volume of freight able to transport.

- Type of aircraft, whether it is passenger, pure cargo or mixed aircraft.

- Regularity and frequency of flights.

- Decision of doing auto handling or handling to a third party.

- Freight willing to transport, regarding the characteristics that could required.

- Maximum volume of package at hold.

- Maximum weight of package at hold.

Consignee: Person or company responsible of picking up the freight.

The decision variables for this agent are:

- Lesser extent depends on the same variables as the forwarder.

- Connectivity level, which determines whether the return is empty or loaded.

External trade pattern

The model of external trade deduced from the study of a representative airport, Zaragoza Airport (Spain) reveals that the significant parameters define a pattern.

Each variable matches a distribution, under the assumptions extracted from the airport to study, using monthly data for export, orders and volume.

The distribution of inter arrival time per order is calculated (1), which matches with a lognormal:

$$\text{Inter-arrival time} = \text{Lognormal}\,(\mu, \sigma) \tag{1}$$

with mean $\mu = 2.37$ minutes and standard deviation $\sigma = 0.64$ minutes.

The distribution of the volume per order is estimated (2), which will be useful to calculate the packages in each load device given its capacity. The monthly kilograms per order also match with a lognormal:

$$\text{Volume per order} = \text{Lognormal}\,(\mu, \sigma) \tag{2}$$

with mean μ = 28.47 kilograms and standard deviation σ = 15.68 kilograms.

For the simulation it is essential to know not only the volume and orders frequency but also the distribution of the orders and volume in terms of destination.

Both distributions are discrete. The contribution of total volume could be approximated by a Poisson distribution (3).

$$\text{Volume-contribution} = \text{Poisson} (\lambda) \tag{3}$$

with the expected number of occurrences within a given time interval λ = 40.

On the other hand, the contribution of total number of orders could be approximated by a uniform distribution (4).

$$\text{Order-contribution} = \text{Uniform (min, max)} \tag{4}$$

with the interval min = 1 and max = 5.

Simulation of the air cargo supply chain: general model

The air cargo supply chain has been defined and modeled with WITNESS, simulation software for production and manufacturing processes, as well as transportation.

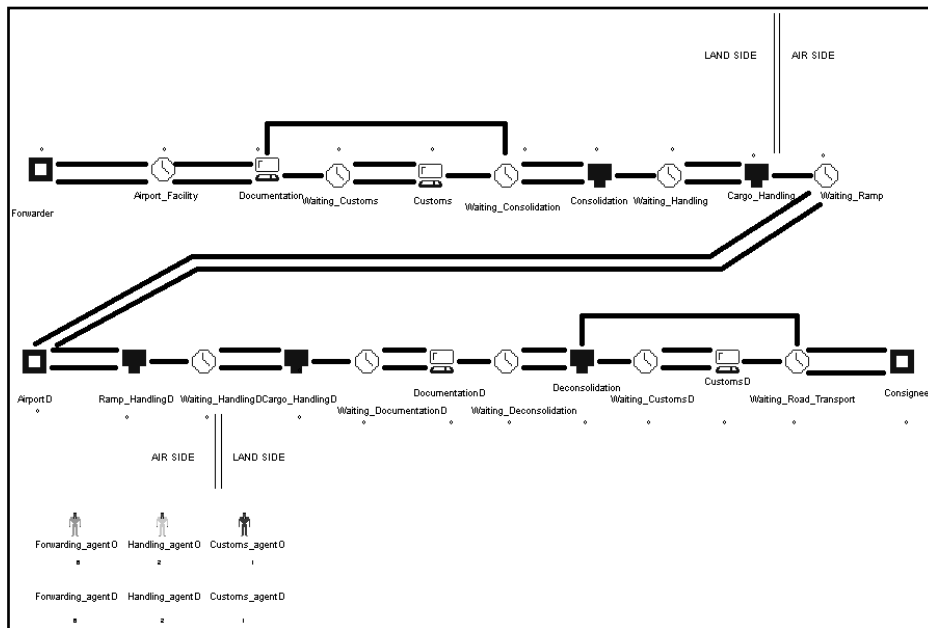In the following Figure 2 the diagram of the simulation is displayed.

Figure 2. Simulation of Air Cargo Supply Chain

The simulation covers all operations of the air cargo supply chain from origin to destination, representing all the links from the forwarder to the consignee. The defined elements in the chain are classified in buffers, machines, vehicles, labor, tracks, paths and parts.

Modeling the specified parameters with their variables, constraints and assumptions as detailed in the methodology, provides an outcome of the most relevant factors to use on the sensitivity analysis.

For buffers, one of the most relevant variables is the capacity. As results, it is observed the current capacity, maximum capacity, average time stored and average size of the store. Subsequently, the buffer could be well-measured to optimize the space.

Results from machines, active elements that execute operations, show idle and busy time, blocked and waiting labor percentage. These outcomes will be useful to identify bottlenecks, allocate more labor or even improve cycle time.

Labor is one of the resources to optimize. Outputs such as percentages of being busy or idle, with the average job time are the key information to make decisions related to reallocate, assign or remove labor.

For vehicles, other type of resource subjected to optimization, several percentages can show whether it is idle, demanded, loaded, stop or blocked. Distances and number of loads are also known. This information contributes to support decisions regarding the optimal number of vehicles or even when they should be ready.

These vehicles cover their respective tracks, for which percentages of being busy, empty or blocked are measured.

On the other hand, for paths, ways that do just need labor, results represent the percentages of being busy or idle, the parts and labor that goes in and out.

Lastly, parts, the demanded products in the chain, can be turned into other kind of parts, if they are assembled or produced in the cases of consolidation and deconsolidation, respectively. Outcomes of this element are, for instance, the number of parts entered, shipped or scrapped.

Once the model is defined and the relevant variables and possible results are known, we represent a particular case where these parameters can be calibrated and their performance evaluated.

Simulation of the air cargo supply chain: Particular case (Zaragoza Airport)

This integrated model is an approximation of the real case of Zaragoza Airport.

Based on the assumptions described in the methodology, some results are extracted, providing more information and findings to the decision making process and upcoming sensitivity analyses.

The results for buffers after running the model are shown in terms of volume storage in different situations. The maximum will be needed for better measuring the capacity of the buffers, taken into account the average size to not over measure the warehouse. The buffers that require more capacity are the airport facility and the buffer waiting for customs office. Comparing the packages that are now in with the maximum and the average size, together with the average time, it could be figured out that packages are cumulating in those two buffers. That accumulation means that inflows are more than outflows, which results a bottleneck in the following operation. For instance, the buffer for waiting consolidation is much more agile, noticing that total in and total out are almost equal, and the average size is about zero, which suggests that outflows are as quick as inflows.

For machines, Customs operations and documentation are quite busier than other operations. This supports the previous idea of bottlenecks in those operations due to the increasing stock in their preceding buffers. In addition, a changeable blocked percentage appears for almost every machine. The blocked time comes from a machine that is unproductive, is spite of having ended the operation, because the package cannot move on. The reason could be, dismissing the possibility of waiting labor because is already considered in the statistics, waiting for vehicle, a congested path or track.

Regarding labor, apart from customs agents, who work 60% of the run, the others have a low utilization. This piece of information will be use for the sensitivity analysis in order to optimize their yield.

For vehicles, by looking at the percentage that a truck is loaded compared with the demanded time, it could figure out that trucks are parked waiting freight most of the time, given that distances are the same for one way and return road. This fact makes this resource capable of improvement in the following chapter.

Vehicles that cover the tracks between buffers with more stock and the operations that cause bottlenecks have a closed relation among loaded, idle and demanded

time. The favorable reply of these vehicles has to do with the regularity of consignments due to the fact that the buffer has always enough stock to ship. The rest of vehicles that links other nodes behave as the trucks at origin and they should be subjected to optimization. For planes, idle time prevails over busy time. The aim of this project is not to optimize the fleet of aircrafts neither resources at destination are not considered in the optimization analysis because it is assumed they must have enough capacity to stand for the demand of other origins.

Vehicles travel by tracks. These routes, including air, follow the same pattern, except the track that goes to documentation, where there is a bottleneck. For that reason, unloading operations are blocked most of the time waiting the machine to empty. Roads act similarly. Return roads have a high percentage of being blocked since trucks have to wait until buffer has enough stock to load them. Tracks are not subjected to optimization in this study.

Finally, the busiest path is the route that goes from documentation to waiting for customs. Inflows and outflows, not only for parts but also for labor follow the same outline. As in the case of tracks, paths are not objected to study.

From the results, it might be noticed that there are some parameters that could be improved and are subject to further analysis in the study.

Sensitivity analyses in a particular case: Zaragoza Airport (Spain)

The purpose of this paper is to improve the efficiency of the air cargo supply chain. By integrating the operations and the agents it has been demonstrated that some factors could be optimized. Three scenarios are presented as an example of the possibilities that this tool have for optimizing the supply chain and for helping decision-makers once its performance is well known.

Scenario 1: Reducing resources for a constant flow: vehicles

Scenario 1 considers the situation of a constant demand while maintaining a certain service level. In this case, vehicles, as a resource is reduced for optimizing the supply chain. The variation of resources is done at origin site because the demand for imports is unknown at destination site.

Results are alike the outcomes of current situation in terms of outflows. In Scenario 1, it has been demonstrated that integrating the operations and having information about the processes of the other agents, resources such as vehicles could be reduced from 33% up to 40% in some cases, maintaining the same service level.

Scenario 2: Reducing resources for a constant flow: labor

Scenario 2 also takes into consideration a constant demand while maintaining a certain service level. Labor is the resource subjected to optimization in this second case. The adjustment of resources also focuses at origin site. In the model, the defined labors are forwarding agent, customs agent and handling agent. The quantity of each is proportional to the real situation.

Results are even better in scenario 2; the average time for consignee is less. States have improved, but idle times still really significant. That is due to a poor allocation of them. In this example, reallocation of labor is not considered. Apart from the reallocation of labor, which could even improve their yield, in scenario 2 it has been proved that for the same demand an a certain service level, staff of forwarding agents and handling agents could be reduced 25% each.

Scenario 3: Identifying and removing bottlenecks

In current situation, as it has been mentioned, two bottlenecks have been identified at origin site. These bottlenecks are formed by documentation and customs. They affect to airport facility and waiting for customs, respectively. In this scenario, once bottlenecks are distinguished, the aim is to reduce or even remove them.

Some alternatives have been considered for that purpose. Increasing resources such as labor or vehicles has been rejected because in scenarios 1 and 2 it was proved that there is over manning and means of transport in excess. Taking into account that tracks and paths were assumed to be constant and not subjected to optimization in the scope of the project, a solution has been accomplished by combining different decisions.

This result has been feasible incorporating other workplace at documentation and two at customs office. For documentation, current labor is reallocated, but for customs an extra labor is needed to remove the bottleneck. Otherwise, considering no more than one additional workplace at customs using existing labor, bottleneck would be only partially reduced. Reductions of both bottlenecks are demonstrated as a drop of stock in those buffers.

Therefore, adding a workplace at documentation, a reduction of 78% is achieved in airport facility. Moreover, bottleneck at customs office has been totally removed. For this solution, labor has been reallocated and just one resource apart from working places has been acquired.

Besides, those decreases imply a raise on flows of 24%. By reducing bottlenecks, the utilization of machines has increased, especially at origin site. Blocked periods in general have decreased. Yields of labor have also increased. However, there is still enough idle time.

Consequently, this scenario could be merged with scenario 2, reducing labor to optimize even more the integrated process.

In addition, capacity of warehouses could be optimized with this tool. Running the model an adequate number of times, it is possible to identify the trends of maximum capacity and average size of buffers at origin site. In Figures 3 and 4, those trends are displayed for each warehouse, comparing current situation with scenario 3. Airport facility at current situation suffers the effects of the bottleneck at the next step, increasing the stock at a high rate. In scenario 3, bottleneck has been reduced 78%, which could be noticed in the decrease of the slope of the line. As the trend is increasing, capacity of the warehouse should be oversized. However, regarding current situation capacity could be optimized due to the change of the slope.
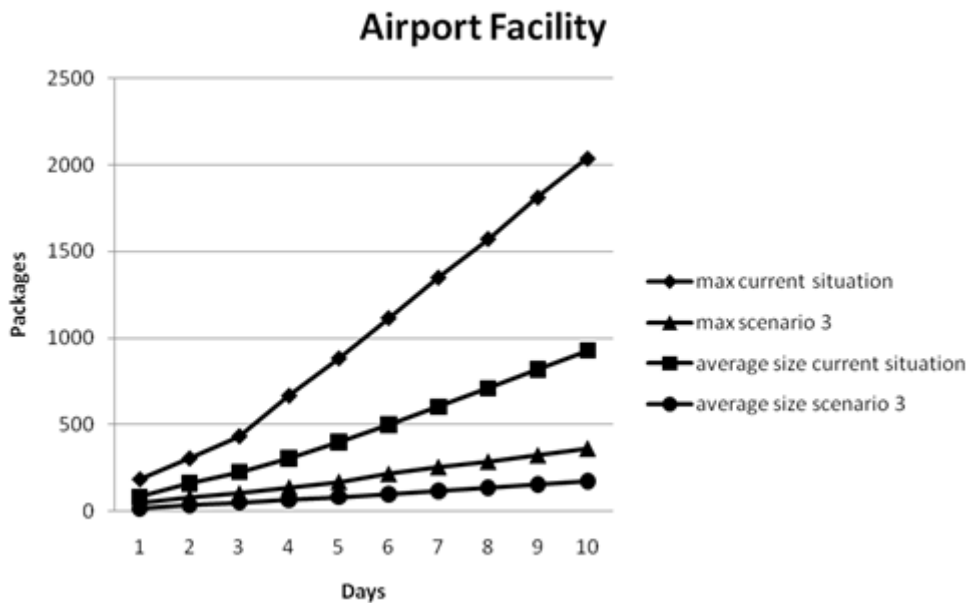

Figure 3. Comparison of Airport Facility Capacity

On the other hand, the second bottleneck has been completely removed. The affected buffer, waiting customs has changed from an increasing tendency to an unnecessary buffer, with an average size of less than one package. Hence, under scenario 3, it could get rid of that warehouse.

Figure 4 Comparison of Waiting Customs Capacity

Maximum capacity and average size at waiting consolidation is stable in the long run for both situations. Under scenario 3, maximum registered capacity is closed to the result under current situation.

Finally, waiting handling performance is similar than waiting consolidation, with a flat progression. In these cases, size of buffers could be optimized, taken into account that maximum capacities remain constant through the time.

6. Conclusions

By integrating operations in the air cargo supply chain, relations among agents would improve and, hence, operations themselves.

A simulation modeling software could optimize the whole chain or any of its components and would help decision-makers by providing them information about the performance of each link in the chain.

For a given demand and a certain service level in exports, trucks could be reduced 33% and forklifts up to 40% at origin site.

For a given demand and a certain service level in exports, staff of forwarding agents and handling agents could be reduced 25% each at origin site.

The simulation tool allows identifying bottlenecks. By creating a workplace and reallocating labor, a reduction of 78% is achieved in documentation. With two

workplaces in customs and allocating another customs agent, the bottleneck has been totally removed. These improvements imply an increase of 24% in flows.

By running the model an adequate number of times, trends of maximum capacity and average size of buffers at origin site can be recognized to optimize the capacity of warehouses and buffers. Airport facility has reduced its slope, although it should be oversized because of the increasing trend. Moreover, waiting for customs has become unnecessary.

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