

Chapter 4

A Study of Cargo Receipt Logistics for Flower Exportation at El Dorado International Airport in Bogotá D.C.

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Abstract Efficiency in logistics when transporting perishable products that are subject to seasonal demand is a key factor in maintaining product quality, reducing costs and achieving improved competitiveness. A significant percentage of total Colombian flower exports are sent from the international cargo terminal at El Dorado International Airport in Bogotá. In the last few years, the cargo terminal has suffered from severe traffic congestion and protracted waiting times in respect to cargo reception. This study presents a quantitative analysis of the current situation in order to identify critical factors and measure operational performance. Additionally, it contains a sensitivity analysis to identify the highest impact factors by using simulation techniques. As a result, changes in systemic operational parameters are proposed and evaluated so that the performance of logistical activities in the cargo terminal can be improved.

4.1 Introduction

Over the last 40 years, Colombia has become the second largest flower exporter in the world, with around 14% of total market share (Eyerdam 2009). The country is currently also the largest supplier of cut flowers to the United States (Spencer 2008). Moreover, flowers are Colombia's third largest export product after oil and coffee. Indeed, about 95% of Colombia's total flower production is sold abroad. These statistics serve to illustrate how prominent the country is in the flower market worldwide. Additionally, economic indicators show that the sector grew by about 8.3% annually between 1993 and 2007 (MAPFRE 2009), contributing significantly and beneficially to the balance of trade statistics and employment within the country

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(Tenjo et al. 2008). All these factors show just how important it is to improve logistical operations and achieve further efficiencies in order to respond effectively to customers. In addition, the recent entry of new competitors in the market, such as China and Kenya, also gives renewed focus and profile to the examination of this issue.

According to a study by the Colombian Organization for the Promotion of Exports (ProExport), 92% of Colombian flower exports are produced in the Bogotá region and the Department of Antioquia (Ruiz and Perez 2008). ProExport estimates that over 60% of all cargo transported from El Dorado International Airport are flowers (Llorente 2007). According to statistics provided by the Airports Council International (ACI 2010), El Dorado International Airport is the busiest airport for cargo traffic in Latin America and the Caribbean, transporting around 530,000 t of cargo per year.

In the process of exportation, flowers pass through different companies (or agents) in the supply chain that ensure the punctual arrival of the product in suitable condition for retail sale. Factors such as proper handling of the shipment and cold-chain maintenance are key aspects in maintaining the required characteristics of the product. This is vital because a lower-quality product can result in a reduction of up to 50% in the selling price of the flower (Van der Hulst 2004). In fact, as soon as the flower is harvested, the product has little time to withstand environmental conditions before reaching the customer.

One of the most important actors in the export chain of flowers from Colombia are the air transport operators (ATO), who receive the product from all crops in the region at the cargo terminal. ATO operations focus on scheduling vehicle unloads and the reception of air export goods. The operation is very complex, due to the high volume of cargo and vehicles received by each ATO.

Different actors in the export chain have expressed frequent concern about heavy congestion at the terminal and excessive waiting times, which often exceed 3 or 4 h and can be as long as 8 h. This issue illustrates the magnitude of the problem in receiving the load at the air terminal and the need for improving the process.

The analysis of this problem was done through a field study and the implementation of a discrete simulation model. The model was used to study different scenarios by adjusting the operating parameters to achieve better performance indicators.

The main issues addressed in the studied system are:

- Each vehicle carries its load to one or more servers (ATOs).
- Arrivals are not uniformly distributed over the time horizon.
- Servers have different attention-time windows throughout the working day.

4.2 Literature Review

Computer simulation is a tool to solve problems in complex systems that involve the modeling and imitation of a real-life process over time (Banks et al. 2009). Simulation elicits knowledge about system behavior and incorporates stochastic elements present in a real system, such as multi-server queuing systems.

Several studies address the application of discrete-event computer simulation to analyze and optimize complex queue systems with multiple servers. Some analytical studies have been developed for simple system configurations. Gao et al. (2004) presented an analytical technique for queuing systems with multiple servers in response to a geometric distribution of service time. Bruneel and Wuyts (1994) analyzed a discrete model of queues with multiple servers and independent arrivals to obtain an explicit expression for queue sizes.

Recent works on queuing simulation include the study prepared by Artalejo and Lopez-Herrero (2007) for multi-server retrial systems with discrete times and finite populations. This paper studies the incidence of the queuing discipline on the waiting time through simulation techniques. The simulation model evaluates waiting times for three different queuing disciplines: random order, first-come-first-served (FCFS) and last-come-first served (LCFS).

Yildirim et al. (2009) developed a multi-modal discrete-event simulation model for the deployment planning problem (DPP). DPP involves planning the movement of military units from their home bases to the final destinations using different transportation assets on a multi-modal transportation network. A real-world case study shows the robustness and benefits of the simulation approach to support operational decisions under urgent situations.

Kim et al. (2010) used a simulation approach to double-ended queuing problems with stochastic inter-arrival times and batch sizes. They evaluated their results by a sensitivity analysis and then considered the application case of a job placement agency to illustrate how the proposed simulation analysis allows for obtaining optimal conditions for the behavior of this kind of system.

Boon et al. (2010) carried out an analytical approach to a system consisting of two sequential single-server queues with two levels of customer priorities (low and high). They studied cycle and waiting times of the customers in the system. The improvement of mean waiting times for customers with high priority is measured through a numerical example.

Lee and Jacobson (2011) analyzed both steady-state and transient queuing and modeled the process for a multi-level security system for an airport terminal checkpoint by capturing the dynamic behavior of passengers sequentially arriving at the checkpoint. They obtained optimal policies for assigning passengers to the multi-level security system for maximizing the probability that a true alarm occurs, while minimizing the expected amount of time that passengers spend in the security system.

Davidrajuh and Lin (2011) presented a tool called GPenSIM, designed to model and simulate a discrete-event system that represents Harstad/Narvik Airport in Evenes, Norway. The scope of their paper is limited to analyzing the flow capacity performance considered the most critical issue for the traffic in the airport. The flow capacity involves the number of passengers using the airport per time unit and the average time required for getting their transportation at the airport.

4.3 Framework Description

4.3.1 *Operations in the Cargo Terminal*

Cargo reception at El Dorado International Airport's cargo terminal is undertaken by a series of air transport operators. These operators are responsible for receiving the goods, preparing the air pallets and loading aircrafts. Each operator has a number of loading docks (or gates), from 1 to 6 depending on the size of the operator. Each loading dock can only serve, at any given time, a single vehicle. At the time of the study, there were nine operators and 32 loading docks in the air cargo terminal.

The process begins when each land freight transport operator (LFTO) vehicle arrives in the cargo terminal. Upon arrival, the vehicle is directed to the parking area and the driver goes to the ATO to deliver the necessary documentation and request his turn to unload. An ATO official assigns a turn for each vehicle in accordance with the arrival order (FIFO policy); however, this practice is not generic and the receipt of cargo is frequently prioritized to suit preferential customers or crops (usually from the largest firms).

According to turn assignment, the ATO calls each vehicle forward to be unloaded. Sometimes, the LFTO is not present, because he may be unloading cargo in another ATO. In this case, the LFTO loses his turn and must wait for a new call to unload in the ATO. If the vehicle is available, it parks in the dock assigned by the ATO and the truck driver opens the truck gates and starts unloading. The unloading is done manually, box by box, with each placed on a conveyor belt leading to an X-ray scanner where the inspection of the cargo takes place. During the unloading, there are interruptions attributable to equipment problems or a more detailed inspection of the cargo.

The size of the shipments is specified using as a base a "full-standard box" unit equivalent to a box of $110 \times 17 \times 50$ cm that weighs approximately 18 kg, depending on the variety and quantity of bloom.

After all relevant documents are delivered; the LFTO waits for another call to unload or exits the terminal in the event that he has completed delivery of his entire load. Figure 4.1 schematically illustrates the process of load reception.

Carriers commonly transport crop shipments to several ATOs, frequently with more than one order (bill of lading) to be delivered to the same ATO. Some ATOs manage a consolidated receipt procedure in which all shipments transported by the vehicle are received in a single unloading. In contrast, other ATOs manage an individualized (non-consolidated) reception in which one unloading call is performed for each shipment order, according to the flight schedule.

4.3.2 *Field Study*

A field study was conducted to collect data so that the size of the operation and the times associated with each stage of the process could be characterized. Data were

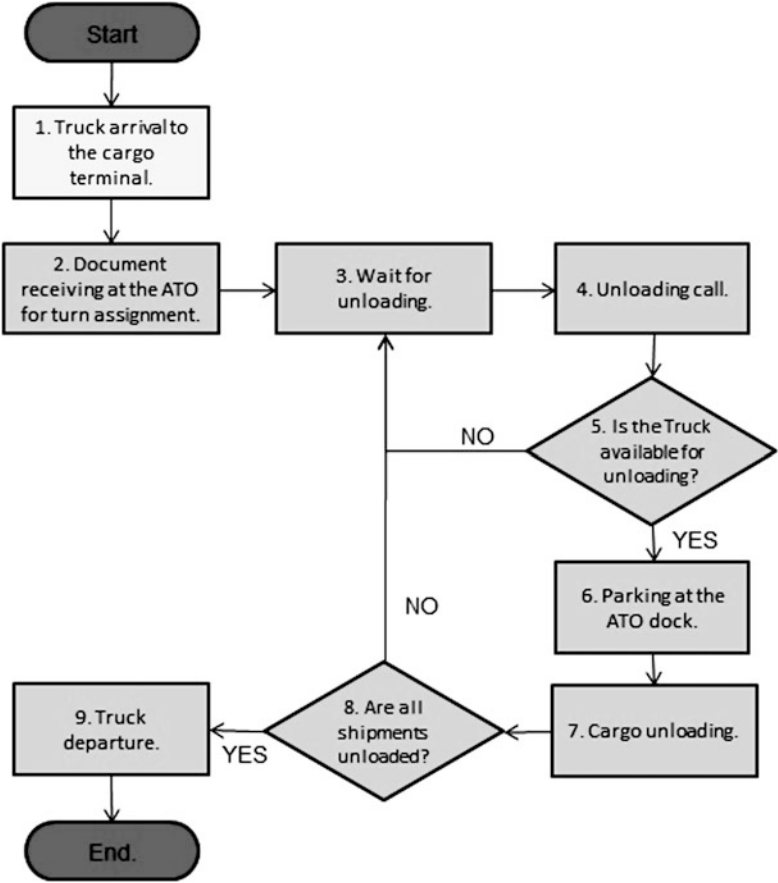


Fig. 4.1 General process of load reception

collected over a period of 7 days during the Mother’s Day season, from 2:00 pm to 5:00 am of the next day, the period in which the cargo terminal experiences the highest levels of arriving flow load.

The Colombian Association of Flower Exporters (Asocolflores) reports that a quarter of total annual sales takes place before St. Valentine’s and Mother’s Day. For the 2010 Mother’s Day season Asocolflores exported over 500 million flowers. An estimated 1,250,000 boxes flew out of El Dorado and José María Córdova International Airport, which services Medellín, representing approximately 12% of total annual sales (FreshNews 2010). This amount of cargo requires a daily average of 28 aircraft, compared to four aircraft used for low demand seasons.

The field study collected data in respect to arrivals and operation times so that the vehicle arrival pattern, the size of the shipments, the unload times and the time spent in the cargo terminal could be modeled. The last measure is used as a

benchmark to validate the implemented models and to compare the results obtained by making the operational changes suggested in the study.

The information collected was used to adjust the probability distributions used as input parameters in the simulation model. In summary, we considered the following system parameters:

- Vehicle arrival rates discriminated by hour (vehicles per hour).
- Distribution of the number of ATOs visited by each vehicle.
- Distribution of the size of shipments.
- Distribution of internal travel time and parking at the ATO docks.
- Number of docks and daily schedule of attention in each ATO.
- Unloading rates in the ATO (number of full standard boxes per minute).

The process's operational efficiency is evaluated mainly by using two performance measures:

- Average permanence total time of vehicles in the terminal (including unloading and waiting times), henceforth referred to as dwell time.
- Average number of vehicles in the cargo terminal.

4.3.3 *Current Situation Analysis*

Analysis of the current situation included a characterization of those elements with potential effects on the performance of operations in the cargo terminal. Measurements and classifications were used to design input parameters for the simulation model.

The vehicles were classified into four categories, according to cargo capacity (in full-standard boxes). Table 4.1 shows the defined classification. The first type of vehicle, named c1, is composed of panel vans with a capacity of less than 101 full-standard boxes. The second one, c2, is composed of box-trucks with a capacity of less than 201 boxes. Larger-capacity box trucks are classified into category c3. The fourth type of vehicle is formed by semi-trailer trucks whose capacity reaches more than 500 boxes.

During the field study, vehicle classification was used to establish a detailed characterization of the incoming vehicles to the cargo terminal. On average, 426 vehicles arrived at the terminal by day during the time frame studied. The percentage by type of vehicle in the terminal is showed in Fig. 4.2. It shows that the small box trucks (c2) made up the largest number of vehicles, with 62.7%.

Vehicle arrivals throughout the day present a pattern, with higher incoming flow between 3:00 pm and 10:00 pm, leading to increased congestion. This resulted in an increased stay time for vehicles in the terminal. Figure 4.3 shows the distribution of the number of vehicles arriving at the terminal every hour.

The second identified factor impacting congestion is the number of shipments dispatched to different ATOs. Figure 4.4 shows the relevant distribution. A vehicle carries, on average, deliveries to 2.2 ATOs. According to the distribution, more

Table 4.1 Types of vehicles

Type	Vehicle	Capacity
Panel van (c1)		Less than 100 boxes
Box truck 1 (c2)		101–200 boxes
Box truck 2 (c3)		201–350 boxes
Semi-trailer truck (c4)		More than 500 boxes

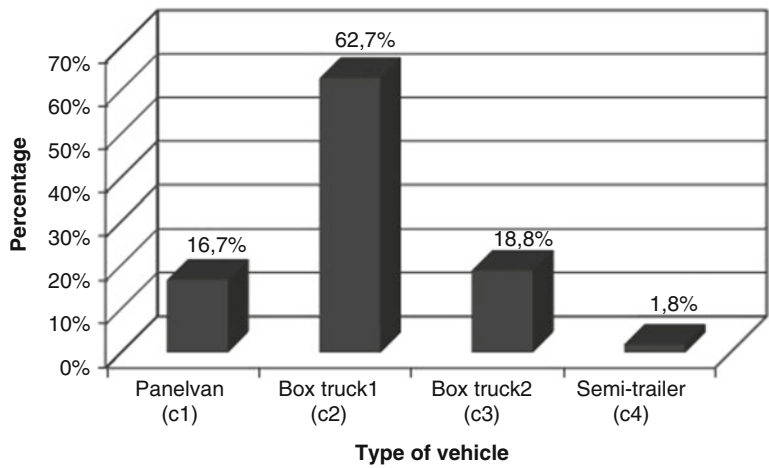


Fig. 4.2 Distribution of vehicle types

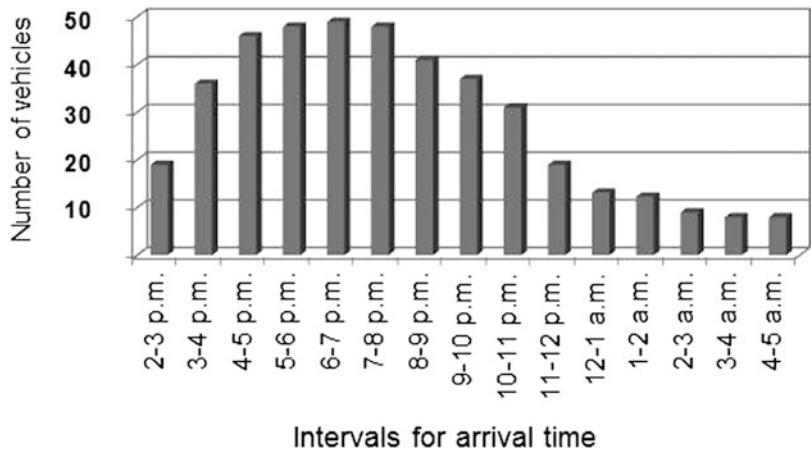


Fig. 4.3 Vehicle arrival pattern in the cargo terminal

than 29% of the vehicles visit more than 2 ATOs to unload cargo. This occurs because of a lack of coordination between crops and LFTOs and a limited use of cargo consolidation strategies.

The distribution of the shipment size, shown in Fig. 4.5, is another important factor that increases congestion. The total cargo arriving in the terminal divides into a large number of small-volume shipments. On average, the size of a shipment is 66 boxes. In addition, the utilization level of vehicle capacity is around 65%.

The final likely parameter affecting system performance is the unload rate (boxes per minute). Different unload rates were observed depending on the

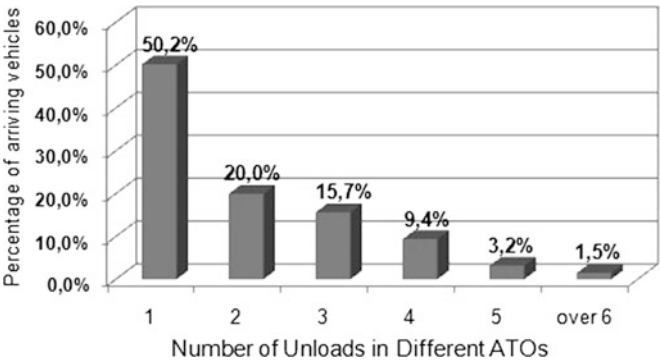


Fig. 4.4 Distribution of number of unloads in different ATOs

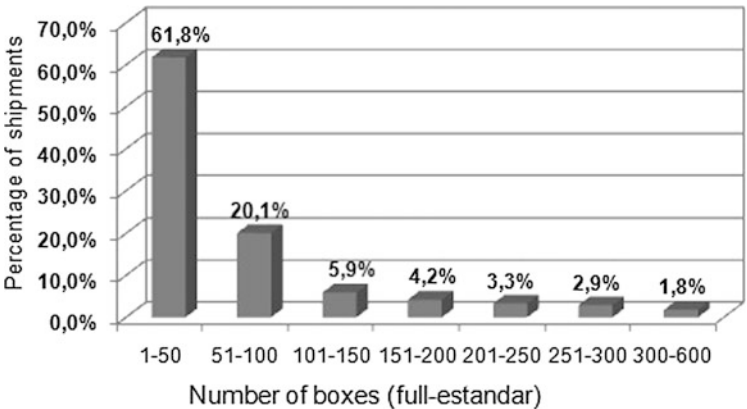


Fig. 4.5 Distribution of shipment sizes

Table 4.2 Unload rates

	Shipment size (number of boxes)			
	1–50	51–150	151–300	More than 300
Average unload rate (boxes/minute)	3.07	4.16	5.04	5.86
Probability distribution (mean, variance)	Log-normal (3.07–1.14)	Log-normal (4.16–1.04)	Weibull (5.04–1.22)	Normal (5.86–1.44)

unloaded shipment size as shown in Table 4.2. Based on the collected data, probability distributions were obtained in order to adjust the data behavior for each shipment size range. The global unload rate is around 3.99 boxes/minute;

Analysis of the performance of current operations in the cargo terminal focused on evaluating the service level, measured mainly by using the average dwell time metric (DT). The frequency distribution for DT according to the collected data in the field study is shown in Fig. 4.6. An average of 318 vehicles with “arrival-

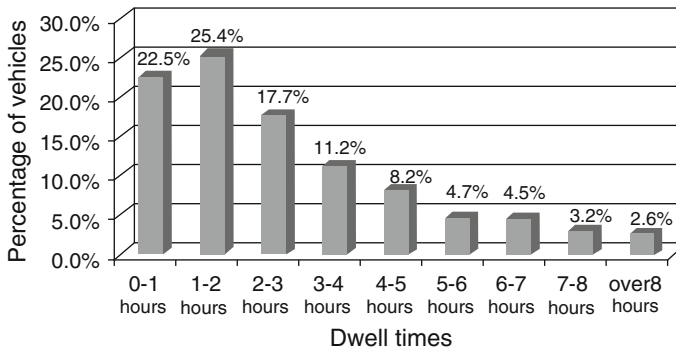


Fig. 4.6 Dwell time distribution for the current situation

Cross-tabulation Statistics - Chi-Square Test										
Rows: day		Columns: range								
Chi-Square = 41.44.		DF = 48.		P-Value = 0.737						
Range (hours):		r0-1	r1-2	r2-3	r3-4	r4-5	r5-6	r6-7	r7-8	over8
Expected Frequencies:		22.48	25.44	17.66	11.24	8.18	4.67	4.49	3.19	2.65
Total Count:		501	566	393	249	182	104	100	71	59
		All								
		2225								

Fig. 4.7 Comparison test for daily dwell time distributions

departure” times were registered each day. In the histogram, stay times are categorized by 1-h intervals. The first rank correspond to vehicles with DT smaller than 1 h, the second one to vehicles with DT equal to or greater than 1 h and lower than 2 h, and so on.

A chi-square test for homogeneity proved that the distribution of relative frequencies for each rank for the seven studied days is the same. Results generated with Minitab software® are summarized in Fig. 4.7.

As the study states, the current average vehicle dwell time (DT_{avg}) is around 2.96 h, a value considered as a maximum limit by users of the cargo terminal. In addition, the histogram shows that approximately 34% of vehicles must stay more than 3 h in the cargo terminal to unload the export shipments. This work focus mainly on finding alternatives for improving efficiency and reducing stay times for vehicles in the cargo terminal.

4.4 Simulation Model Implementation

4.4.1 General Background

To analyze the system performance in considering different configurations, a detailed simulation model was designed and implemented using Rockwell Arena software © Professional Version 12.

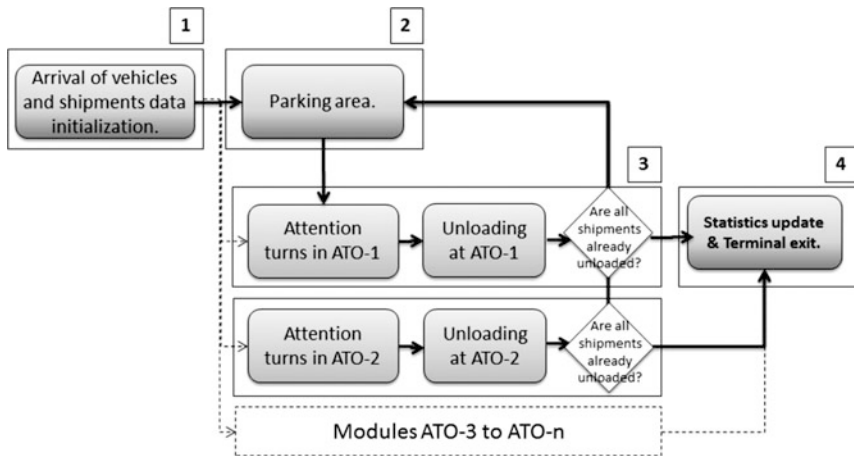


Fig. 4.8 General structure of the simulation model

The model supports the operation of high- and low-demand seasons by changing settings and input parameters for each one of these scenarios, in particular by adjusting the data related to the number of vehicles, number of boxes for delivery and number of docks in operation. Additionally, the model can add (or eliminate) new ATOs and reception gates easily, to simulate other terminal configurations.

The model simulates the cargo reception process on the basis of one working day. By running the model through a sufficient number of replications, it provides average statistics for daily performance indexes for the purpose of robust analysis.

Specifically, the model gathers statistics and reports of the simulation for the following global indicators:

- Average dwell time of vehicles in the terminal (hours).
- Average number of vehicles in the terminal.
- Effective reception rate in ATOs (boxes/hour per ATO).
- Use of reception gates (%).
- Size of unloading queues.

4.4.2 Model Structure

The model is organized into four main modules (Fig. 4.8). The first module contains the logic to generate the vehicles' arrivals at the terminal. The ATO (one or more) to be visited and the size of shipments (in full-standard boxes) using the fitted distributions are assigned. The second module corresponds to the parking area where the carriers wait for the unloading call. The third module implements the call to unload and the delivery of cargo at the ATO's gates. When a gate is released, a new vehicle is called to unload according to the schedule. If the called vehicle is

available, it goes into the ATO. If the vehicle is being served in another ATO, it loses the assigned turn and must wait for a new call. After unloading, if the vehicle still has pending shipments to deliver, it returns to the parking lot. Otherwise, it goes to the last module where statistics are tabulated and the vehicle (the simulation entity) departs from the cargo terminal.

In the implemented model there are two types of entities, vehicles and shipments. Each truck that arrives at the terminal may have one or more entities (of the shipment type) waiting to be called to the corresponding ATO modules. When the vehicle is available, it stays in the parking lot until the next unloading call. A concurrence control was implemented to avoid simultaneous deliveries of the same vehicle to different ATOs.

The unloading time for a specific shipment is calculated in the receiving process according to the shipment's size by using the unload rate distribution found based on the collected data in the field study.

4.4.3 Model Verification and Validation

Functional verification of the model was undertaken to analyze the compliance of the implemented logic with the real process. Verification included checking the implemented code against the process flow diagram. A visual animation of the system activity was also used to assess the level of congestion over time and the vehicle flow in the terminal.

A statistical quantitative validation was performed by comparing the performance measures generated by model execution (outputs) with respect to statistics estimated from the data collected in the field study.

The dwell time indicator was used as the basic performance measure to estimate the number of replications. The maximum error for the confidence interval (ϵ) to be estimated was set to 10 min (0.167 h). An initial estimate of variance (S^2_o) by using an initial sample (R_o) of 20 replications was $S^2_o = (0.46)^2$.

The number of replications (R) to be used in the simulation study was set to 35 following the method presented in Banks et al. (2009). According to the proposed method, R must be the smallest integer ($R \geq R_o$) satisfying Eq. 4.1.

$$R \geq \left(\frac{t_{\alpha/2, R-1} S_o}{\epsilon} \right)^2 \quad (4.1)$$

A statistical quantitative validation was performed by comparing the performance measurements generated by model execution (outputs) with respect to statistics estimated from the data collected in the field study.

To validate the behavior of the implemented simulation model, a statistical comparison using the output dwell time metric was performed. Table 4.3 shows

Table 4.3 Average dwell time comparison for model validation

Field study	Simulation results (outputs) for DT				Mean comparison test	
Average dwell time DT_{avg} (hours)	Average	Half-Width	Lower limit	Upper limit	t -test statistic t_{calc}	P-Value
2.96	2.99	0.13	2.86	3.12	0.49	0.63

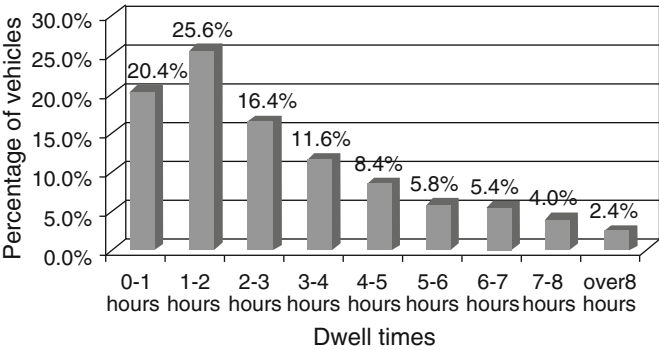


Fig. 4.9 Distribution of dwell time for simulation model

Table 4.4 Dwell time distribution comparisons for model validation

Day	Number of observations	χ_{calc}^2	χ_0^2	P-Value
Day 1 (Monday)	331	10.45	15.51	0.23
Day 2 (Tuesday)	319	8.23	15.51	0.41
Day3 (Wednesday)	327	10.89	15.51	0.21
Day 4 (Thursday)	322	10.68	15.51	0.22
Day 5 (Friday)	302	6.64	15.51	0.58
Day 6 (Saturday)	259	7.24	15.51	0.51
Day 7 (Monday)	372	10.1	15.51	0.26

the average dwell time (DT_{avg}) found for the real system and the 95% confidence interval reported by the Arena© simulation model for 35 replications.

The confidence interval can be seen to contain DT_{avg} , and $t_{calc} < t_{0,025,35-1}$ ($0.49 < 2.03$). In addition, the worst-case error ε -worst ($UpperLimit - DT_{avg}$) is around 0.15 h (about 10 min), considered acceptable for validation.

Figure 4.9 shows the discrete probability distribution for dwell time (DT) built by using a total of 12,320 “arrival-departure” records logged by running the 35 replications.

The Pearson’s chi-square test was used to assess the goodness of fit between the simulation model distribution and the observed frequency distribution for each day considered in the field study. Table 4.4 shows the value of the calculated test-statistic (χ_{calc}^2) and the critical value (χ_0^2) for 95%.

Results show that we would not reject the null hypothesis that dwell time distributions for observed data and the simulation model are the same; therefore, the simulation model is accepted to be closed enough to the real system.

4.5 Performance Analysis and Improvement Proposal

4.5.1 Sensitivity Analysis

A sensitivity analysis for those factors with a significant expected effect on system performance was carried out. The analysis for each factor was done by evaluating the impact of modifying the factor's value using liable levels. Each factor was analyzed independently. For each analysis, values for other input parameters were set using the current values for the actual situation.

The following analyses (one per factor) additionally aim to measure potential improvements in the service level and identify the more relevant factors.

- A1: Increasing the rate of cargo unloading.
- A2: Increasing the percentage of vehicle capacity utilization.
- A3: Reduction in the amount of visited ATOs by vehicle.
- A4: Changes in the daily arrival pattern of vehicles to the terminal.
 - From current (seasonal) arrivals to a uniform arrival pattern.
- A5: Increasing the number of gates in operation.
- A6: Changes in reception policies:
 - For turn assignment:
 - i. First come, first served (FCFS), and
 - ii. By priorities.
 - For unloading mode:
 - i. Consolidated unloading, and
 - ii. Non-consolidated unloading.

For each factor, between 3 and 4 levels (values) were defined in considering feasible changes to be implemented in the operating conditions of the system.

Figure 4.10 shows the behavior of dwell time according to the variation in the arrival pattern. The figure exhibits the average values with their corresponding 95% confidence intervals. The change in the pattern of arrivals to more uniform patterns generates a reduction of up to 44% in the vehicle's dwell time in the terminal. In contrast, Fig. 4.11 shows a lower observed impact generated by increasing the percentage of vehicle capacity utilization.

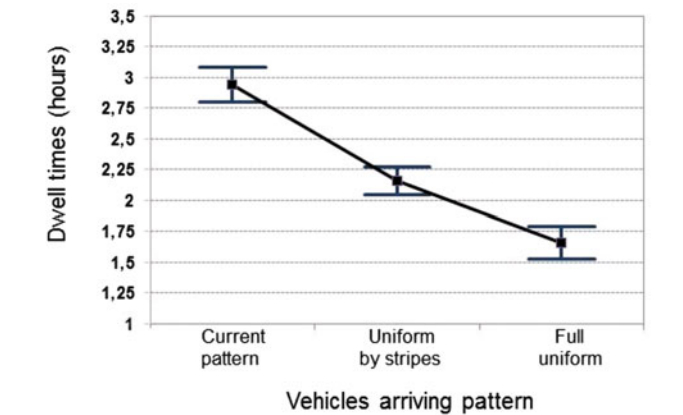


Fig. 4.10 Arrival pattern change effect

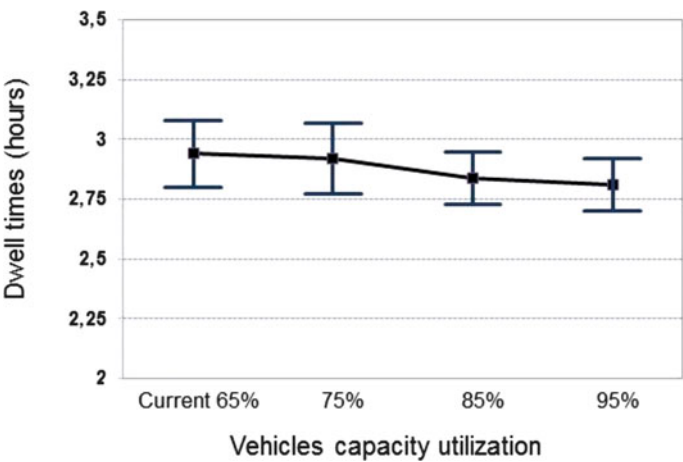


Fig. 4.11 Percentage of vehicle capacity utilization change effect

Table 4.5 summarizes results obtained by statistically testing the relevance of each factor by using the ANOVA procedure. In the last column the table reports the average of mean differences for each factor by comparing consecutive levels. These values, in addition to p-values, allow for identifying the factors that most impact system performance.

According to Table 4.5, the more relevant factors found are the vehicle arrival pattern, the unload mode policy, the cargo unloading rate and the number of visited ATOs by vehicle.

In the comparison between the consolidated and non-consolidated attention strategies, the former was found to be better. This is because the widespread use

Table 4.5 Summary of sensitivity analysis results

Factor	Levels	ANOVA P-Value	Average mean differences (h)
Cargo unloading rate	1: 3.99 2: 4.8 3: 5.6 4: 6.0 (boxes/min.)	<0.001	0.34
Vehicle capacity utilization	1: 65% 2: 75% 3: 85% 4: 95%	0.32	0.04
Amount of visited ATOs (on average)	1: 2.0 2: 1.5 3: 1.25 4: 1.0 ATOs	<0.001	0.34
Vehicle arriving pattern	1: Current pattern 2: uniform by stripes 3: Full uniform	<0.001	0.64
Number of operating gates	1: 24 2: 26 3: 29 4:32 (gates)	0.042	0.18
Unload mode strategy	1: Consolidated 2: non-consolidated	<0.001	0.6
Turn assignment policy	1: FCFS 2: by priorities	0.84	0.02

Table 4.6 Configurations for improvement and ideal scenarios

Factors	Improvement scenario	Ideal scenario
Vehicle arrival pattern	Uniform by strips	Completely uniform
Cargo unloading rates	4.8 boxes/min	6.0 boxes/min
Number of ATOs visited by vehicle	1.5 ATO	1.0 ATO
Number of gates in operation	29 gates	32 gates
Vehicle capacity utilization	85%	95%

of the second strategy would increase the average attention time to about 20% (from the current value of 2.94 to 3.54 h). It would also reduce the effective rate of box reception at the ATO by 10% (from 723 to 654 boxes per hour).

The results of the analysis of alternative attention policies showed that, for a priority attention strategy (for largest shipments), the average wait time does not increase significantly compared to FCFS policy. The results showed that, with a widespread use of priorities for shipments of more than 300 boxes, the average stay time would increase by only about 3%.

4.5.2 Analysis of Global Improving Scenarios

A global scenario corresponds to a specific value assignment for each one of the input system factors. Analysis of scenarios allows for the evaluation of the global impact of simultaneously setting input parameters (factors) in accurate levels.

Based on the previous sensitivity analysis results, two global improving scenarios were proposed. The first one corresponds to a short-term improvement setting on the bases of small feasible improvement changes for each factor. The second one defines the ideal scenario by setting each factor to the top (outstanding) level, according to the sensitivity analysis.

Table 4.6 shows the level selected for each factor for the two defined scenarios. By default, in both scenarios, consolidated attention strategy and FCFS-turn assignment policy (the actual policies) are maintained.

Table 4.7 Results of the global proposed scenarios

Performance measurement	Current situation			Improvement scenario			Ideal scenario		
	Average	Lower limit	Upper limit	Average	Lower limit	Upper limit	Average	Lower limit	Upper limit
Dwell time in the terminal (hours)	2.96	3.1	2.91	1.34	1.24	1.44	0.79	0.74	0.84
Vehicles in the terminal	101.6	94.35	108.85	32.7	30.5	34.9	17.3	16.65	17.95
Effective reception rate (boxes/hour)	723.2	684.8	761.6	791.8	740.3	843.3	658.7	602.2	715.2

The performance of the system for the two presented scenarios was evaluated. Table 4.7 shows the results reported by using the implemented simulation model. The table exhibits the average values for the dwell time with their corresponding 95% confidence intervals.

In general, a reduction of up to 54% for the vehicle dwell time in the terminal could be achieved in the improvement scenario. A grater improvement (around 74%) could be attained in the ideal situation. Additionally, a considerable reduction in the terminal congestion is observed. The average number of vehicles in the terminal could drop from 101 (in the current situation) to 32 in the improvement scenario.

The implementation of changes in operational factors, even to the improvement scenario, would require a huge effort and agreement between the supply-chain stakeholders to develop coordinated processes for transportation and delivery of cargo. Improvements in unloading taxes and available gates are expected in the next 2 years, according to the recent infrastructure modernization project for El Dorado’s cargo terminal. Changes related to the shipment schedule, and the use of best practices regarding capacity vehicle utilization, cargo consolidation and organization of cargo deliveries can be promoted and implemented with the coordination of Asocolflores.

4.6 Conclusions

In this paper, simulation techniques were used to study the current situation in the cargo reception process of Colombian flower exports at the international cargo terminal at Bogota’s El Dorado International Airport. The main purpose of the study was to evaluate different configurations in order to optimize operational performance. Using a simulation model, a sensitivity analysis was conducted to establish the most relevant factors affecting system performance.

The following factors were identified as the most important: the pattern of arrivals to the terminal, the number of air transport operators visited by vehicle,

the number of gates available for cargo terminal, and the rate of flower boxes unloaded. An increased level of vehicle capacity utilization was found to produce less effect on performance than the factors previously mentioned. Finally, the most appropriate policy for reducing waiting times was found to be the reception of the cargo with a consolidated strategy, as currently used by the majority of air transport operators.

The data collection showed that a pattern for vehicle arrivals at the terminal exists. The highest volume of cargo arrivals takes place between 3:00 and 10:00 pm (approximately 66% of the total flower-related cargo). This surge increases congestion and reduces the flow of vehicles through the terminal. For this reason, we recommend implementing mechanisms to coordinate the vehicle arrival schedule. The air transport operators may arrange unloading turns by assigning attention slot times for each reception programmed shipment. To implement this strategy it would be necessary to analyze the functionality and capacity of existing information systems to support the management of reservations.

The results obtained using the simulation model showed that the proposed changes could achieve a reduction in vehicle wait time and stay time of about 1.6 h. The analysis of the potential impact of the number of available reception gates and a likely increase of unload rates provides important information to support decisions for physical and technological reforms in the cargo terminal.

Finally, it is important to emphasize the need to continuously track indicators obtained in this study in order to effectively monitor the impact of ongoing changes to the infrastructure and processes in the cargo terminal.

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