

Model to determine optimal fleet size in a cargo truck operation using @Risk

By: David Osorio

✉ dosorio@rentingcolombia.com

October 2010

Relevance of the study

- ✓ Companies located in major cities of Colombia, experience **logistic costs that represent about 18% of the total cost** ⁽¹⁾
- ✓ Usually companies hire a third party (3PL) to transport their cargo to and from ports, **paying a pre-defined freight**, regulated by the government.
- ✓ Having its **own fleet, in whole or part of it**, might be a good alternative, looking for a transportation cost reduction
- ✓ However, determining an optimal fleet size is not an easy task, because the demand is not constant in time, loading and unloading times are uncertain as do travel times, among other factors.



⁽¹⁾ Inter American Development Bank (IDB), 2009: **Latin American economies stymied by high transportation costs**

Main objective

To evaluate economic benefits for the decision of owning a fleet for cargo transportation in an line haul operation (from plant to port), for a manufacturing company.

Specific objectives.

- To estimate the appropriate fleet size for the operation
- To estimate the round-trip cost, considering all the involved costs.

Overall operation description



- ✓ Company ABC has its production plant in the city of Bogota.
- ✓ Imported raw material from Buenaventura port is transported by semi-trailer trucks.
- ✓ The Company also has to transport finished goods from Bogota to Buenaventura port (same truck may be use).
- ✓ The amount of imported raw material and finished goods for exportations ; depends on the market demand and varies over time.
- ✓ Currently, transportation is hired with a third party, paying a regulated fee.

1. Fleet size determination

1.1. Round-trip time

1.2. Initial information (database)

1.3. Modeling input variables.

- a. *Waiting time in port*
- b. *Travelling time*
- c. *Waiting time for unloading*
- d. *Unloading time*
- e. *Waiting for departure*
- f. *Demand*

1.4. Output Variables (results)

- a. *Round-trips/ month*
- b. *Satisfied Demand*
- c. *Fleet size required*

2. Costing

2.1. Current cost

2.4. Costing Results

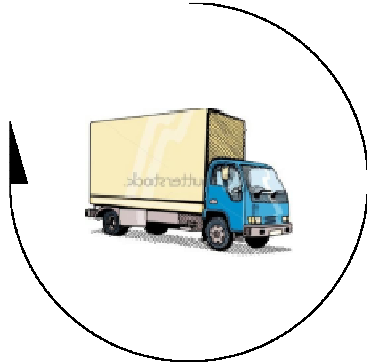
3. Conclusions

4. Further work

1. Fleet size determination

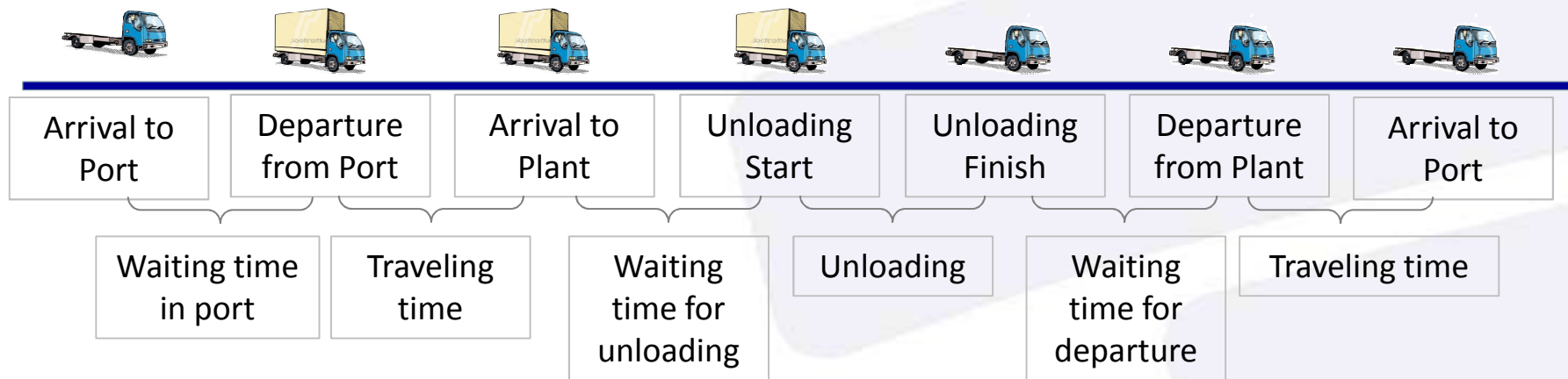
1.1. Round-trip time

1st Option : To model the round-trip as a whole

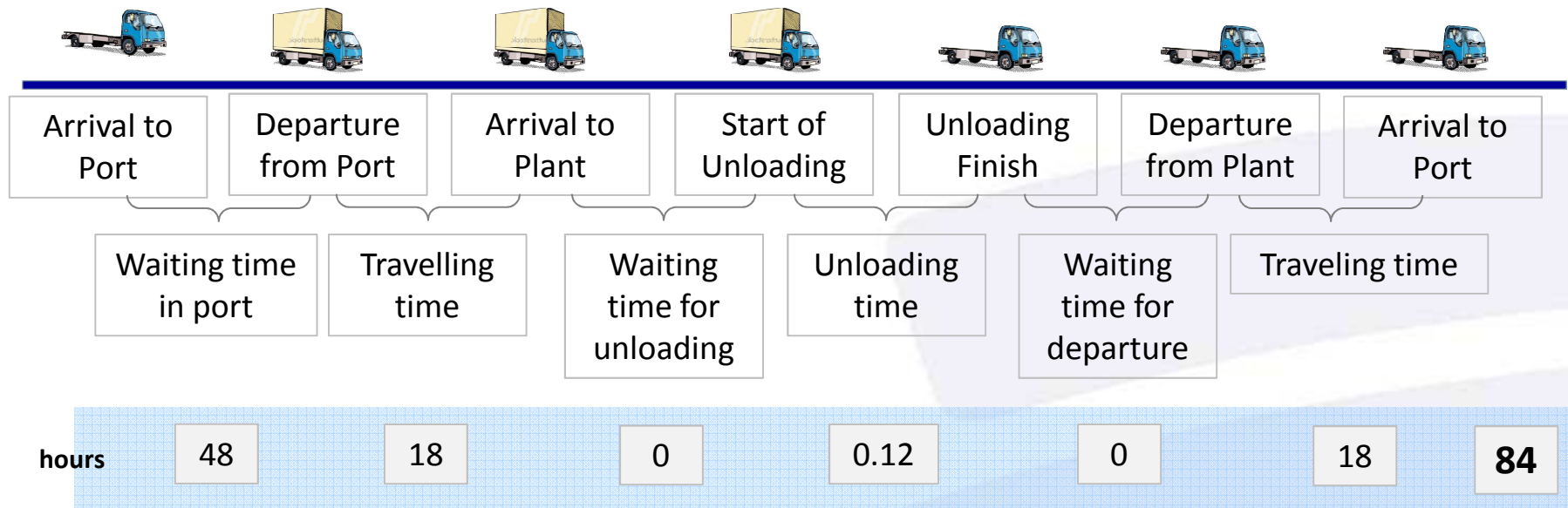


It does not allow to simulate different policies looking for improvement on times.

2nd Option: To model each component of the total cycle.



1.1. Round-trip time



In a first approach, the client provided the above mentioned **deterministic times**.

According to those times, it is possible to make 7.4 round-trips in a month

(84 hrs/round trip = 3.5 days/round trip = 7.4 round trips / month)

Next step: to explore data base in order to validate and consider the possibility of using stochastic times.

1.2. Initial information (database)

Data base:

- # Containers
- License plate
- Container number
- Arrival date to port
- Departure time from port
- Arrival date to plant
- Unloading start time
- Unloading finish time
- Departure time
- Third party name

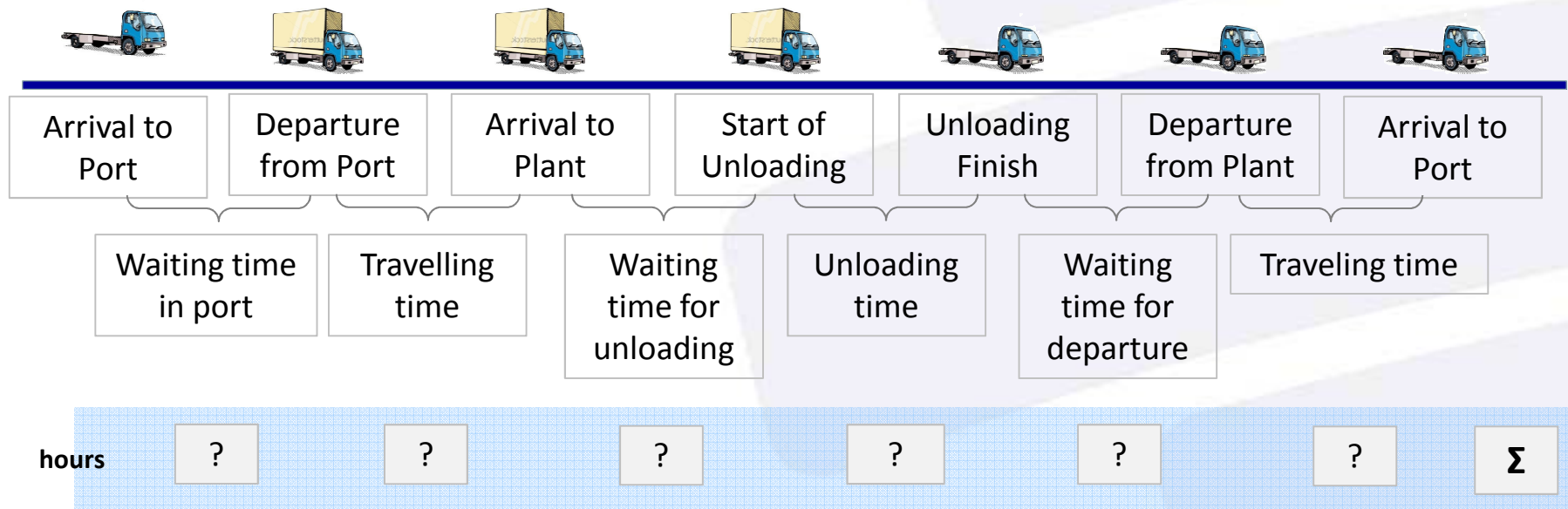


6 months historical data

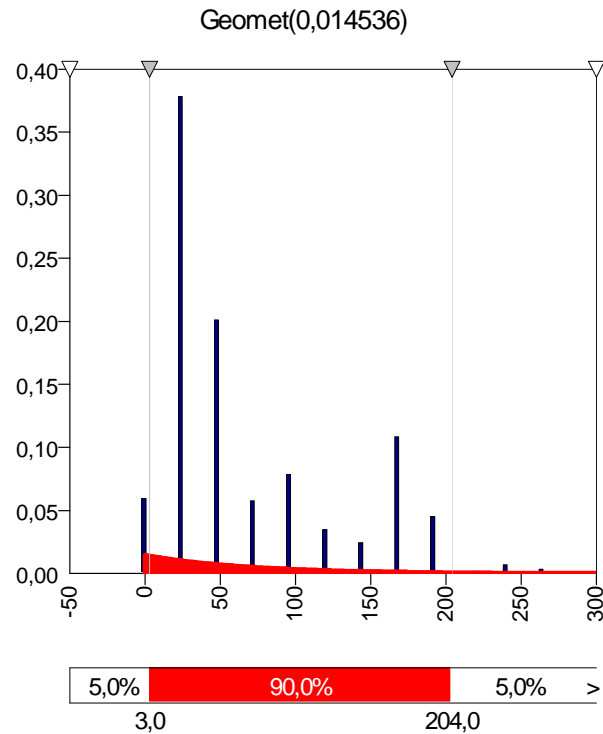
Considerations

- No uniformity in data
- Some missing information

1.3. Modeling input variables



1.3.1 Waiting time in port



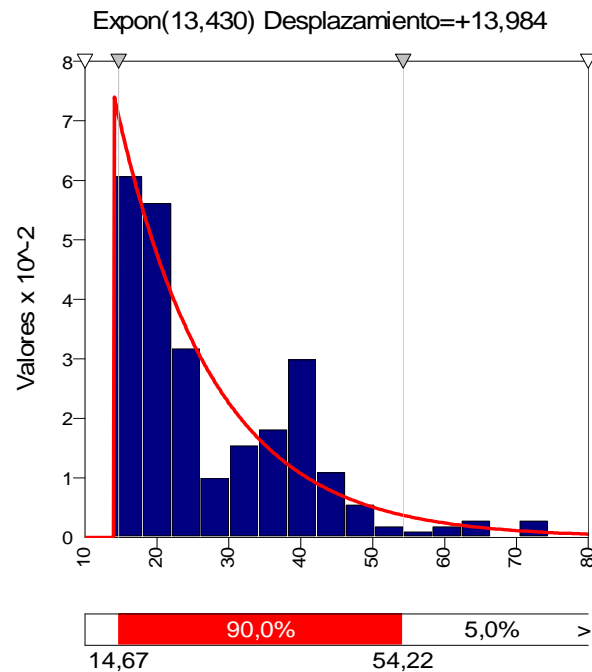
| | Hours | Days |
|--------------------|--------|--------|
| Minimum | 0 | 0 |
| Maximum | 264 | 11 |
| Mean | 67,8 | 2,8 |
| Standard deviation | 59,34 | 2,47 |
| Dispersion | 87,50% | 87,50% |
| Mode | 24 | 1 |
| Median | 48 | 2 |



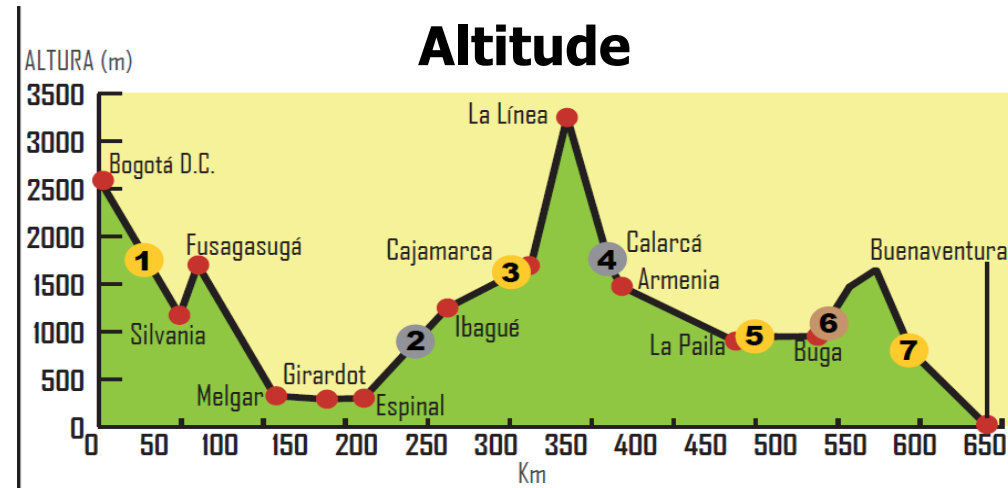
The waiting time in port is described with a discrete distribution. It has mean 67,8 hrs and a standard deviation 59,34 hrs.

It was modeled as a discrete variable

1.3.2 Travelling time

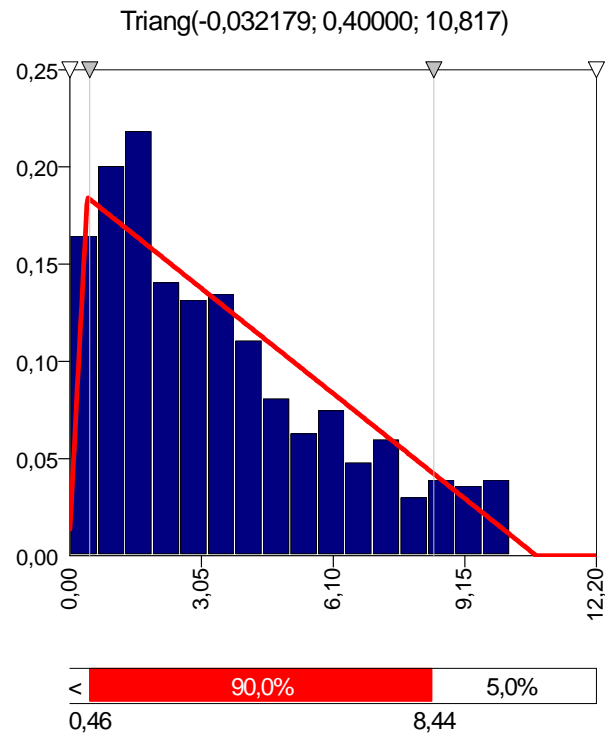


| | Real |
|--------------------|-------------|
| Minimum | 14,03 |
| Maximum | 74,55 |
| Mean | 27,46 |
| Standard deviation | 12,16 |
| Dispersion | 44,30% |
| Mode | 22,383(est) |
| Median | 22,56 |



The travelling time followed an exponential distribution, where the mean is 27 hrs and the standard deviation is 12 hours.

1.3.3 Waiting time for unloading

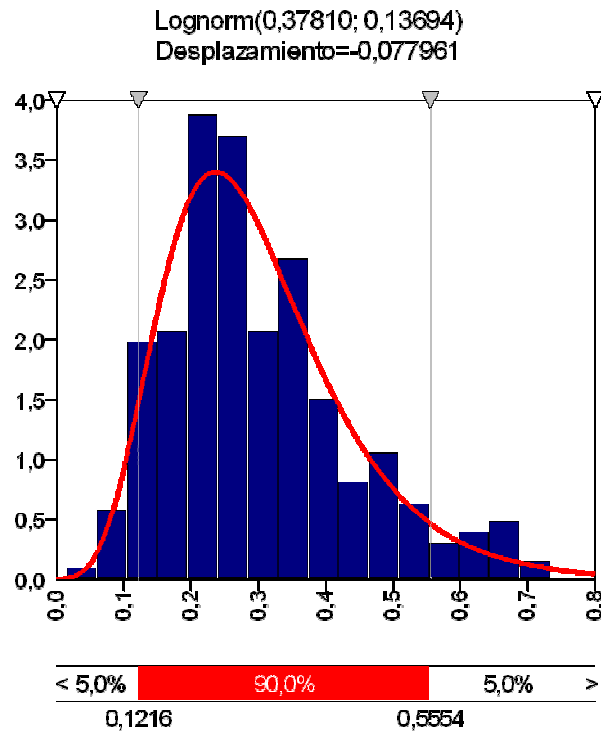


| | Real |
|--------------------|--------|
| Minimum | 0,02 |
| Maximum | 10,22 |
| Mean | 3,49 |
| Standard deviation | 2,61 |
| Dispersion | 74,64% |
| Mode | 1,35 |
| Median | 2,87 |



This plot indicates that the waiting time for unloading appears to *follow a triangular distribution*, with a **minimum** of 0,02 hrs, a **maximum** of 10,22 hrs. and a **mode** of 1,35 hrs.

1.3.4 Unloading time

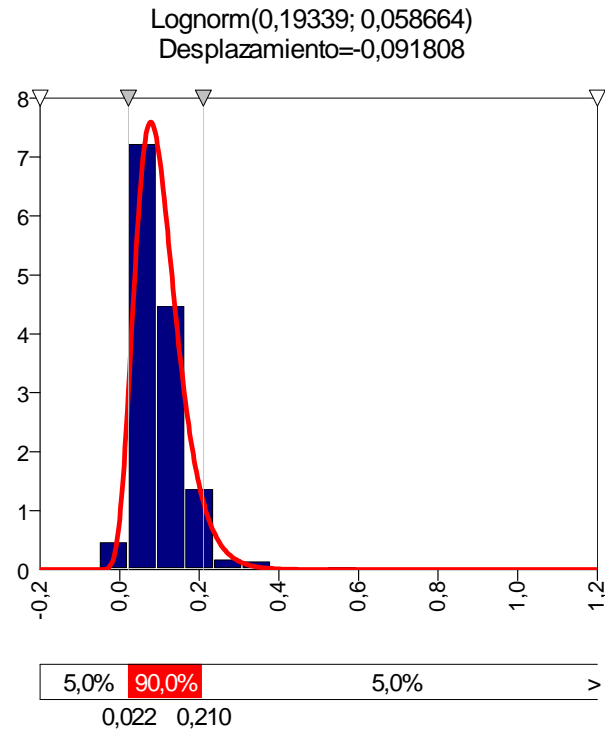


| | Real |
|--------------------|--------|
| Minimum | 0,02 |
| Maximum | 0,73 |
| Mean | 0,3 |
| Standard deviation | 0,14 |
| Dispersion | 45,20% |
| Mode | 0,22 |
| Median | 0,27 |



Unloading time follows a lognormal distribution, it has mean 0,3 hrs and a standard deviation of 0,14 hrs.

1.3.5 Waiting time for departure

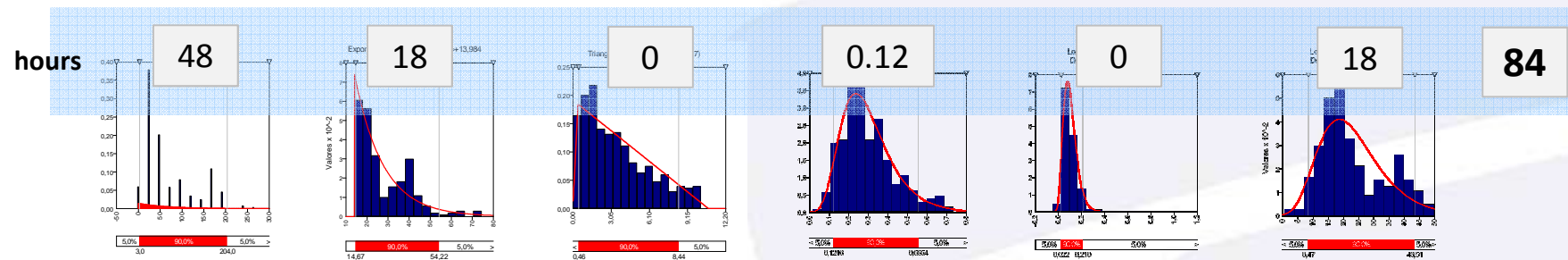
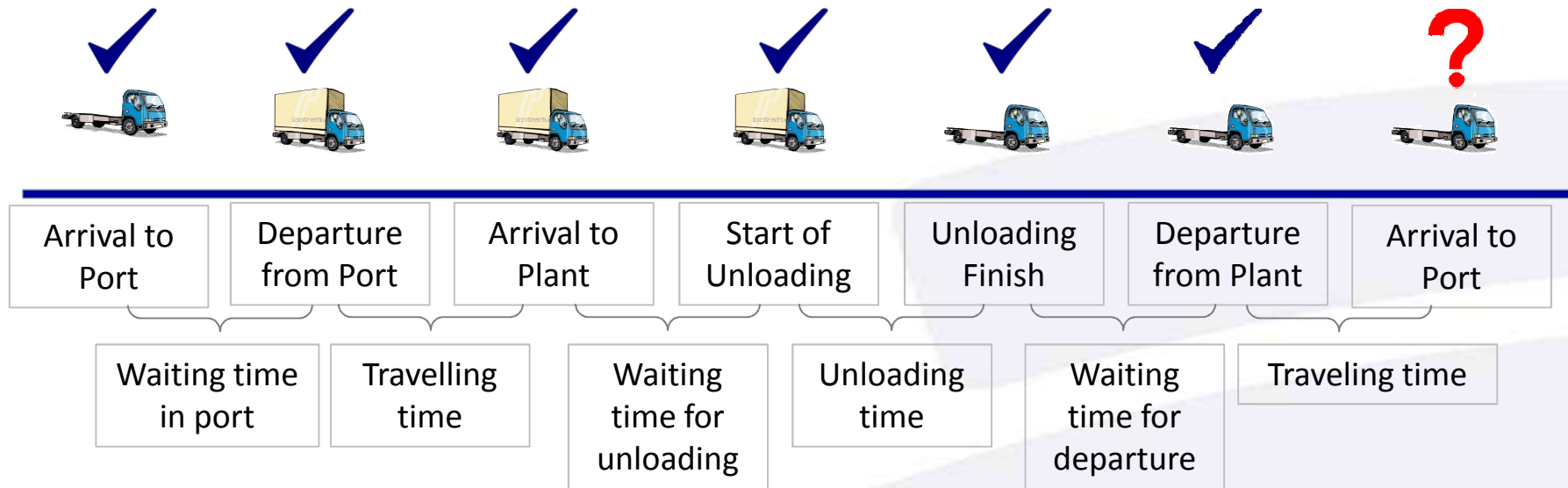


| | Real |
|--------------------|--------|
| Minimum | -0,05 |
| Maximum | 1,1 |
| Mean | 0,1 |
| Standard deviation | 0,07 |
| Dispersion | 72,30% |
| Mode | 0,08 |
| Median | 0,08 |



The waiting time for departure is described with a lognormal distribution. It has **mean** 0,1 hrs and a **standard deviation** 0,07 hrs.

2nd Option: To model each component of the total cycle.

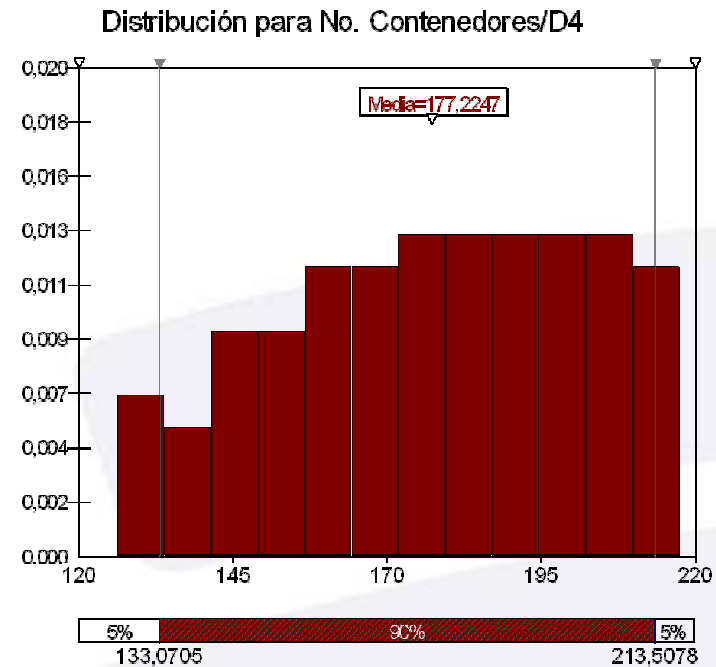


No deterministic round-trip time

Round-trips per month, no deterministic

| Semana | No. Contenedores |
|----------------------|------------------|
| 4 | 21 |
| 5 | 218 |
| 6 | 125 |
| 7 | 199 |
| 8 | 214 |
| Total general | 777 |

| | |
|--------------------|-------|
| Average | 189 |
| Standard deviation | 43,4 |
| Dispersion | 23,0% |
| Left truncated | 125 |
| Right truncated | 218 |

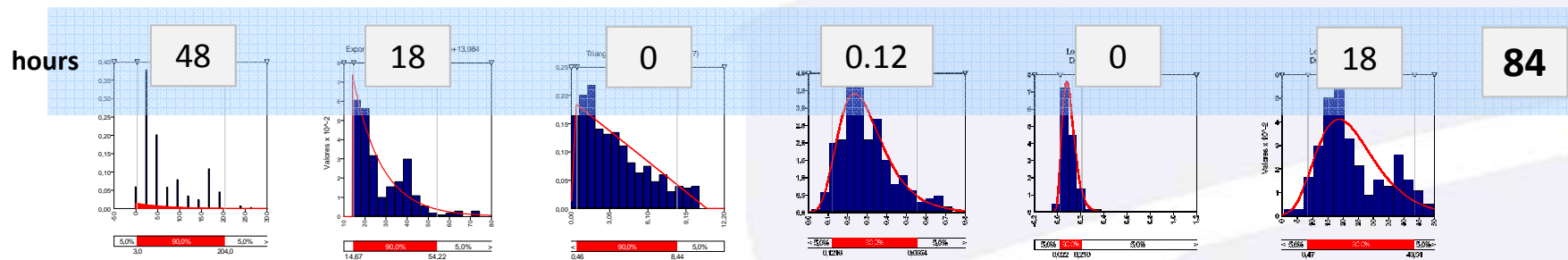
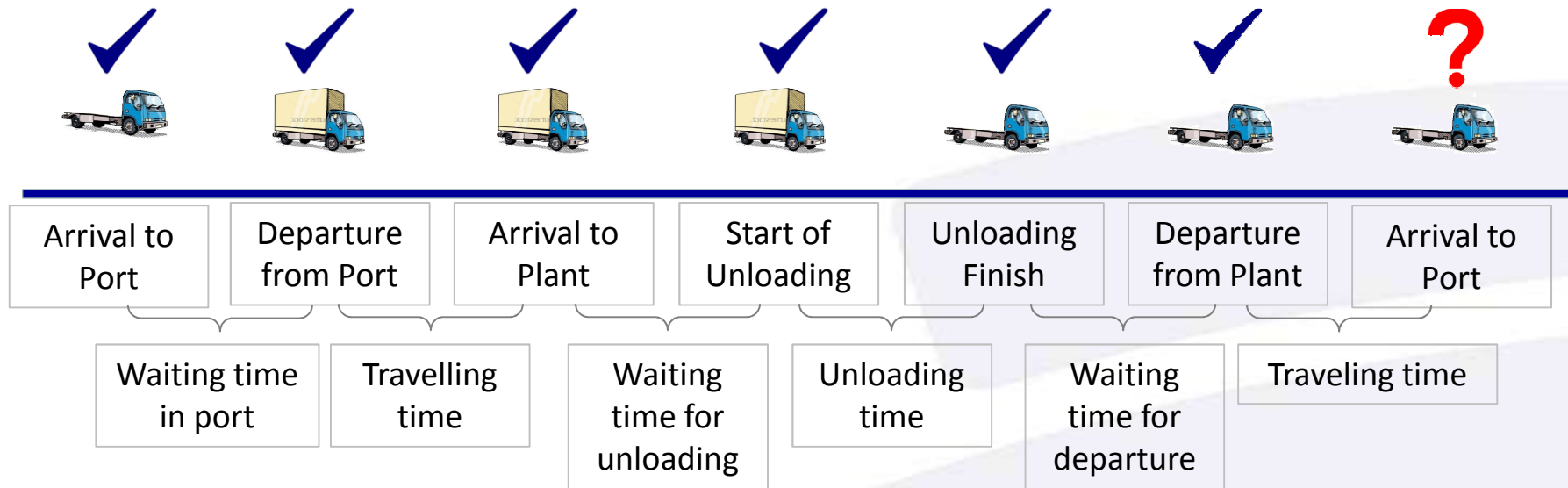


There is not enough data to have significant results and to use a probability distribution.

It was agreed with the client to use a truncated normal distribution.

1.4. Output variables

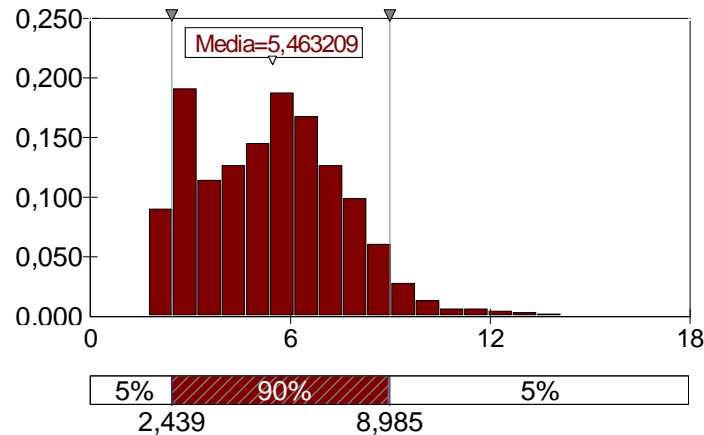
2nd Option: To model each component of the total cycle.



No deterministic round-trip time
Round-trips per month, no deterministic

1.4.1. Round trip time and cycles per month

Distribución para Viajes / mes / veh
//E17



| | Cycles/month |
|--------------------|--------------|
| Minimum | 1,76 |
| Maximum | 17,06 |
| Mean | 5,46 |
| Standard deviation | 2,19 |
| Dispersion | 40,10% |

On average a vehicle makes 5.4 cycles / month, with a spread of 40.1% (ie., 96% of months a truck makes between 1 and 9 cycles).

High dispersion, can be corrected by changes on input variables (policies)

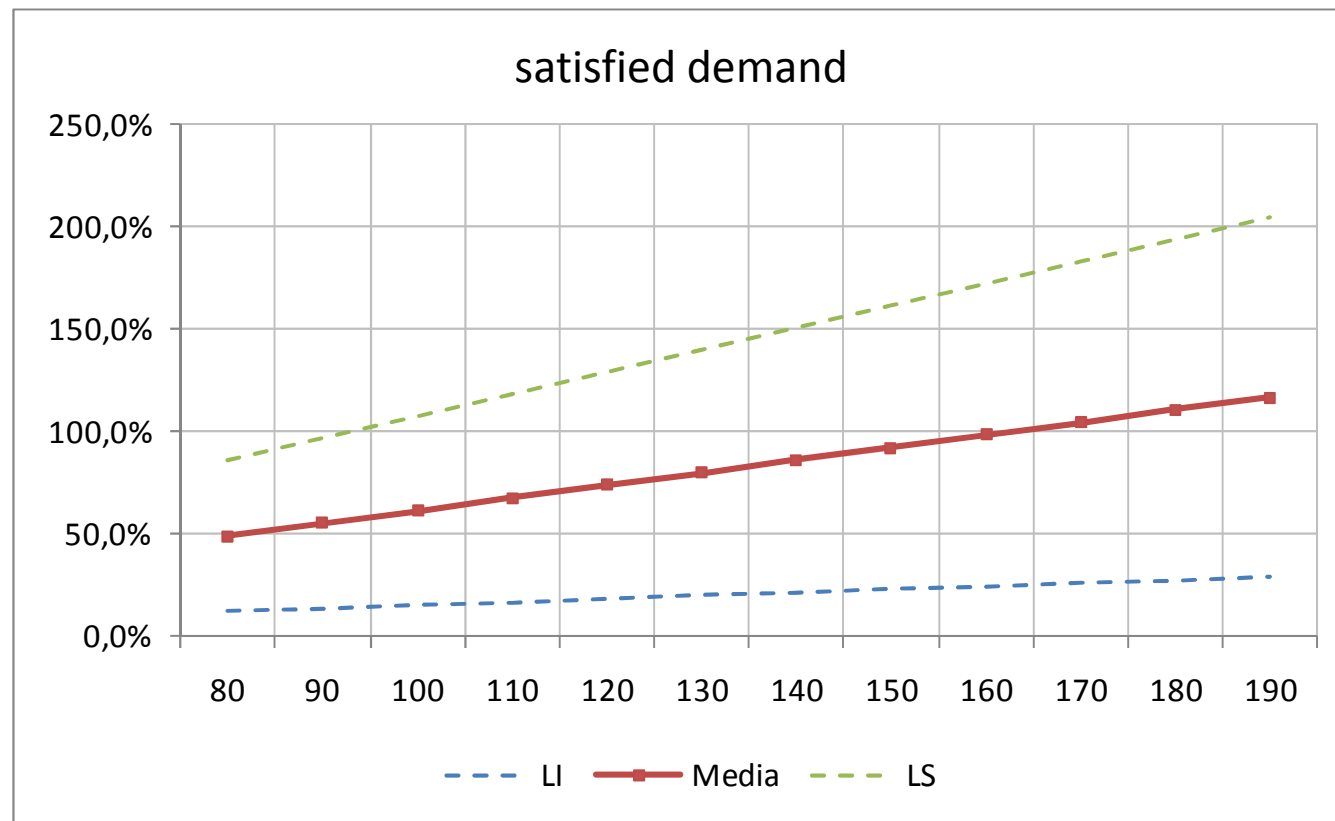
Deterministic data: 7.4 cycles / month

1.4.2 Satisfied demand

The next table shows the satisfied demand for each level of trucks. It has to be considered not only the satisfied demand mean, but also the standard deviation.

| Number of units | Minimum | Maximum | Mean | Standard deviation |
|-----------------|---------|---------|---------|--------------------|
| 80 | 16% | 133,70% | 49,20% | 18,50% |
| 90 | 18% | 150,40% | 55,40% | 20,80% |
| 100 | 20% | 167,10% | 61,50% | 23,10% |
| 110 | 22% | 183,80% | 67,70% | 25,40% |
| 120 | 24% | 200,50% | 73,90% | 27,80% |
| 130 | 26% | 217,30% | 80,00% | 30,10% |
| 140 | 28% | 234,00% | 86,20% | 32,40% |
| 150 | 30% | 250,70% | 92,30% | 34,70% |
| 160 | 32% | 267,40% | 98,50% | 37,00% |
| 170 | 34% | 284,10% | 104,60% | 39,30% |
| 180 | 36% | 300,80% | 110,80% | 41,60% |
| 190 | 38% | 317,50% | 116,90% | 43,90% |

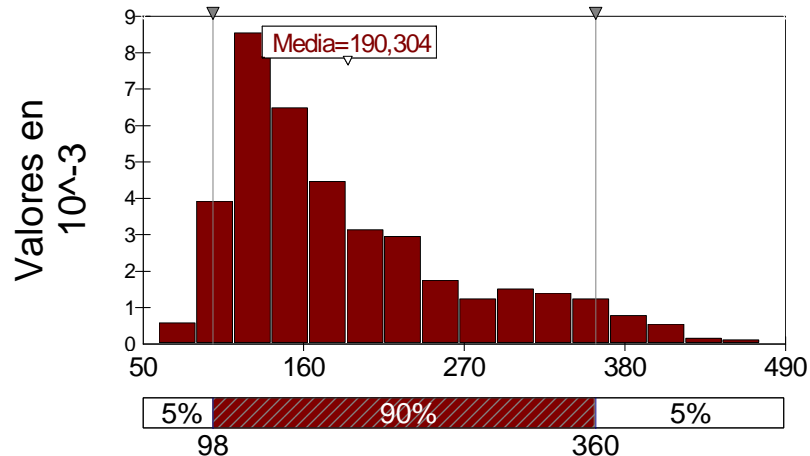
1.4.2 Satisfied demand



UL and LL +/- 2 standard deviations

1.4.3 Fleet size required

Distribución para No. Vehículos necesarios/E20 (Sim núm11)



| | Necessary vehicles |
|--------------------|--------------------|
| Minimum | 61 |
| Maximum | 473 |
| Mean | 190 |
| Standard deviation | 82 |
| Dispersion | 43,20% |

On average, **170 trucks** are required to meet trip demand for containers (mean >100%) , with a 43.2% dispersion

High dispersion, can be corrected by changes on input variables (policies)

Deterministic data: 135 trucks

2. Costing

2.1. Current Cost

The regulated current cost for a round – trip in the route Plant – Port – Plant is **U\$ 2,800.**



- For the costing, 3 different truck brands were considered using an operational lease alternative.
- The lease fee includes also operational expenses (maintenance, insurance, registration, and others)
- Additional costs as driver, fuel and other expenses not included in the operational lease were also considered.

2.2 Costing results

| | Cost / cycle |
|----|--------------|
| 2 | 4.768 |
| 3 | 3.515 |
| 5 | 2.512 |
| 6 | 2.261 |
| 7 | 2.082 |
| 8 | 1.948 |
| 9 | 1.843 |
| 10 | 1.760 |
| 11 | 1.691 |
| 12 | 1.635 |

If an owned truck can make just 2 cycles during a month, then the cost of each cycle will be U\$4,768.

If the truck can make 10 cycles, then the cost of each cycle will be U\$ 1,635

- Historical data shows that the times in the cycle, are not deterministic and therefore should not be treated as such to make decisions.
- The fleet size will depend on the level of demand that wants to be met, and considering that demand is variable, it has to be considered that for a determined level of owned trucks some of them may not be used 100% of the time.
- The decision of owning a fleet or part of it, has to be compared with a third party logistic provider cost, and when comparing economic benefits, it has to take into consideration all the expenses involved.
- The cost per round-trip in an owned fleet will decrease if the number of cycles increase.
- Results are highly sensitive to changes in times of the cycles, and some variables that affect it can be controlled and improved by the company.

- To improve or collect more data in order to redefine the probability distribution used.
- To define policies in order to truncate probability distribution.
- To consider demand forecasts.
- To evaluate policies that allow to increase the number of round-trips per month, and to cost again under these policies.
- To explore and evaluate different alternatives of owning such as credit, renting, leasing or own capital.

Thanks for your attention

A decorative graphic on the right side of the slide consists of three overlapping, rounded rectangular shapes in a light blue color, arranged in a diagonal pattern from top-right to bottom-left.

Model to determine optimal fleet size in a cargo truck operation using @Risk

By: David Osorio

✉ dosorio@rentingcolombia.com

www.rentingcolombia.com

October 2010