

# Dynamics of Transportation Economics

Maximo Claudio Flores-Cabezas, Master of Science<sup>1</sup>

<sup>1</sup>Universidad Privada del Norte, Perú, [maximo.flores@upn.edu.pe](mailto:maximo.flores@upn.edu.pe)

<sup>2</sup>Desiree Diane Flores-Moya, Peru, [u21102419@utp.edu.pe](mailto:u21102419@utp.edu.pe)

*Abstract– The purpose of this research was to show the metaphorphosis of a transportation service organization paralyzed by the lack of innovative policies to face the changes in the environment, customers and competitors. Its objective is to develop, through System Dynamics (SD), qualitative and quantitative scenario models, identifying the economic variables: auxiliary, flow and level, which affect the development of the organization; and using the concepts of economy of scale, economy of distance (to determine the costs and profits for the vehicle rental service and for the freight service for a given distance respectively); and economy of scope, as an evaluation factor in the execution of the two types of services. This study was carried out empirically and deductively, by means of field work, collecting information through the follow-up of the units as well as formal and informal meetings. The result of the research allowed determining and validating quantitatively that it is advisable for the organization to break its paradigm of performing only one type of service and to adapt to performing the two types of services or business in parallel, since it has an economic scope of 4.16% and a profit of \$ 33.2 per day for the service of vehicle use.*

*Keywords– System Dynamics, Road Transportation, Economy of Scale, Economy of Distance and Economy of Scope.*

## I. INTRODUCTION

This research was carried out in a company XXX, which started with 5 heavy vehicles of two axles, offering a rental service. Later, it increased the number of vehicles to 20. Due to the uncertainty of the demand, it opted to provide freight service. Just like the previous service, it presented discontinuity in the demand and began to offer the two services according to the demand and the availability of the vehicles.

Automotive freight transport in Latin America is responsible for the mobilization of more than 70% of the national freight in the region [1]. The use of means of transport and the improvements in their systems seek to expand accessibility, connectivity and trafficability, increasing the strength of the economy of the agglomeration, generating positive effects on the production function of the companies that exploit these assets.

The organization realized that transportation has become a strategic industry for an open and globalized economy, and that offering a better service would increase its profitability, expand its level of assets and scope of action, and that the future of transportation is marked by its technological evolution.

The use of vehicles as a means of transportation continues to contribute to the development of geographic spaces, since it is a basic tool to increase the productivity of the organization

and productive sectors, increasing the population and also its income, as the need to provide and distribute resources grows [2, 3, 4], connecting consumers and producers, developing and enhancing productive specialization and consumer access to an increasing variety of products of higher quality. In this way, the organization provides transportation services, boosting social economies, aiming for equity and helping their connectivity and growth.

The city is a complex and constantly changing system due to the exchange of products and services, and to meet the needs of the population, the organization needs to satisfy the daily mobility needs [5, 6]. To this end, 20 vehicles are available for rental and/or freight transportation services.

The company contributes to the development of communities by capitalizing on the placement of these assets for rental and freight transportation services, moving from a point of origin to a point of destination, and it does so in order to meet the demand [7] derived from the needs of customers and the availability of the road. The greater the demand and development of road infrastructures, the organizations in this sector will increase their investment in the use of vehicles as the main asset and this will create productive markets, increasingly expanding their geographic area [8] due to network and agglomeration economy.

The organization considers both a qualitative and quantitative transport network in a given geographical area to be a requisite for access to economic and service activities [9]. Transport costs are also important for services related to goods, such as retail and wholesale trade (according to WTO estimates, they represent 19% of total trade costs [10] and the World Bank has estimated regional logistics costs at between 16% and 26% of GDP [11]), as well as road infrastructure, which are all civil works such as tracks, intersections, stops, roundabouts or traffic circles, etc.

Organizations in this sector consider that the importance of using transportation as a service is to make people arrive at their destination in the most efficient way, at the lowest possible cost and in the shortest possible time. This contributes to lower product prices and make business in the geographical area more attractive.

Identifying the type of freight to be transported, the distance to be traveled, travel time, and the costs of the resources to be used in order to obtain a higher economic profitability for their investment, is one of the functions of the decision-makers. The longer the time of use of the vehicle(s) or the distances traveled between the point of origin and the point of destination, the higher the price of the service and its profitability [12]. To this end, it is important to identify the costs incurred by the use of productive resources in the use of vehicles. The lack of knowledge and reaction on the part of the

**Digital Object Identifier (DOI):**

<http://dx.doi.org/10.18687/LACCEI2022.1.1.202>

ISBN: 978-628-95207-0-5 ISSN: 2414-6390

organization to manage resources and determine costs and prices quickly and accurately were the factors that contributed to the generation of economic losses due to inadequate decisions.

The manager of the organization had to look for mechanisms that would simultaneously improve operating conditions, satisfy customers with their high expectations and lack of patience (they are no longer satisfied only with obtaining a quality service), and the other actors in the system [13]. What was required was to make use of strategies such as the consolidation of merchandise to optimize the size of consignments, the reduction of distances traveled, the reduction of the assignment in the use of the necessary vehicles, as well as the generation of agile processes to reduce the response times required to carry out transport operations and attend to customers, among other strategies.

The efficient use of this resource allows to reduce costs and increase profitability, but it was not done properly because the organization did not identify the relevant decision factors for good management, such as efficiency, safety, precision, speed of delivery and, among the resources, the use and control of fuel, maintenance and the driver, among others.

A non-continuous demand, the emergence of competition with new technologies in their vehicles has forced the organization to innovate and recognize that, at this time, it is essential to have the gift of ubiquity, which incites to take risks and explore new formulas that allow to make quick decisions on the effective use of resources, in order to reduce costs to satisfy the customers and bring them closer to our services.

This article allowed the organization of this sector, by means of scenario models, to determine and compare the costs and profitability associated with the assignment of the vehicle(s) for the transportation service and/or the distance traveled for the freight service.

#### A. Statement of the Problem

Due to a non-continuous demand for vehicle rental, increased competition with new technologies in their vehicles, the increase in the construction of road infrastructure by the state, the increase in requests for freight transportation, and providing only one rental service with their vehicles, the organization watched helplessly how their business was collapsing. Faced with this situation, decision makers needed to answer the following questions:

Can the organization develop a disruptive change when faced with the threat of core activities that have historically generated profits?

Is the organization integrated enough to grow a new line of business or provide both types of services or lines of business in parallel?

What indicator will allow the organization to determine if the increase in business lines is feasible and how will the resources used be identified and quantitatively determined?

How will the organization determine the most competitive costs, profit and price, and will it be quick and accurate for the customer?

What are the attributes that determine the value of the company due to the paradigm changes that should be made by the organization?

#### B. Objective

It is to show how the organization learned to take advantage of its strengths, recognizing its three attributes: effectiveness in the economic results through control and measurement, the attractiveness of the company that allowed professional growth, and the satisfaction of employees and the unity of the organization through the identification of employees with respect to the objectives. This boosted the capacities by devising an economic simulation model that emphasizes the organization's criteria at the time of decision making in order to face uncertainty and for the organization to increase its knowledge during change processes.

#### C. Hypothesis

Trying more of the same in difficult times is the wrong way. Organizations must move towards a radical change as well as be disciplined in the process. Genuine transformations require leaders to define and communicate what they are looking for with them and to be skilled at starting the engine of change: the flow of energy and ideas that will propel the organization towards the desired goal, which is to undertake strategic and organizational initiatives at the same time, to implement any innovation and to support its development.

## II. METHODOLOGY

This article corresponds to an empirical and applied research. The collection of information was carried out through formal interviews previously scheduled through meetings, and the informal interviews were developed through visits and tours made with the vehicles at each point of destination. The processing and analysis of the information was carried out by using the concepts of Economy of Scale, Economy of Distance, Economy of Scope and System Dynamics as tools for the development of scenario models, such as causal diagrams and flow charts.

In order to understand this research, the following concepts were developed:

#### A. Economy of Scale

The application of the economy of scale is long-term and represents an advantage in the reduction of unit costs. Companies reduce their costs as they expand. In other words, the more a company produces or provides a service, the lower the cost for the company to make a product or provide a service. Economies of scale are the impact that production has on average cost structures when all inputs increase in the same proportion [14], but not their fixed costs. The applicability in the transportation sector is developed through the increase in the number of vehicles used for a given time, with the objective of generating lower unit costs, as shown in the following equation (1) and in Figure 1.

$$\text{Unit Cost} = \frac{\text{FixedCost} + \text{UnitVariableCost} * \#\text{Vehicles}}{\#\text{vehicles}} \quad (1)$$

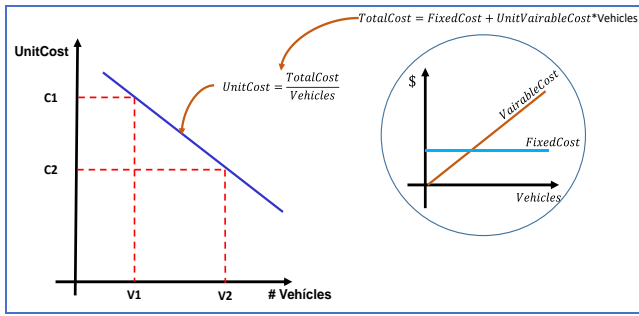


Figure 1: Cost Behavior in Vehicle Use.

The use of the number of vehicles for a given period of time is directly proportional to the unit variable cost, but not to the fixed cost, since the latter is added and tends to decrease. Fixed costs are those that have no direct relationship with the quantities produced and remain constant throughout the production period, and variable costs are those that are in direct relationship with the quantities produced [15].

Variable costs are considered to be all costs incurred in order for the vehicle to be operational. The greater the number of vehicles used for the service, the higher the variable costs, but the fixed cost remains constant over time, see equation 2.

$$\text{Total Costs} = \text{Fixed Costs} + \text{Unit Variable Cost} * \text{Vehicles Used} \quad (2)$$

### B. Economy of Distance

Vehicles travel distances to transport freight from the point of origin to the point of destination. The greater the distance traveled, the higher the cost of fuel used. As a result of the distance traveled, the vehicle is subject to wear and tear, and, therefore, requires maintenance. The driver, the main asset in this type of service, is the one who drives the vehicle. These three resources are important for the operation of the vehicle and are considered variable costs.

$$\text{Total Costs} = \text{Fixed Costs} + \text{Unit Variable Cost} * \text{Distance Traveled} \quad (3)$$

Fixed costs remain constant over time. The longer the distance traveled, the lower the unit cost, since the distance is inversely proportional to the total cost as shown in Figure 2.

$$\text{Unit Cost} = \frac{\text{FixedCost} + \text{UnitVariableCost} * \text{Distance}}{\text{Distance}}$$

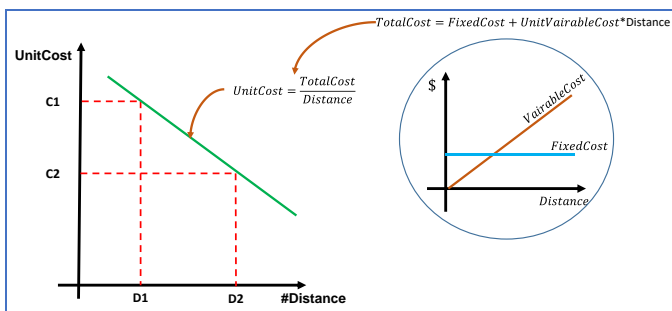


Figure 2: Cost Behavior by Distance traveled by the vehicle(s).

### C. Economy of Scope

The organization, due to the threat of competitors, increase of road infrastructure and the increase of companies requesting transportation of their goods, began to expand its scope with two types of services or line of business in parallel, either by the request of loading to a certain distance and/or by the rental of vehicle(s). The objective was the maximum use of assets, i.e. not to keep the vehicles parked without providing any type of service, since it is a loss for the organization. In this way it increases its productivity through use.

The following formula was used to determine, by economy of scope, if it is beneficial for the company to have two lines of business:

D: Distance traveled by the vehicle

V: Number of vehicles assigned for rent

$$\text{CostScope}(D, V) = \frac{\text{Cost } D + \text{Cost } V - \text{Cost}(D, V)}{\text{Cost}(D, V)}$$

$$\text{CostScope}(D, V) = \frac{\text{FixedCost}}{\text{FixedCost} + \text{Unit.VariableCost} * D + \text{Unit.VariableCost} * V} \dots$$

If:

CostScope(D,V)>0, there is economy of scope

CostScope(D,V)<0, there is diseconomy of scope

CostScope(D,V)=0, there is no economy of scope, nor is there diseconomy of scope

Figure 3 shows the behavior of fixed and variable costs for each service, as well as unit costs. As the line of business or service increases, the fixed cost remains constant; only the variable cost varies according to the service provided. The unit cost shows a downward trend, which allows for an increase in profit.

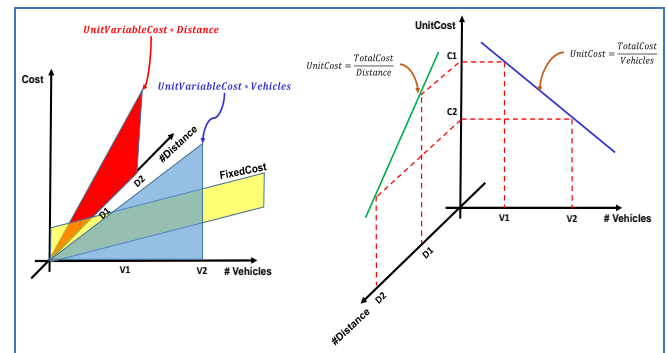


Figure 3: Cost Behavior

### D. System Dynamics

Within the concept of System Dynamics the following can be pointed out:

- It is a tool that allows to represent any type of flow, and it does so by connecting and interrelating the variables represented by edges [16, 17, 18, 19].
- Its field of application is the strategic analysis to evaluate the impact of manufacturing processes [20, 21, 22].
- System Dynamics SD is a computer technique for dynamic modeling of systems or processes, in which a real process is imitated as it advances in time. The operation of a real system is represented as a sequence of discrete events occurring over a period of time [23].

For an effective decision making, the organization must visualize at a macro level all the resources used for the services provided, and determine the level of cost behavior and its profitability, product of its services in a quantitative way. To do this, it must develop visual thinking that communicates ideas, patterns and concepts visually through images and diagrams, so that the relationship between the idea and its representation can be identified. For its application, the organization collected information on the activities it carried out and the resources it used. A causal diagram was elaborated to visually identify the variables and establish the relationships between them, in order to determine the effects produced at economic level.

The software used for the development of scenario models was Vensim, which facilitated the construction of causal diagrams and flow charts, allowed simulations and predictions

through quantitative values for each type of service or both, assigning a certain number of vehicles for each one of them. It shows graphically the behavior of the variables exposed therein. The software has an equation editor that helps to define the equations of the model, performing simulation by changing parameters or constants for multiple variables, and also allows the use of functions and macros.

### E. Causal Diagram

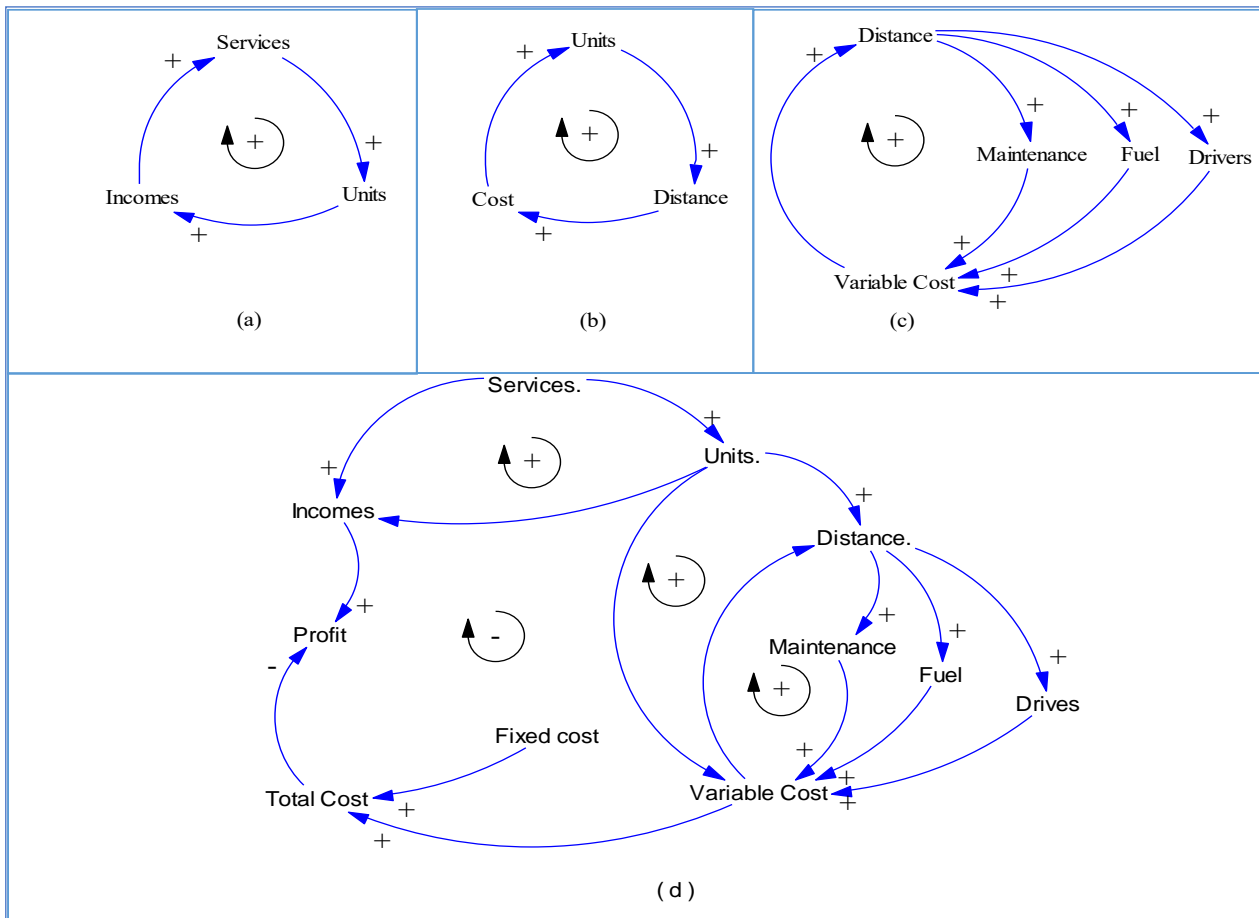
It is a diagram that collects the key variables of a system, which are then linked by arrows to know their directionality and effect, which can be direct, when it has a positive sign and inverse when the sign is negative, being more specific if the variables tend to increase or decrease. The preceding variable will also present an increase or decrease (+ sign). If the variable presents a decrease or increase, the variable that precedes it will present the opposite effect, i.e. its respective increase or decrease (- sign).

Figure 4 shows the causal diagram which is made up of 4 loops and each loop is made up of variables in which the cause-and-effect relationships between them are identified.

Table (a) shows that the greater the number of transportation services requested by the customers, the greater the number of vehicles required and, consequently, the higher the income for the service provided.

In table (b), the greater the use of vehicles, the longer the distance traveled and the higher the cost.

Table (c) shows that the longer the distance traveled by the vehicles, the higher the fuel consumption, the higher the



maintenance cost and the longer the time spent by the driver.

Table (d) is the union of the above charts. It shows that the greater the number of services, the higher the income and profits. Variable costs will increase due to the above-mentioned resources, but fixed costs will remain constant.

and the interrelation between costs, income and profit for the use of the vehicle(s) for the service provided, as well as the determination of its economy of scale, economy of distance and economy of scope.

Figure 5 (a) shows 16 auxiliary variables, 4 flow variables,

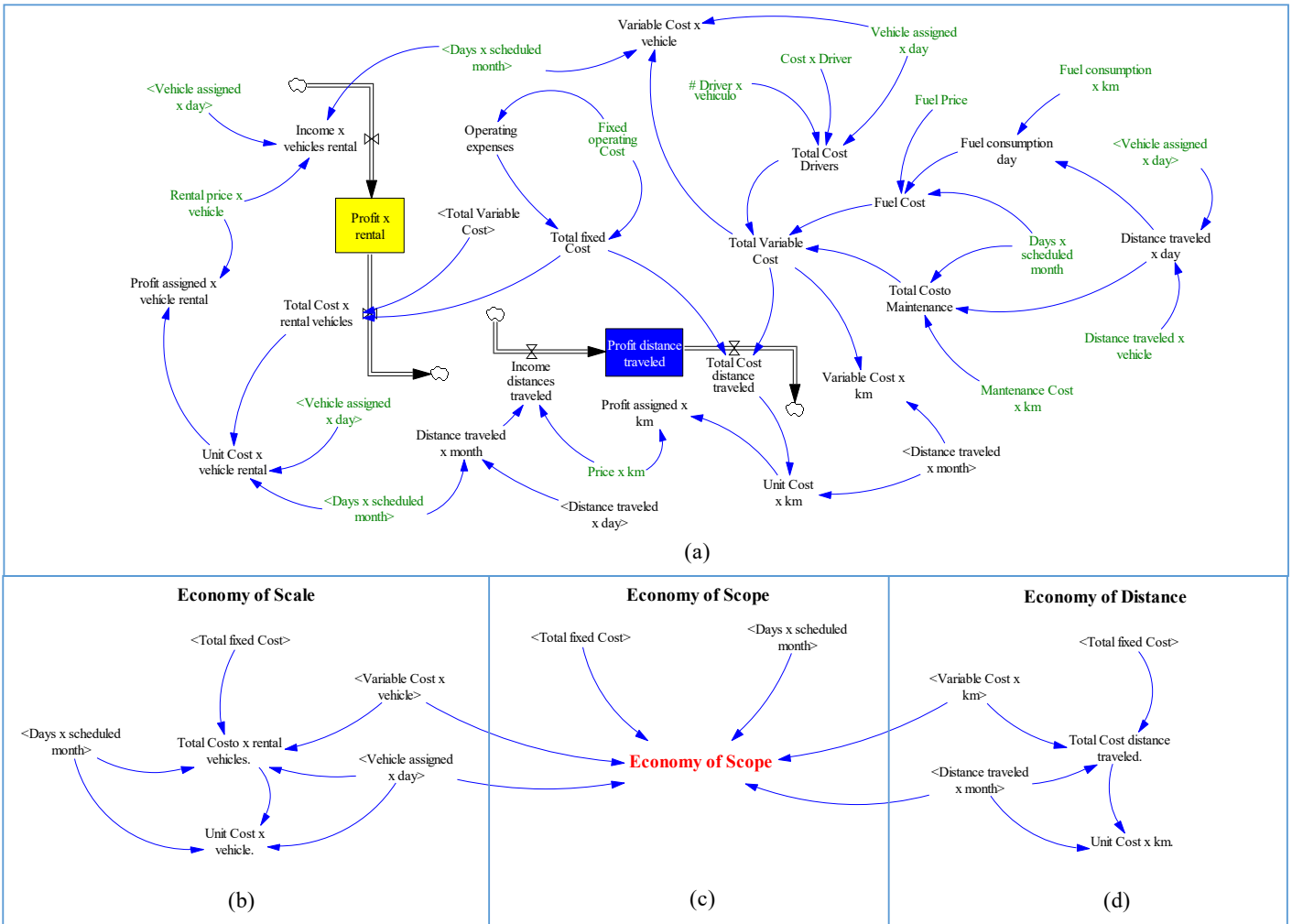


Figure 5: Flowchart

2 level variables and 11 parameters or constants as initial conditions. Table 1 shows the initial conditions.

Table 1: Initial conditions taken into consideration for this study.

Variable	Initial	Final	Step
Time (month)	0	12	1

For the characterization of the model in figure 5(a), the input data, considered in the flow chart as parameters or constants and represented with green colored text, were taken into consideration. See the following table.

Table 2: Parameters or constants used as input in the model.

Distance traveled x	120	Kilometers/vehicle
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#### F. Flow chart

It is a diagram that is constituted by level variables, flow variables, auxiliary variables and coefficients or parameters, (figure 5), being level variables those that define the behavior of the system and it is identified by a box [24]. Flow variables are those that are located on the sides of level variables, which determines the change of the level variable at a certain period of time, and this is affected by auxiliary variables or parameters. And, auxiliary variables are intermediate variables that receive information from other variables or parameters.

#### G. Mathematical Formulation

The flow chart in Figure 5 is divided into 4 flows (a, b, c and d), where Figure 5a shows the interrelation between costs, income and profit for the distance traveled by the vehicle(s)

vehicle		
Fuel consumption x km	0.10	gallon/kilometers
Fuel Price	3.125	\$/gallon
Maintenance Cost x km	0.0625	\$/kilometers
Cost x Driver	400	\$/ (driver*month)
Fixed operating Cost	1300	\$/month
Price x km	0.825	\$/ kilometers
Rental price x vehicle	99.442	\$/vehicle
# Driver x vehiculo	1	driver*day / vehicle

For the simulation the following values were used:

Vehicle assigned x day: from 1 to 20

And the scheduled working days per month are presented in table 3.

Table 3: Parameters or constants used as input in the model.

Month	Scheduled Days (days / month)
1	26
2	24
3	26
4	24
5	26
6	24
7	26
8	26
9	25
10	27
11	25
12	25

Formulating the income, costs and profit in Figure 5 (a) to determine quantitatively for each period, and, cumulatively, the level flow variable "Profit per distance traveled" is as follows:

$$\frac{ProfitDistanceTraveled(d + \Delta d) - ProfitDistanceTraveled(d)}{\Delta d} = ProfitDistanceTraveled$$

$$\lim_{\Delta d \rightarrow 0} \frac{ProfitDistanceTraveled(d + \Delta d) - ProfitDistanceTraveled(d)}{\Delta d} = ProfitDistanceTraveled$$

$$\int_0^d \frac{dProfitDistanceTraveled}{ProfitDistanceTraveled} = \int_0^d \Delta d$$

$$\ln(ProfitDistanceTraveled) = k * d + C$$

$$ProfitDistanceTraveled = C e^{k*d}$$

If,  $d = 0$

$$ProfitDistanceTraveled(d) = C$$

$$ProfitDistanceTraveled = ProfitDistanceTraveled(d) e^{k*d}$$

$$ProfitDistanceTraveled(d) = ProfitDistanceTraveled * e^{-k*d}$$

Where  $\rightarrow k = \text{constant}, d = \text{distance}$

$$ProfitDistanceTraveled(d) = (IncomeDistancesTraveled - TotalCostDistanceTraveled) * e^{-k*d}$$

$$ProfitDistanceTraveled(d) = (PriceKm * DistanceTraveledxMonth - (TotalFixedCost + TotalVariableCost)) * e^{-k*d} \quad (5)$$

And formulating the income, costs and profit from the use of vehicles, in Figure 5 (a), to determine quantitatively for each period and, cumulatively, the level flow variable "Profit from the rental of vehicles", is as follows:

$$ProfitxVehicleRental(v + \Delta v) = ProfitxVehicleRental(v) + (IncomexVehiclesRental - TotalCostxRentalVehicles)\Delta v$$

$$ProfitxVehicleRental(v + \Delta v) - ProfitxVehicleRental(v) = (IncomexVehiclesRental - TotalCostxRentalVehicles)\Delta v$$

$$\frac{ProfitxVehicleRental(v + \Delta v) - ProfitxVehicleRental(v)}{\Delta v} = ProfitxVehicleRental$$

$$\lim_{\Delta v \rightarrow 0} \frac{ProfitxVehicleRental(v + \Delta v) - ProfitxVehicleRental(v)}{\Delta v} = ProfitxVehicleRental$$

$$\frac{dProfitxVehicleRental}{dv} = ProfitxVehicleRental$$

$$\int_0^v \frac{dProfitxVehicleRental}{ProfitxVehicleRental} = \int_0^v \Delta v$$

$$\ln(ProfitxVehicleRental) = k * v + C$$

$$ProfitxVehicleRental = C e^{k*v}$$

If,  $v = 0$

$$ProfitxVehicleRental(v) = C$$

$$ProfitxVehicleRental = ProfitxVehicleRental(v) e^{k*v}$$

$$ProfitxVehicleRental(v) = ProfitxVehicleRental * e^{-k*v}$$

$$ProfitxVehicleRental(v) = (IncomexVehiclesRental - TotalCostxRentalVehicles) * e^{-k*v}$$

Where  $\rightarrow k = \text{Constant}, v = \# \text{ vehicles}$

$$ProfitxVehicleRental(v) = (VehicleAssignedxDay * RentalPricexVehicle * DaysxScheduledMonth - (TotalFixedCost + TotalVariableCost)) * e^{-k*v}$$

Considering the variables immersed in the flow chart in Figure 5, the following is summarized:

- Unit costs through the economy of scale for the use of vehicles for the freight transportation service (figure 5 (b)).

Replacing equation (2) with the chart variables.

$$TotalFixedCost + VariableCostxVehicle(v) * VehicleAssignedxDay * DaysxScheduledMonth = TotalCostxRentalVehicles(v)$$

$$UnitCostxVehicleRental(v) = \frac{TotalCostxRentalVehicles(v)}{VehicleAssignedxDay * DaysxScheduledMonth} \quad (7)$$

- In Figure 5 (c), in order to determine the economy of scope and profitability, quantitative values for the two types of services, i.e. for freight transportation over a given distance and for vehicle rental per day, were taken into consideration for the simulation. The constants were as follows:

# Vehicle assigned x day	1 - 20	vehicle/day
# Distance traveled x	50-	kilometers/day

vehicle	250	
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To determine the economy of scope, the total variable costs for each type of business are found:

$$TotVariabCostDistanceTravel = VariableCostxKm * DistanceTraveledxMonth \quad (8)$$

$$TotalVariabCostRentallVehic = VariableCostxVehicle * VehicleAssignedxDay * DaysxScheduledMonth \quad (9)$$

From (8) and (9) into (1)

$$EconomyScope = \frac{TotalFixedCost}{(TotalFixedCost + TotVariabCostDistanceTravel + TotVariabCostRentallVehic)}$$

- The unit costs for distance economy based on the distance traveled by the vehicle(s) for the freight transportation service (figure 5 (d)).

Replacing equation (3) with the variables of the chart.

$$TotalFixedCost + VariableCostxKm(d) * DistanceTraveledxMonth = TotalCostDistanceTraveled.(d)$$

$$UnitCostxKm.(d) = \frac{TotalCostDistanceTraveled .(d)}{Distanc eTraveledxMont h} \quad (8)$$

### III. RESULTS

When the model or flow chart is tested, it is observed that the result obtained has the potential to define the dynamics that considers both learning and decision making at the organizational level. The initial conditions according to Table 1 for this flow chart were made for twelve months and the level of response was monthly.

By simulating an organization that only rents 5, 10 and 20 vehicles, with a fixed cost of \$ 1339 per month that remains constant for the whole period, its unit costs tend to decrease: \$ 71.39, \$ 66.10 and \$ 63.46, respectively. Figure 6 shows the behavior of costs for the rental of 10 vehicles.

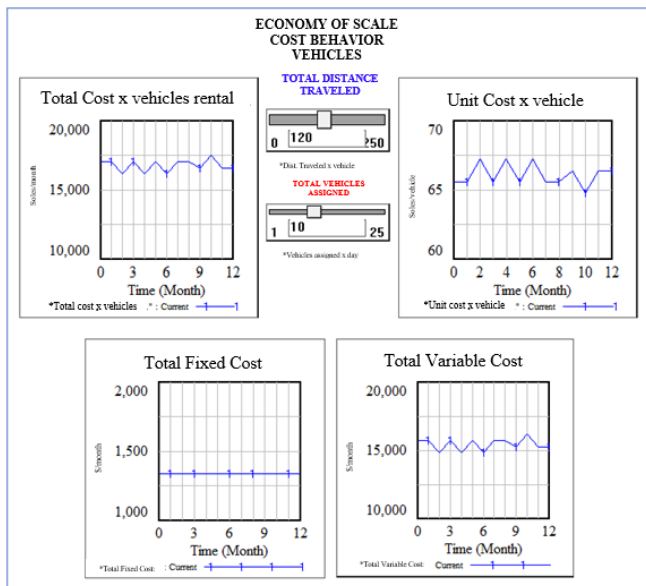


Figure 6: Behavior of costs for the rental of vehicles

If the organization only offers the freight service, taking the distance it travels as a direct variable, the simulation was done for the use of 10 vehicles and for a distance of 100, 150 and 200 kilometers per day, with a fixed cost of \$ 1339 per month.

The unit costs show a downward trend of \$ 0.589, \$ 0.517 and \$ 0.482.

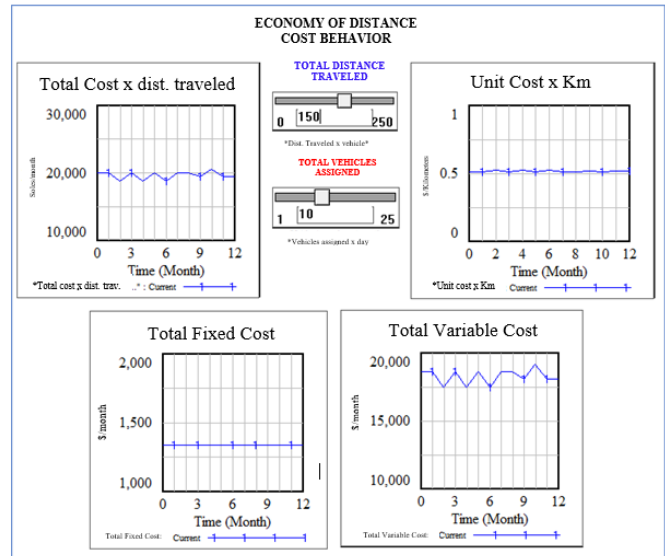


Figure 7: Behavior of unit costs, total costs and assigned vehicles.

If the company makes the decision to offer the two types of services or lines of business, assigning 5 vehicles per month for rental and using 5 vehicles for freight transportation that will travel a distance of 120 kilometers per day, its economy of scope is greater than zero. The average profit percentage per vehicle is 4.16%, and \$ 33.2 per day, as shown in Figure 8.

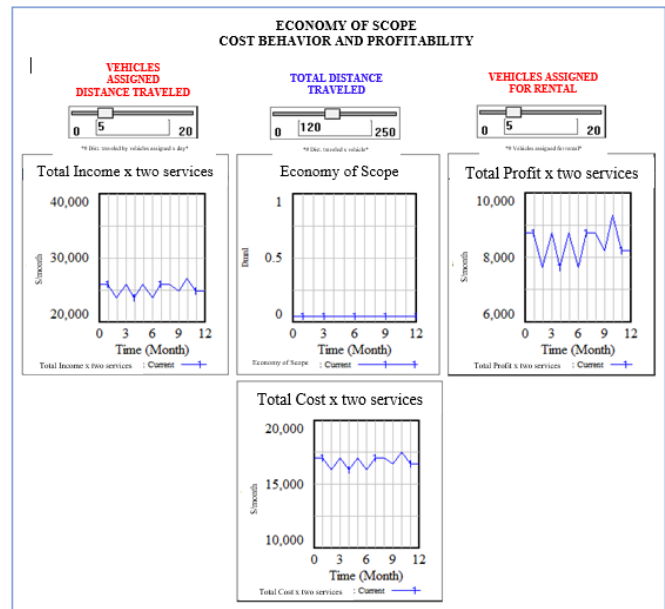


Figure 8: Behavior of fixed costs, variable costs, and distance traveled by vehicles.

### IV. DISCUSSION

In the results of the research, it could be observed that by means of the economy of scale and economy of distance for

each type of service, the higher the use of vehicles for rental in quantity and distance traveled, the lower the unit costs. This coincides with the research articles by Kim [25], Mauler [26], Wu [27], Yoshida [28], although the development of these articles does not present conceptually the variables that influence these processes, which limits the cause-and-effect analysis between them.

Fielbaum [29] conducted a discrete research work of economy of scale by using the volume of passengers and the spatial disposition of the transit lines through which the passenger vehicles travel, concluding that the more passengers in the vehicle, the lower the unit costs. This calculation has been made heuristically. It should be noted that unlike this article, this is for passenger transportation and not for heavy freight, but the use of economy of scale as a means to reduce unit costs is also valid.

Horang [30] conducted the research on economy of scale and economy of scope in small household rice farming in Vietnam, which also quantitatively validates that both economy of scale and economy of scope reduce costs for higher production and for a variety of products or services provided.

In the research work of Samuel [31], a conceptualized presentation of a closed multi-component circuit with nonlinear variables was made, in which costs were determined by using the economy of scale heuristically.

## V. CONCLUSIONS

The causal model or diagram shows that the organization is predominantly focused on the short term by providing vehicle rental services, but its long-term focus can be strengthened if the organization becomes more demanding when selecting new lines of business such as freight. Although changing the process of business evolution that is rooted in the organization's attitudes is complicated, this dynamic model, which shows the relationship between the variables by simultaneously running the two types of business through a sequential schedule that respects the needs of the customers, demonstrates that it is easier than it seems, with attitude and discipline.

The qualitative and quantitative scenario models validate that it is more advisable for a company to carry out both types of transportation services, such as freight transportation by distance traveled and vehicle rental for a certain period.

If a company were to engage in only one type of business, such as vehicle rental services, its level of utilization for this service would be lower, which would generate losses in its income. The activities in these two types of services complement each other which is an opportunity for the organization to reduce its operating costs. Organizations should adapt to customer needs by evaluating the level of utilization of their available internal resources (vehicles, drivers, etc.) as well as external resources such as the quality of the road infrastructure since the latter is in direct relationship to the cost of vehicle maintenance.

The challenge for companies that provide freight and rental services is to have a sustainable system over time. For this, they must continually evaluate accessibility, congestion, energy use, types of financing for the acquisition of these assets with new technologies; that the vehicles are fast, efficient, safe, and comfortable; that the system is resilient and robust to any failure so that the vehicles continue to operate.

Regarding congestion, we can point out that the more congestion a geographic area has, the less reliable the travel times, the higher the fuel consumption, and the greater the wear and tear without movement.

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