INTRODUCTION TO FLEET MANAGEMENT

ADVANCEDFLEET
MANAGEMENTCONSULTING

José Miguel Fernández Gómez has developed this book to share his experience and knowledge acquired through his career and education in the vehicle fleet management field.

I'm the manager of Advanced Fleet Management Consulting; our company provides advanced consulting services on vehicle fleet management. Visit our webpage and blog to know more about our services, you can also find us on LinkedIn, Facebook and Twitter.

I previously worked at INSEAD (France), one of the best business schools in the world, developing consulting and research activities for The United Nations Refugee Agency (UNHCR), optimizing the size and management of their vehicle fleet that is spread all over the world (6,500 vehicles). I was also fleet manager of a 1,000 vehicles fleet for a cleaning street company in Madrid (Spain).

I hold a Ph.D on Industrial Engineering from the Polytechnic University of Madrid; I received the International Mention since I made two research stays at The University of Liverpool (England), and The Royal Institute of Technology–KTH (Sweden). I usually conduct research on optimization activities for fleet management, and I have developed some models that I've published on international congresses on industrial organization.

We are an independent Fleet Management Consultancy company and provide the following services:

►Fleet Management Audit/Consultancy: the audit is the key tool to know the overall status and provide the analysis, assessment, advice, suggestions and actions to take in order to cut costs and increase the efficiency and efficacy of the fleet management; it's the previous step to carry out a larger consultancy project.

►Fleet Management course: the main goal of this course is to provide the knowledge and skills to manage any kind of vehicle fleet through all its activities and key aspects; the course is aimed to executives, middle managers, fleet managers and any professional related to fleet management.

►Fuel consumption reduction: we have our own methodology, additives and great experience in vehicle fleet, mining, ships etc. getting around 20% on fuel savings.

► Fleet Management Simulation: we use the simulation software Simio to optimize the operations, processes and calculate the optimal number of vehicles of your fleet.

► We reprogram the motor control center (MCC) getting an increase in power between 20-25% with fuel savings between 8-14%.

► Technical inspections and assessment of your vehicles to know his real value and state before selling/purchasing them.

► Mechanical warranties that cover breakdowns like engine or transmission.

We work over the world, at any country.

If you wish to contact us, you can e-mail us at:
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1. INTRODUCTION TO VEHICLE FLEET MANAGEMENT

Fleet management is the use of a set of vehicles in order to provide a service to a third-party, or to perform an activity internally in an organization, in the most efficient and productive manner with a determined level of service and cost.

Fleet management is a key aspect to develop the general strategy of the organization, and for this reason it has to be designed and implemented based on its guidelines, characteristics and goals of said organization.

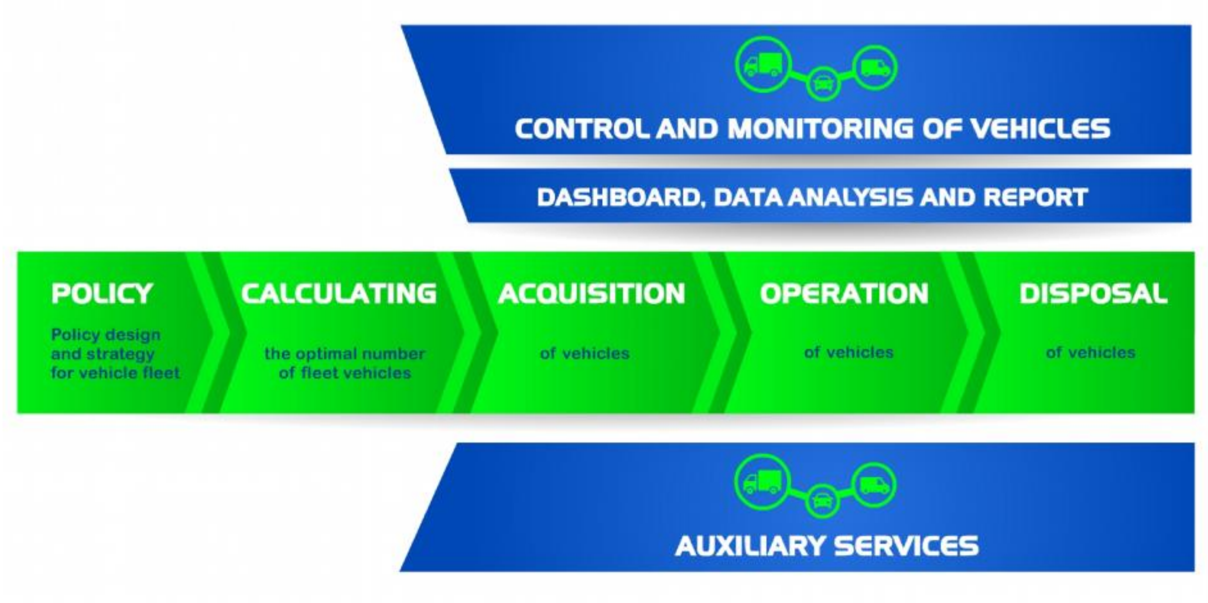
For some organizations, their vehicle fleet management is the main activity in their value chain, and represents its major asset to provide its service. This would be the case for passenger transportation companies, ground shipping, car rentals, renting companies, taxicabs, mail services, or cleaning and trash collection services provided by city councils.

For other organizations, it's a support activity to their main one, or a bonus such as a car, given to their executives for their personal use. This would be the case for companies with sales representatives (pharmaceutical industry, IT services, etc), airports, supermarkets, and non-governmental organizations (NGOs).

There are three vehicle fleet categories, and are the following: the ones that perform in planned routes; the ones that have an aleatory demand of vehicles; and the ones that have assigned a vehicle to one driver/user or to a permanent activity.

Each category has different operations, characteristics and goals, as well as there are several variables and factors involved in fleet management, making each fleet unique and different, reaching the best feasible solution for his management.

The goal of this document is to propose a methodology and provide a global vision for vehicle fleet management through its key factors and all the involved activities shown in the graph 1.



Graph 1: vehicle fleet management activities. Own source.

1st Designing and implementing policies that should include the guidelines for fleet management.

2nd Calculating the optimal number of vehicles, their capacity, and routes if available.

3rd Choosing the vehicle’s type, brand, equipment, and how to acquire them.

4th Vehicles’ operation such as maintenance management, traffic accidents, etc.

5th Designing policies for the disposal/replacement of vehicles and their sales channels.

These five activities have three support activities.

1st Control and monitor to know the vehicles’ status, where they are and who is using them.

2nd Scoreboard, data analysis and report, because during acquisition, operation and disposal activities is generated relevant information that must be analyzed in order to make decisions, know the status and the evolution of how the fleet is managed.

3rd The auxiliary services that must be done in order to comply with any current laws and regulations in the country where the fleet operates such as traffic lines, technical inspection of the vehicles, accidents, etc.

Aside from the already mentioned activities, fleet management is made by the necessary processes, organizational structure, staff, facilities, software and hardware.

This document is an introduction to vehicle fleet management, and each described activity can be developed and extended deeper. In the same way, each fleet is different and unique, and the methodology proposed in this document has to be adapted to the characteristics, operations and goals of each fleet.

The activities with the highest value in fleet management are: designing policies for fleet management, calculating the optimal size of the fleet, vehicles operation, scoreboard, data analysis and report. For the same reason, in this document these activities are more developed than the others.

In the following chapters, each activity shown in the graph 1 are explained in detail, as well as the principle key aspects of fleet management in the most efficient and productive manner fulfilling a determined service level and cost.

2. FLEET MANAGEMENT POLICY

The starting point for fleet management is to design and implement its policies, establishing its operational guidelines and long-term planning, in order to develop the organization's general strategy and achieve more efficiency and productiveness at a determined service level and cost.

The company's executives must design, develop and implement the fleet management policies starting from the strategy guidelines of the organization. These policies must be supported, abided and known by every person involved in the fleet management. Frequently, the absence of such policies, ambiguous policies, or poorly developed are the origin of unsatisfactory fleet management.

The following guidelines are some fleet management policies for different types of organizations.

- An organization that has an environmental friendly policy as part of their general strategy must have a fleet that are the least harmful pollution such as electric, hybrid or hydrogen vehicles.

- An organization focused on low cost rentals has to have a low-end fleet, with very few models to choose from; on the contrary, an organization focused on clients with high acquisition levels must have a high-end vehicle fleet.

- An organization that has its drivers and clients' safety as part of their general strategy must have a fleet of vehicles with the best equipment and latest technology in safety.

- A logistics company in charge of distributing commodities or passenger transportation, whose strategy is to be the company that takes the least time to perform the offered service in their market, has to have the optimal number of vehicles to do so.

- An organization, in which one of the guidelines of its strategy is to increase its brand image through their vehicles, must have high-end vehicles.

2.1. GENERAL GUIDELINES

Fleet management policies must have the following general guidelines, which need to be reviewed and updated on certain periods of time, and have to be adapted accordingly with the fleet's characteristics, operations and goals.

1. Fleet management policies.

- Establish who is responsible for designing and implementing the policies.
- Communicate the policies to all the people involved in the fleet management.
- Establish how often the policies must be reviewed and updated.

2. Budget and costs of the fleet.

- Establish and control the fleet's budget.
- Identify and sort out the fleet's costs.
- Establish the information system to control the fleet's costs.

3. Calculating the optimal number of vehicles in the fleet.

- Establish the service's level in which the fleet will perform.
- Establish the maximum distance limit that the vehicles should travel.
- Establish the maximum operational costs' limit.
- Establish how to calculate the optimal number of vehicles in the fleet (using the needed software or through other means), the variables that should be minimized (fuel, travelled distance, or service time), the vehicles' capacity, the routes if available and identify the fleet's pattern.

4. Acquisition of vehicles.

- Establish how to acquire the vehicles: buying, renting/leasing, car sharing, or a combination.

- Establish what type of vehicles to acquire: fossil fuel, hybrids, electric, hydrogen, natural gas, or a combination.

- Establish the age or mileage limit for the second-hand vehicles acquisition.

- Establish if the vehicles to acquire are premium or low end.

- Establish and standardize what brands, vehicle's model and equipment to acquire.

- Establish the insurance car: full coverage, franchised, or third parties.

- Establish the vehicles suppliers.

- Establish through what means the vehicles are acquired.

- Establish a central buying body.

5. Vehicles Operation.

- Write down and establish the fleet's operations manual.

- Design and establish the maintenance program.

- Establish what vehicles have priority for maintenance and repairing.

- Design and establish the analysis program of breakdowns.

- Establish what kind of spare parts to use: official or alternative.

- Design and establish the system to reduce and control fuel consumption.

- Design and establish the system to select, control and check up tires.
- Establish what kind of tires to acquire: premium or low cost.
- Design and establish the policies to lower and prevent the traffic accidents, and how often they should be reviewed and updated.
- Design and establish the audits for reducing and preventing the traffic accidents, and in what period of time to do it.
- Design and establish the criteria needed to transfer a vehicle from one operation center to another.
- Establish if the organization will own the workshops or they'll be outsourced.
- Establish the suppliers for spare parts, tires, or external workshops.
- Establish the specific software for vehicles operation.

6. Disposal of vehicles.

- Establish when to disposal/replace a vehicle from the service: age, mileage or whichever comes first.
- Establish priority rules to disposal/replace the vehicles.
- Establish means to disposal the vehicles.
- Establish the suppliers to sell the vehicles.
- Establish the deadline to sell the vehicles once disposal from the service.
- Establish the central selling body.
- Establish the specific software for selling the vehicles.

7. Information system.

- Establish what information needs to be collected.
- Design and establish indicators and in what activities.
- Establish how often data will be gathered and analyzed and the period of time to write the general report about the fleet's management performance.

8. Measurement of the fleet management performance.

- Establish the frequency of data gathering and measure how the fleet is being managed.
- Establish what variables have higher priority to increase the service level and lower the variable costs.
- Establish which is the priority period time, if long or short time, to increase the service level and lower the variable costs.
- Establish margins for the service level and variable costs.

9. Control and monitor of the vehicles.

- Establish what type of information and what degree of details must be recorded.
- Establish the specific software needed for control and monitor of the vehicles.

10. Auxiliary services.

- Establish the insurance company for the vehicles.
- Design and establish the schedule plan for the vehicles' technical inspections.
- Design and establish the fuel cards management.

- Design and establish the traffic fines/tickets management.
- Establish what auxiliary services activities are performed by third-parties.
- Establish the suppliers of auxiliary services activities performed by third-parties.
- Establish the specific software for some or all of the auxiliary services activities.

11. Outsourcing and organizational structure.

- Establish the criteria and guidelines for any outsourcing activities the fleet may need, and how often this criteria and guidelines need to be reviewed.
- Establish what fleet management activities are performed by third-parties, and which are done by the organization itself.
- Design and establish the organizational structure, the main organizational processes, and what activities to perform.
- Establish the criteria for choosing external suppliers.
- Design and establish the personnel's profile.

12. Fleet management software.

- Establish the criteria for choosing the fleet management software.
- Establish what fleet management activities the software is used.
- Establish what information the software needs to register.

13. Telematics services.

- Establish the criteria for choosing the telematics services.
- Establish what information the telematics services need to report

3. VEHICLE FLEET´S COSTS

It is crucial to know all the fleet's costs in order to: establish and control the fleet's budget; establish the prices and rates of the offered services; know the cost of every mile/kilometer traveled; know the Total Cost of Ownership (TCO); calculate the disposal/replacement periods of each vehicle; control and follow up the fleet's economic performance; calculate the fleet's main economic and financial indicators; do the ABC analysis of the fleet's costs; have the costs history registry to predict future forecasts; find the relationship between the service level and direct costs; and gather valuable information for decision making.

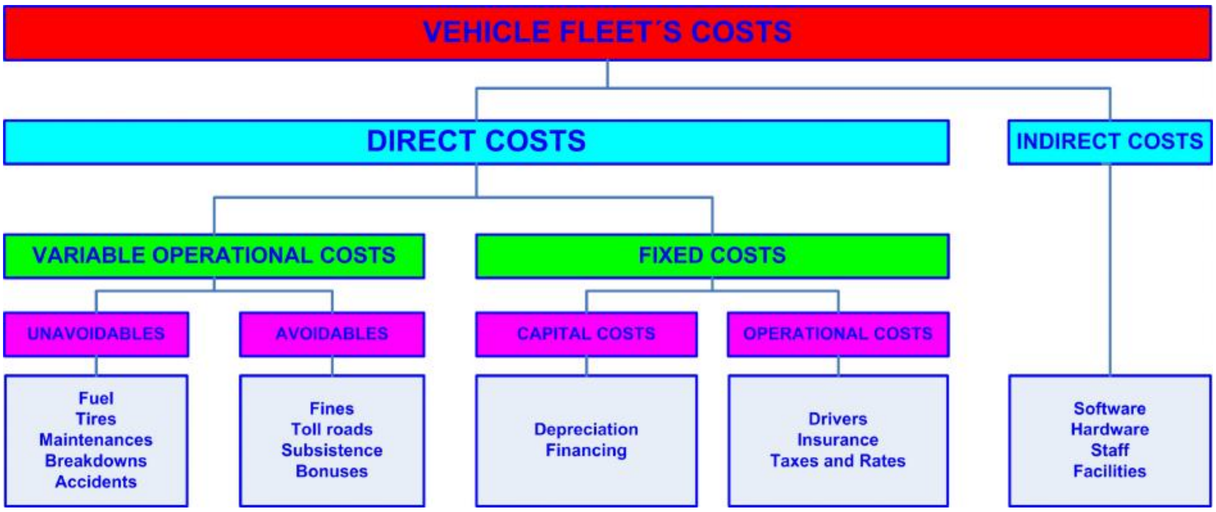
Fleet's costs are classified in two types:

- Direct costs: the costs related to the vehicle's possession and exploitation, and are divided in two subcategories:

    - Fixed costs: the costs sustained by the vehicle whether it's being used or not, and are computed per units of time, normally by a natural year.

    - Variable operational costs: the costs related to the vehicle's activity, and are computed by distance traveled or hours used.

- Indirect costs: the costs attributed to the vehicle, not by possession or exportation, but as a result of fleet management, like software, hardware, the involved staff, and the necessary facilities (offices, parking, fuel storage). Graph 2 shows the vehicle fleet's costs structure.



Graph 2: fleet's costs structure

3.1. VEHICLE FLEET'S FIXED COSTS

Fixed costs are those related to the vehicle's possession and are divided in capital costs and operational costs.

3.1.1. Capital costs

The capital costs are the acquisition costs and the chosen financing. They're divided in depreciation and financing.

- Depreciation: the decrease in the value of the vehicle, complimentary equipment, or fitting bodies during their period of use. Depending on the chosen financing option the decreasing will be equal to the amortization during its service life or to an inferior period.

- Financing: the sum of financing costs of the vehicle, complementary equipment or fitting bodies in a year. The vehicle's financing can be done in following main ways: If the vehicle is acquired through credit or a loan, it'd be the annual interest rate; if the company has issued its own debt, then it'd be the sum of the annual interest amount paid to the buyers; if the company uses its own funds, it would have to calculate the opportunity cost to invest the resources in other investment.

If the vehicle, complementary equipments, or fitting bodies have been acquired through renting/leasing, the acquisition and financing costs are included in the annual fee.

3.1.2. Operational costs

The operational costs are the following:

- Drivers: the annual gross cost of the company's drivers of the vehicles destined to perform the service. In Spain this includes the gross salary and the social security contributions.

- Insurance: the annual costs of the insurance for the vehicle, complementary equipments, fitting bodies and commodities.

- Taxes and Rates: the annual costs of taxes and rates, such as the technical inspection of the vehicle that is mandatory in some countries like Spain, transportation cards, taxes on mechanised vehicles, tachograph inspection, and any other authorization or taxes over transportation.

3.2. VEHICLE FLEET´S VARIABLE OPERATIONAL COSTS

Variable operational costs are those related to the vehicle's use. There are two types of variable direct costs: those that are related to the use of the vehicles, and those that may or may not be related to the use of the vehicles and depend on the service performance and how the fleet is managed.

3.2.1. Unavoidable costs

The unavoidable costs of the vehicle fleet are those related to the vehicle's use, and are the following:

- Fuel: annual cost of fuel for the vehicles and complimentary equipment.
- Tires: annual cost of acquisition and repair of the tires.
- Maintenance: annual costs of plannified maintenance in accordance to the vehicle's manufacturer and preventive maintenance, which have to include workforce, spare parts and oil/lubricants.
- Breakdowns: annual costs of the breakdowns, which have to include workforce, spare parts and oil/lubricants.
- Accidents: annual costs of the traffic accidents, which have to include the vehicle's repair and compensation to any third-party that the organization is in obligation to pay.

3.2.2. Avoidable costs

The avoidable costs of the vehicle fleet are those that can be related or not to the vehicle's use, and depend on the service performance and how the fleet is managed, and are the following:

- Traffic fines/tickets: total cost of the tickets to the drivers for any wrong doing or misconduct.

- Toll roads: total cost of payments related to the toll roads, that must be paid to travel through them in order to guarantee quality service, or because they are safer.

- Driver’s subsistence allowance: annual costs of the driver’s trips outside of their permanent residency through a determined period of time.

- Bonuses: bonuses paid to the vehicles’ drivers for several reasons such as lowering the fuel consumption or traffic accidents.

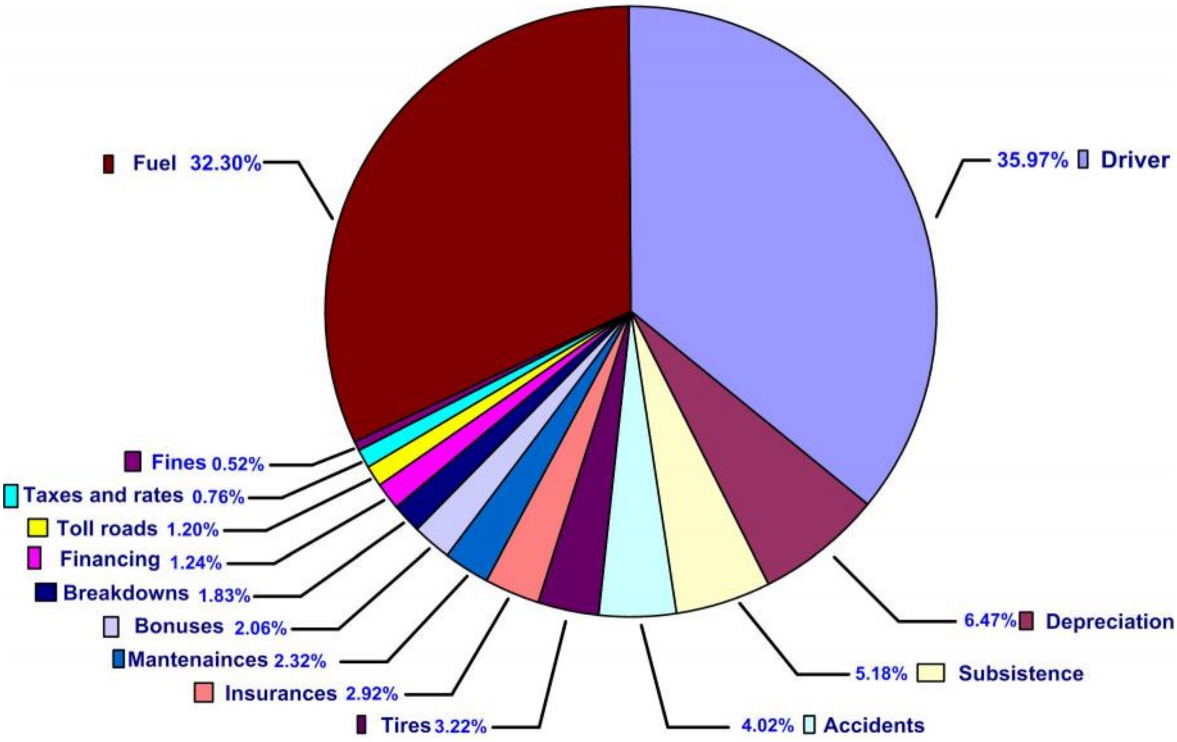
3.3. VEHICLE FLEET´S COSTS CONTROL

The accounting department usually has the generic value of the fleet's costs, but it's advised to have individual costs assigned to each vehicle. The organization must establish the frequency for control and monitor of the costs, which would depend on the characteristics, budgets and goals of every organization. The cost's control and monitor are recommended to do for each vehicle individually, for each type of vehicle and an average for the whole fleet. In the following graphs are some examples on how to do said control and monitor of the vehicles. Chart 1 shows all the direct costs in one year according to the graph 2 for one fleet's vehicle.

Denomination	Cost	%
Fixed Costs (Time)	**38,929.3**	**47.37%**
Operational costs	32,585.71	**39.65%**
Drivers	29,562.14	35.97%
Insurance	2,400.12	2.92%
Taxes and Rates	623.45	0.76%
Capital costs	6,343.59	**7.72%**
Depreciation	5,321.14	6.47%
Financing	1,022.45	1.24%
Variable costs (Miles/kilometers)	**43,253.56**	**52.63%**
Unavoidable	35,897.51	**43.68%**
Fuel	26,548.49	32.30%
Accidents	3,300.45	4.02%
Tires	2,645.14	3.22%
Maintenance	1,902.78	2.32%
Breakdowns	1,500.65	1.83%
Avoidable	7,356.05	**8.95%**
Subsistence	4,253.6	5.18%
Bonuses	1,689.78	2.06%
Toll roads	987.41	1.20%
Fines/tickets	425.26	0.52%
Total direct costs	**82,182.86**	100.00%

Chart 1: direct costs of a fleet's vehicle

Graph 3 shows the distribution of the directs costs.



Graph 3: distribution of the direct costs of one vehicle of the fleet.

Consider the following operational data in chart 2.

Characteristics of operations	Quantity
Kilometers traveled a year	75,000
Traveling days a year	225
Working hours a year	1,900

Chart 2: characteristics of operations of one vehicle of the fleet.

The direct costs by distance and time obtained are the following:

Direct costs per unit	
Cost by Time	**Quantity**
Day	173.019 Euro/day
Hour	20.489 Euro/hour
Cost by Distance	
Kilometers	0.577 Euro/Km.

Chart 3: direct costs by time and distance of one vehicle of the fleet

Consider the indirect costs in the fleet that vary according to the number of vehicles, the following is the cost per kilometer, as shown in chart 4.

Indirect cost per vehicle		
Nº vehicles	**Euro**	**Euro/Km.**
1-20 vehicles	6,800.25	0.091
21-99 vehicles	9,700.89	0.129
100+ vehicles	13,405.85	0.179
Average	9,969.00	0.133

Chart 4: indirect costs of a fleet's vehicle per kilometer

Considering the direct and indirect costs, the cost per kilometer per vehicle is obtained, according to chart 5.

Total costs (direct and indirect)		
Nº vehicles	**Euro**	**Euro/Km.**
1-20 vehicles	88,983.11	1.186
21-99 vehicles	91,883.75	1.225
100+ vehicles	95,588.71	1.275
Average total cost	92,151.86	1.229

Chart 5: total costs (direct and indirect) of a fleet's vehicle.

With the obtained data it can be calculated several economic and financial indicators of the fleet, that depends on each organization.

4. CALCULATING THE OPTIMAL NUMBER OF VEHICLES OF THE FLEET

4.1. SERVICE LEVEL AND ITS DIRECT ASSOCIATE COSTS

The organization has to design and implement the policy concerning the calculation of the optimal number of vehicles, service level, and costs of the fleet. This policy depends upon the following aspects such as the general strategy, market, offered services, competitors, or budget available for the organization.

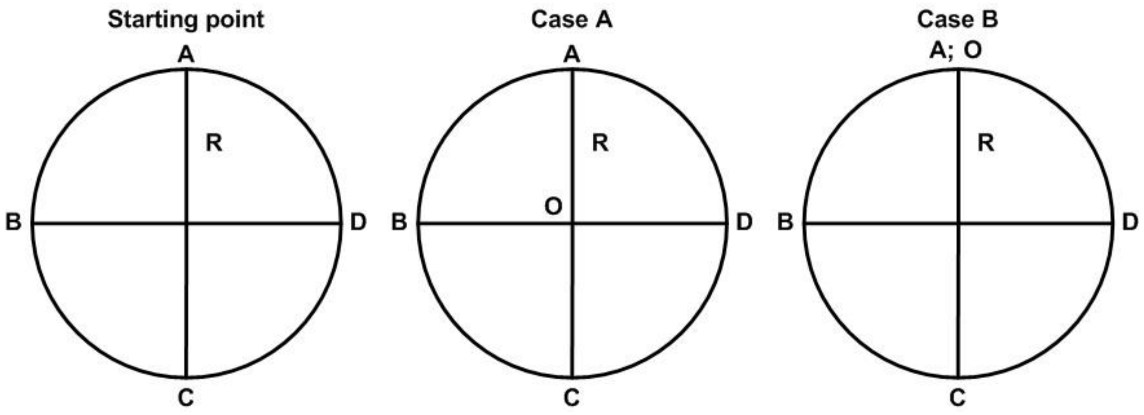
Calculating the optimal number of vehicles of the fleet is complex due to all aspects involved in fleet management such as establishing the service level and its direct associate costs, planning the routes if they are available, what kind of vehicles to use and their capacities, the use of the 100% of the vehicle's capacity, or the localization of the organization's headquarter.

4.1.1. Theoretical and practical case study.

The following is a theoretical and practical case study developed to show the relationship between the optimal number of vehicles, service level and direct costs. The case to analyse is a fleet that delivers and picks-up goods in certain locations.

This case is chosen because it's one of the most complex to analyse and common in fleet management. In order to make the case as simple as possible, the only direct costs are vehicles acquisition, drivers' salaries and fuel costs.

Considering that one unit of goods have to be delivered or picked-up at each location A, B, C, and D, which are uniformly distributed around a circle's circumference with a radius R. The only factual solutions to locate the base (O) are: the center of the circle (case A), or in one of the delivery locations (case B), for this reason a delivery location is eliminated, the graph 4 represents both solutions.



Graph 4: theoric case and its two factual solutions.

There are four different types of available vehicles to choose, and each one has different acquisitive costs and capacity according to chart 6.

Denomination	Capacity	Cost*
C4	4	35,000
C3	3	30,000
C2	2	25,000
C1	1	20,000
*Euros		

Chart 6: capacity and costs of available vehicles

The operational conditions for this theoretical and practical case study are the following:

Denomination	Symbol	Value
Vehicle's service life (years)	a	5
Working days a year	d	220
Radius of the circumference (Km.)	R	50
Average speed (Km./h)	Vm	50
Fuel consumption (liters/100 Km.)	c	8
Fuel cost (euro/liter)	Vc	1
Driver's salary (euro)	S	30,000

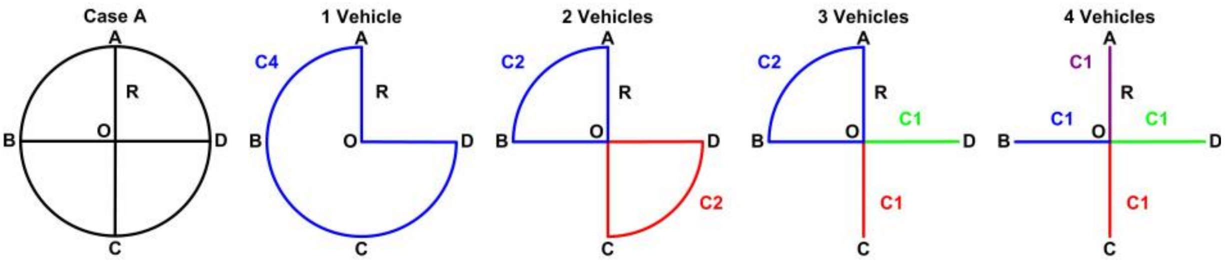
Chart 7: vehicle fleet's operational costs

Considering a null residual value for the vehicles, a traveling road of mixed urban and highway conditions, stop time in locations A, B, C, D are not considered, and the vehicles are used to the 100% of their capacity.

The service level is the highest individual time (hours) from all vehicles in the fleet, from the time they leave the base “O” until they come back to it after completing the delivery and pick-up of goods at the locations A, B, C, D.

Case A

The graph 5 represents the different factual solutions to use one, two, three and four vehicles, their capacities and routes in different colors, for the case A, in which the base is at the center of the circle.



Graph 5: relationship between routes and the number of vehicles for the case A.

Chart 8 represents the solutions for the generic case; the following chart 9 represents the results of the four possible cases using the values of the charts 6 and 7.

Nº Vehicles	1	2	3	4
Service level (SL) (hours)	(3πR+4R)/(2Vm)	(πR+4R)/(2Vm)	(πR+4R)/(2Vm)	2R/Vm
Increment of SL (ΔSL)	-	πR/Vm	0	πR/2Vm
Fuel Consumption (FC)	(3πR+4R)cda/100*2	(πR+4R)cda/100	(πR+12R)cda/100*2	(8R)cda/100
Increment of FC (ΔFC)	-	(4-π)Rcda/2*100	(4-π)Rcda/2*100	(4-π)Rcda/2*100
Fuel cost (FCo)	Vc*CC	Vc*CC	Vc*CC	Vc*CC
Increment of FCo (ΔFCo)	-	Vc*ΔCC	Vc*ΔCC	Vc*ΔCC
Direct Costs (DC)	CCo+S+C4	CCo+2S+2C2	CCo+3S+C2+2C1	CCo+4S+4C1
Increment of DC (ΔDC)	-	ΔCCo+S+2C1-C2	ΔCCo+S+2C1-C2	ΔCCo+S+2C1-C2
Total Km. (TKm)	(3πR+4R)da/2	(πR+4R)da	(πR+12R)da/2	8Rda
Increment of TKm (ΔTKm)	-	(4R- πR)da/2	(4R- πR)da/2	(4R- πR)da/2
Direct Cost per Unit (DCu)	CT/KmT	CT/KmT	CT/KmT	CT/KmT

π=3,14; C4= vehicle capacity 4; C3= vehicle capacity 3; C2= vehicle capacity 2; C1= vehicle capacity 1;
a= vehicle’s service life; d= working days a year; R= radius of the circumference (Km.);
Vm= average speed (Km./h); c= fuel consumption (liters/100 Km.)
Vc= fuel cost (euros/liters); S= driver’s salary (euros)

Chart 8: solutions for the generic case

Nº Vehicles	1	2	3	4
Service level (SL) (hours)	6.71	3.57	3.57	2.00
Increment of SL (ΔSL)	-	3.14	3.14	1.57
Fuel Consumption (FC)	29,534.56	31,423.04	33,311.52	35,200.00
Increment of FC (ΔFC)	-	1,888.48	1,888.48	1,888.48
Fuel cost* (FCo)	29,534.56	31,423.04	33,311.52	35,200.00
Increment of* FCo (ΔFCo)	-	1,888.48	1,888.48	1,888.48
Direct Costs (DC)	94,534.56	141,423.04	188,311.52	235,200.00
Increment of DC (ΔDC)	-	46,888.48	46,888.48	46,888.48
Total Km. (TKm)	369,182	392,788	416,394	440,000
Increment of TKm (ΔTKm)	-	23,606	23,606	23,606
Direct Cost per Unit (DCu)	0.256	0.360	0.452	0.535
Increment of DCu (ΔDCu)	-	0.104	0.092	0.082
The consumption and cost of fuel is the same, since the cost of a liter of fuel is 1 euro. π=3,14				

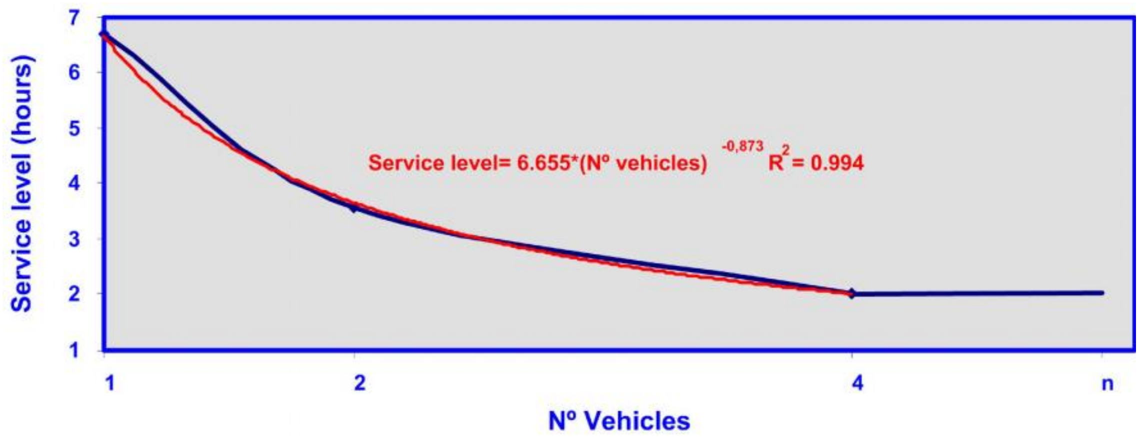
Chart 9: results obtained from the four possible cases for the case A.

The service level, fuel consumption, direct costs, total kilometers traveled and direct costs per unit are increased by the number of vehicles.

The increment produced in the service level are directly proportional to Pi (π=3.14), and the increment produced by the fuel consumption, direct costs, and traveled kilometers are constant. These increments are defined by the equations shown in the chart 8.

In the case of three vehicles, the service level is equal to the case of two vehicles, but the fuel consumption, directs costs, total kilometers traveled, and direct costs per unit are higher, for this reason this solution is dominated by the use of two vehicles, and the solution of three vehicles should not be taken into consideration.

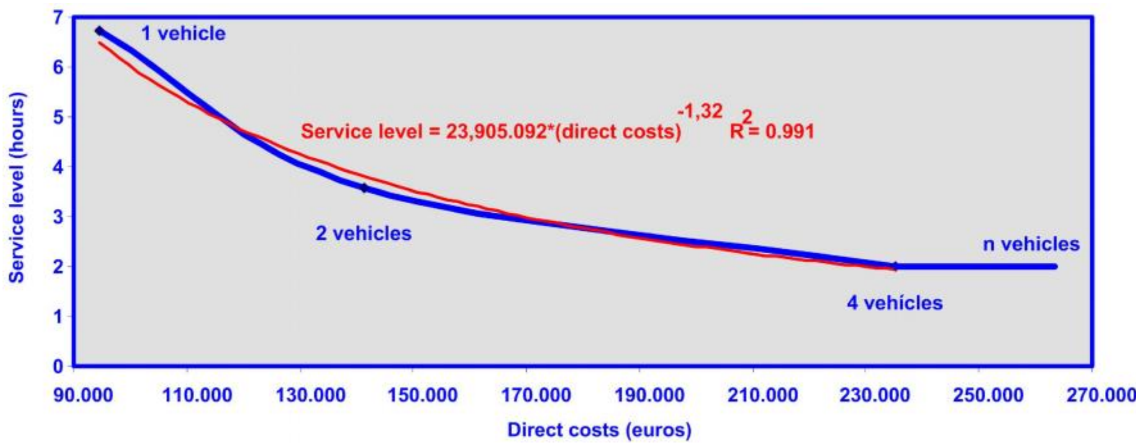
The case of using three vehicles proves that in the fleet could be solutions dominated by better ones that must be identified and eliminated among the options.



Graph 6: relationship between the number of vehicles and service level for the case A

The graph 6 shows that as the number of vehicles increases, the increment in the service level decreases (blue line). The maximum service level corresponds to using four vehicles, and from using more than four vehicles the service level remains constant.

The correlation between the service level and number of vehicles is significantly high (R^2) and corresponds to the potential equation shown in the graph 6 (red line).



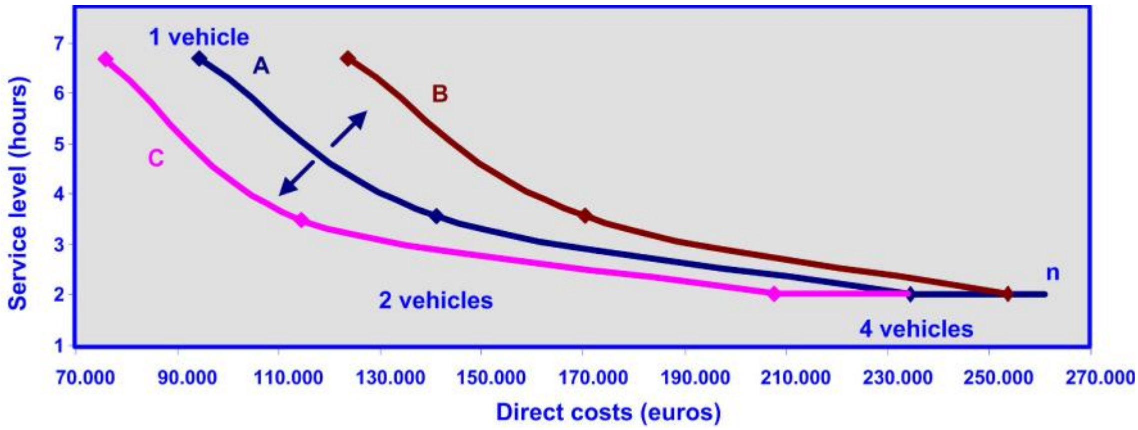
Graph 7: relationship between the service level and direct costs for the case A.

The graph 7 shows that as the direct costs increase, the increment of the service level decreases. The maximum service level corresponds to using four vehicles, which is associated with certain directs costs, and from using more than four vehicles, the service level remains constant but the direct costs increase.

The correlation between the service level and direct costs is significantly high (R^2) and corresponds to the potential equation shown in the graph 7 (red line).

In this theoretical model, if these initial conditions are modified such as if the acquisition costs were higher, the fuel consumption and driver´s salaries increase, the curve A would move further into the right like shown in the graph 8 in the curve B, and for the same service level the direct costs would be higher.

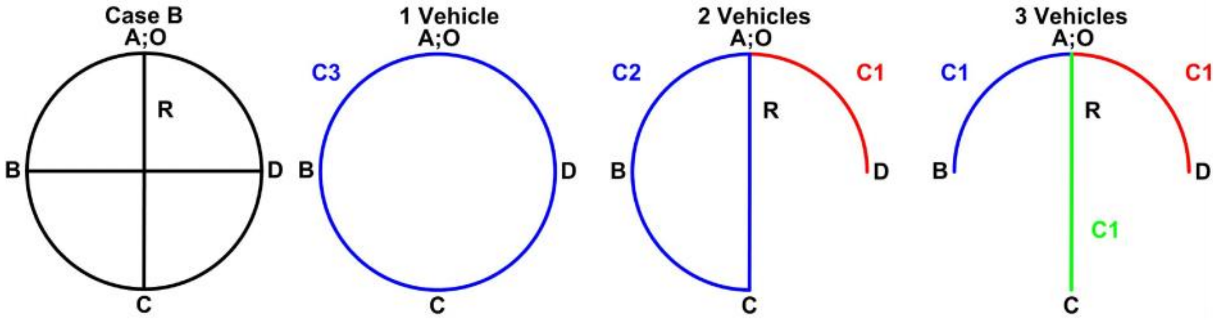
On the contrary, if the acquisition costs were lower, the fuel consumption and driver's salaries decrease, the curve A would move further into the left like shown in the graph 8, transforming into the curve C, and for the same service level the direct costs would be lower.



Graph 8: relationship between the service level and increment or decrement of the direct costs for the case A.

Case B

The graph 9 shows the different cases of using one, two, or three vehicles, their capacities and its routes in different colors, for the case B the base is in the delivery and pick-up location A.



Graph 9: relationship between the routes and number of vehicles for the case B.

The chart 10 represents solutions for the generic case; the following chart 11 represents the results of the four possible cases using the values of the charts 6 and 7.

Nº Vehicles	1	2	3
Service level (SL) (hours)	2πR/Vm	(πR+2R)/Vm	4R/Vm
Increment of SL (ΔSL)	-	(πR-2R)/Vm	(πR-2R)/Vm
Fuel Consumption (FC)	2πRcda/100	(2πR+2R)cda/100	(2πR+4R)cda/100
Increment of FC (ΔFC)	-	2Rcda/100	2Rcda/100
Fuel cost (FCo)	Vc*CC	Vc*CC	Vc*CC
Increment of FCo (ΔFCo)	-	Vc*ΔCC	Vc*ΔCC
Direct Costs (DC)	CCo+S+C3	CCo+2S+C2+C1	CCo+3S+3C1
Increment of DC (ΔDC)	-	ΔCCo-C2+2C1	ΔCCo-C2+2C1
Total Km. (TKm)	2πRda	(2πR+2R)da	(2πR+4R)da
Increment of TKm (ΔTKm	-	2Rda	2Rda
Direct Cost per Unit (DCu)	CT/KmT	CT/KmT	CT/KmT
π=3,14; C3= vehicle capacity 3; C2= vehicle capacity 2; C1= vehicle capacity 1; a= vehicle's service life; d= working days a year; R= radius of the circumference (Km.); Vm= average speed (Km./h); c= fuel consumption (liters/100 Km.) Vc= fuel cost (euros/liter); S= driver's salary (euros)			

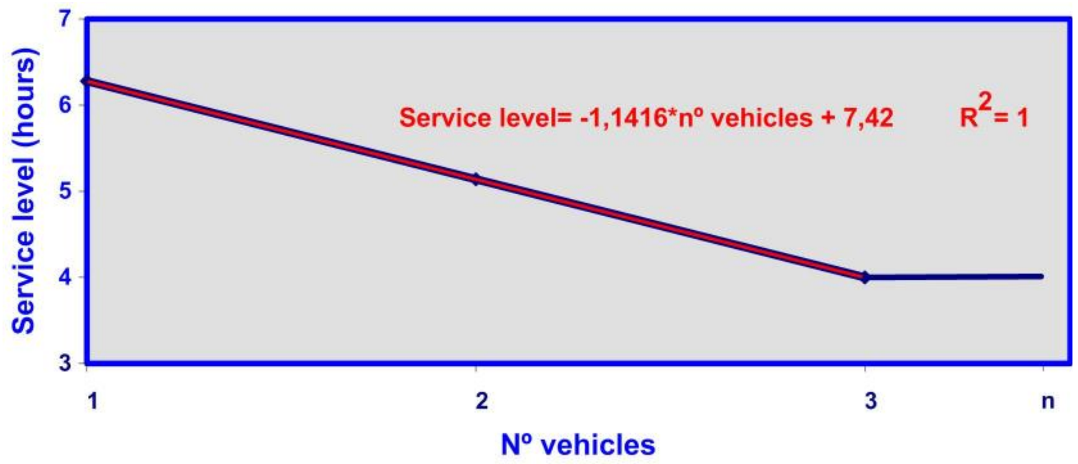
Chart 10: solutions for the generic case for the case B

Nº Vehicles.	1	2	3
Service level (SL) (hours)	6.28	5.14	4.00
Increment of SL (ΔSL)	-	1.14	1.14
Fuel Consumption (FC)	27,646.08	36,446.08	45,246.08
Increment of FC (ΔFC)	-	8,800	8,800
Fuel cost* (FCo)	27,646.08	36,446.08	45,246.08
Increment of* FCo (ΔFCo)	-	8,800	8,800
Direct Costs (DC)	87,646.08	141,446.08	195,246.08
Increment of DC (ΔDC)	-	53,800	53,800
Total Km. (TKm)	345,576	455,576	565,576
Increment of TKm (ΔTKm)	-	110,000	110,000
Direct Cost per Unit (DCu)	0.254	0.310	0.345
Increment of DCu (ΔDCu)	-	0.057	0.035
The consumption and cost of fuel is the same, since the cost of a liter of fuel is 1 euro.			

Chart 11: results of the three possible cases for the case B

The service level, fuel consumption, total traveled kilometers, and direct costs per unit increase with the number of vehicles.

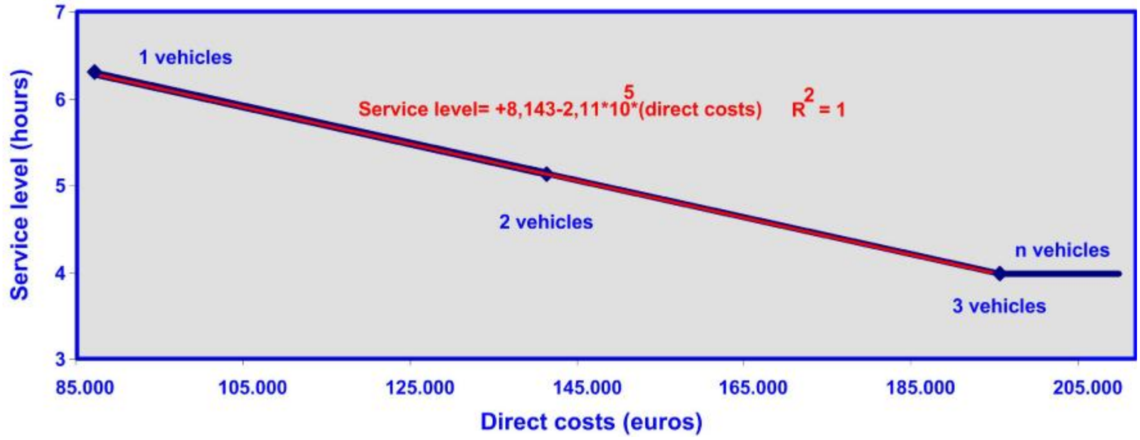
The increments on the service level, fuel consumption, total costs and traveled kilometers are constant. These increments are defined by the equations shown in the chart 10.



Graph 10: relationship between the number of vehicles and service level for the case B.

The graph 10 shows that as the number of vehicles increases, the service level's increment is constant. The maximum service level corresponds to using 3 vehicles, and from using more than 3 vehicles the service level remains constant.

The correlation between the service level is significantly high (R^2) and number of vehicles corresponds to the lineal equation shown in the graph 10 (red line).

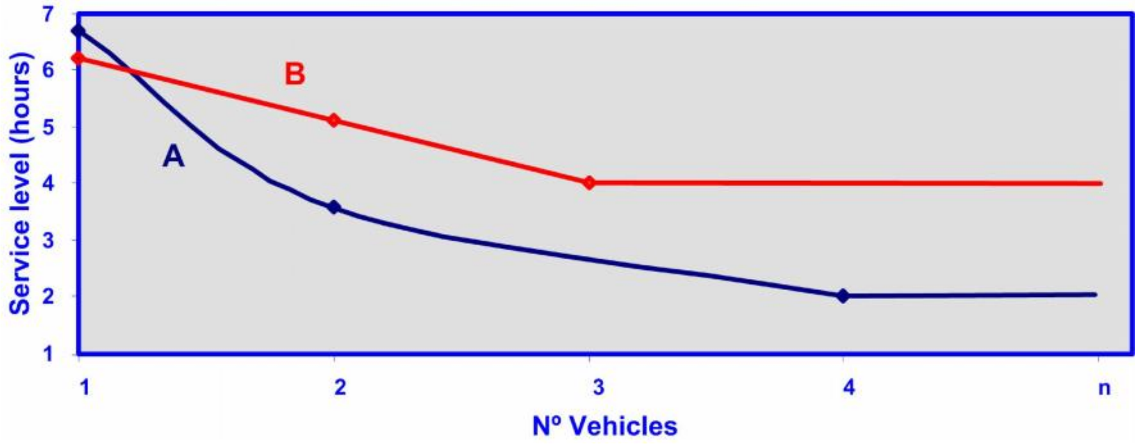


Graph 11: relationship between the service level and direct costs for the case B

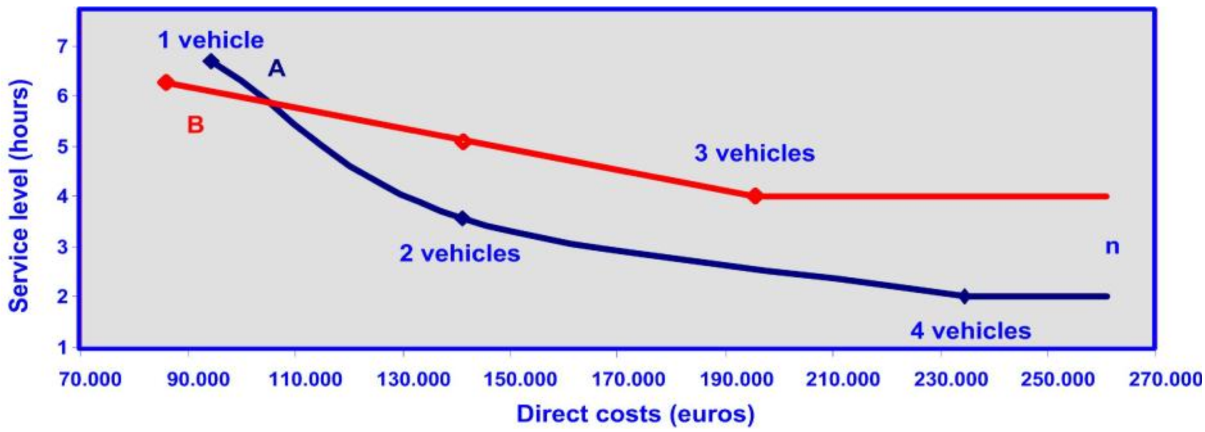
The graph 11 shows that as direct costs increase, the service level's increment is constant. The maximum service level corresponds to using 3 vehicles which is associated with certain directs costs, and from using 3 vehicles the service level remains constant but the direct costs increase.

The relationship between the service level and direct costs is significantly high (R^2) and corresponds to the lineal equation shown in the graph 11 (red line).

COMPARISON OF CASES A AND B



Graph 12: comparison between the number of vehicles and service level for the cases A and B.



Graph 13: comparison between the total costs and service level for the cases A and B.

The graphs 12 and 13, and the charts 9 and 11 shows that if only one vehicles is used, the case B provides a better service level and lower total direct costs, with a slight difference than the case A. If two vehicles are used, the case A presents a better solution than the case B for 2 and 3 vehicles, since it has a better service level and lower total direct costs.

The solution for using only one vehicle in the case B is only factual if in the future there won't be any improvements in the service level increasing the number of vehicles, on the contrary if the company operates in a very competitive market, there would be a need to increase the number of vehicles in the future, and because of this the case A is a better solution.

Conclusions for the theoretical and practical case study.

The principal conclusions for the theoretical and practical case study that could be extended to any kind of fleet would be the following:

- Every service level has an associated number of vehicles and direct costs.

- There is a maximum service level for a determined number of vehicles and direct costs, from which if any other vehicles are added, the service level remains constant but the direct costs increase.

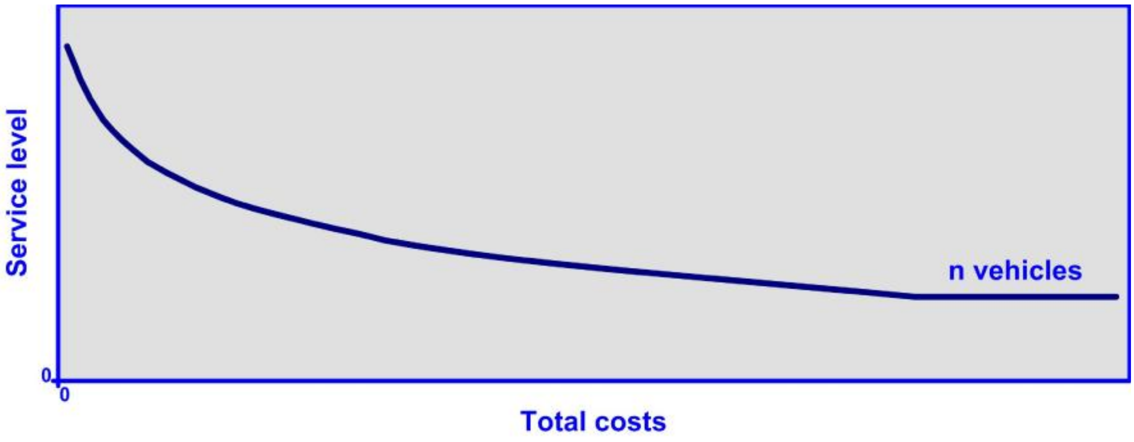
- There can be solutions that are dominated by better ones, for which these should be identified and eliminated from among the options.

- A vehicle fleet can be characterized or defined by its behavioral pattern according to the charts 8 and 10, and the graphs 6,7,10 and 11 in this case study, and they're of great help to implement, plan and make forecasts.

- Depending on the characteristics of the fleet, which in this case study would be the localization of the base (O) and the delivery and pick-up locations, there would be different characterization or behavioral patterns like shown in the cases A and B.

- The more vehicles, the higher are the increment in the variable operational costs, mostly because they'd travel a higher number of kilometers.

- The more vehicles, a bigger facility to stock them would be needed, as well as more staff for the fleet, drivers, processes, controls, etc. and for this reason the increment in the total costs (direct and indirect) increases. Most vehicle fleets that have planed routes follow a characterization of behavioral patterns like the ones shown in the graph 14, where the maximum service level is obtained with n vehicles that correspond to the number of delivery and pick-up locations.



Graph 14: relationship between the service level and total cost for a fleet with planned routes.

The following factors are some examples that have a great impact in the fleet's effectiveness and productiveness, which would lead to lower total costs and a better service level like the existence of fleet management policies, the use of the vehicle's full capacity, planning routes, establishing vehicles acquisition and selling central, establishing the adequate processes, having a fleet management software, an appropriate scoreboard, analyze data (big data), choose the right selling channel, the control and monitor of vehicles, or outsource certain activities to third-parties. In the following chapters these and other factors are developed.

4.2. OPTIMAL NUMBER OF VEHICLES IN THE FLEET

The organization has to have the optimal number of vehicles to perform the service level with maximum effectiveness and productiveness, meeting the direct costs or established budget, for which not having the optimal number of vehicles have the consequences shown in the chart 12:

More vehicles than the optimal number.	Fewer vehicles than the optimal number.
▪ High availability of the vehicles	▪ Low availability of the vehicles
▪ The vehicles are used in a heterogeneous way.	▪ The organization doesn't perform the adequate service level.
▪ Able to cover fleet management's problems.	▪ The vehicles are used over their scheduled hours.
▪ Some vehicles either aren't used or are for personal use.	▪ Vehicles are used over the capacity.
▪ Higher total costs (fixed and variables).	▪ Lower total costs (fixed and variables).
▪ Higher total acquisition costs.	▪ Lower total acquisition costs.
▪ Higher total operational costs.	▪ Lower total operational costs.
▪ Higher total number of traffic accidents.	
▪ Higher total emissions of Co_2.	
▪ Higher total number of breakdowns.	
▪ Higher total fuel consumption.	
▪ Higher support of auxiliary activities.	
▪ Higher quantity of consumed resources.	

Chart 12: consequences of not having the optimal number of vehicles in the fleet.

If the organization has more vehicles than its optimal numbers, the following situations can happen with each vehicle: it is usually assigned to one driver or service, it may not be used, or it's for personal use.

If the organization has a higher number of vehicles than the optimal, the reduction in fuel consumption costs, number of accidents, etc. will be a small amount in comparison with the cost of acquiring more vehicles and the derived consequences shown in the chart 12.

This type of practice hides problems of fleet management like planning, operation, control , monitor, and optimization, consuming more resources than needed increasing the costs.

If the organization has fewer vehicles than the optimal number, the fleet's direct costs (fixed and variables) will be less. However, the organization won't be able to perform the adequate service level, and the fleet will be used over its capacity and scheduled hours, which risks more accidents and breakdowns than expected.

4.3. CALCULATING THE OPTIMAL NUMBER OF VEHICLES OF THE FLEET

The optimal number of vehicles of the fleet varies over time, depending on aspects such as market demands, the service level and available budget, and for this reason the organization has to establish when to calculate the optimal number of vehicles that are needed for a certain period of time.

The resulting scenarios for each period of time are:

- The optimal number of vehicles needed is higher than the one the organization has, and for this reason there must be an acquisition of those vehicles.
- The optimal number of vehicles needed is lower than the one the organization has, and for this reason some vehicles must be disposed of service and sold.
- The optimal number of vehicles needed is the same as the one the organization has, and for this reason there's no need to acquire of dispose any vehicle.

It has to be considered that during this period of time some vehicles might need to be renewed; in chapter 7 the disposal/replacement of vehicles are reviewed.

For this reason, based on this information there has to be a plan for acquisitions or disposals and for the possible renovations of certain vehicles in order to accomplish the service level and assigned budget for this period of time.

4.3.1. Type of vehicle fleets

There are three types of vehicle fleets that can be considered of reference or basic, and are the following:

- Planned routes (Vehicle Routing Problem-VRP): the demand that causes the provision of the service are the delivery and/or pick-up locations in a geographical area, which have associated an amount of goods, waste, passengers, etc. to be delivered or picked-up in a determined period of time (service level) such as hours, days, weeks, etc. and in some cases have to be done in determined time frames.

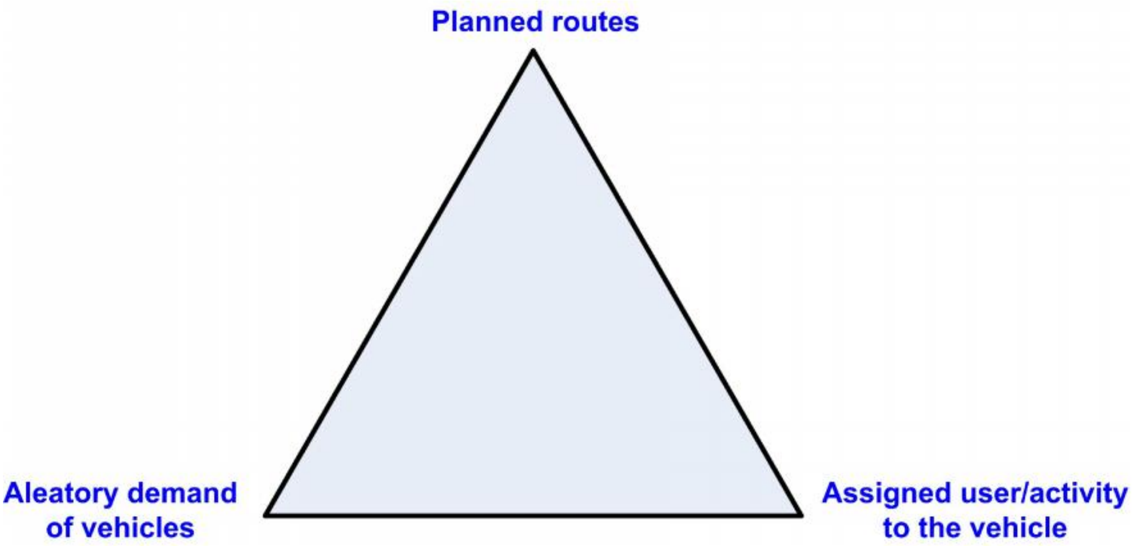
Some examples of this kind of fleet are the following: delivery and/or pick-up of goods and/or passengers, cleaning street services, trash collection, or mailing services.

- Aleatory demand of vehicles: the demand that causes the provision of the service is the random use of the vehicles in a geographical area, like people that use the vehicle to transport themselves geographical (car rental companies, taxicabs, car sharing) or incidents that demand attendance such as firefighters, police, traffic accidents, towing services, or ambulances. In these cases the clients or users could be in a queue in order to use any vehicle of the fleet.

A particular case is when there is a set of vehicles that perform a service for another set of vehicles, like it´s the case for public works or mining, in which there are the following vehicle categories: vehicles extracting land (excavator), and other vehicles that transport it geographically (trucks), for which it's necessary to calculate the optimal number of vehicles for each category considering both.

- A vehicle assigned to a driver/user or to an activity: the demand that causes the provision of the service is a vehicle assigned to a driver/user or a specific activity, since there aren't any planned routes or aleatory demand like in the previous cases. Examples of this kind of fleet are the following: vehicles used by company's executives for private use or salesmen.

Any type of fleet can be assigned to any position in the triangle shown in the graph 15, depending on the characteristics of it. A vehicle fleet can be classified as one of the three reference types of vehicle fleet, or in an intermediate position of two of these three reference types of fleets; because it has the planned routes component and the aleatory demand component, or the planned routes component and the assigned user/activity to a vehicle, or it has the aleatory demand component and the assigned user/activity to a vehicle. Depending on the intensity level of each component, it's closer to one type or the other.



Graph 15: types of vehicle fleets.

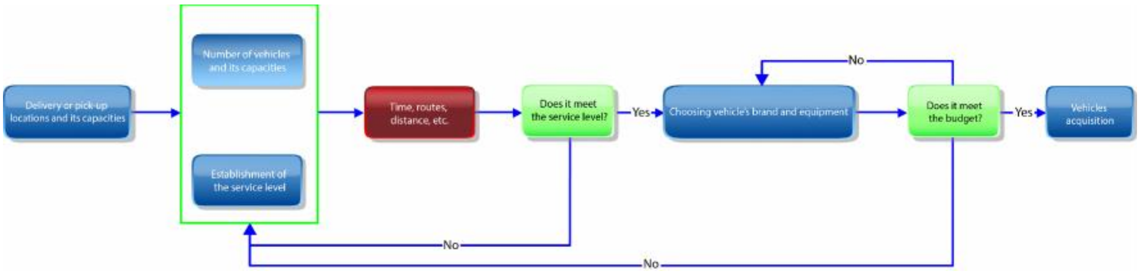
Following is developed how to calculate the optimal number of vehicles for each one of the three reference types of vehicle fleets. For fleets between two of the three types there would be to modify/adapt these proposed models for each fleet.

For example, an intermediate fleet is the sales force of a company where there are clients to visit, and where normally there's an assigned vehicle to each sales associate, in this case the most important part is calculating the routes to travel in a determined time in order to minimize variable costs or maximize the number of visits, considering that the geographical area to cover is divided in zones to have a sales force equilibrium.

4.3.2. Planned routes

This kind of fleet is referred in scientific literature as "Vehicle Routing Problem–VRP" and has developed specific methods and models for its resolution. In the market, there is specific available software to solve this kind of fleet that has been already developed and explained in the previous theoretical and practical case in the epigraph 4.1.

The graph 16 shows the process to calculate the optimal number of vehicles of the fleet in order to start its operations since the beginning for this case.



Graph 16: process to calculate the optimal number of vehicles in a fleet with planned routes.

The first step is to establish the service level (time), the approximate number of vehicles that would be used to accomplish it, and the capacity of each vehicles (m^3, passengers, tons, etc.).

The second step is calculating the routes, which is recommended to be done with a specific software, and considering one or several sub-optimal conditions like minimizing fuel consumption, traveled distance, time of service, or maximize the vehicle's load capacity.

The results are the real service level, routes to travel, or distance to travel. It's very important what vehicles are being used, because it could happen that some vehicles initially assigned won't be used, for which they are no longer necessary.

With the obtained results, it can verified if the service level is met, if it doesn't then they have to go back to the previous phase of establishing the service level or number of vehicles and its capacities, depending on the case one or the other or both will be modified.

If the service level is met, we will get the number of vehicles and their capacities (type of vehicles), the number of drivers and distance to travel, for which the only variable to establish is the vehicle's brand and equipment.

The fleet's direct costs or budget for a determined time period is the sum of the fixed costs and variable operational costs (graph 2).

The fixed costs are determined mainly by the vehicle's type, brand, equipment, and the number of drivers. The variable operational costs are determined by traveled distance or working hours.

Once established the vehicle's brand and equipment, the variable operational costs can be calculated using the distance to travel, obtaining the direct costs or budget for the studying period, some of the direct costs require an estimate or prevision.

If the budget wasn't met, it'd be needed to choose other vehicle's brands and/or models and have to check again if the budget would be met. If none of the solutions meets the budget, then they have to go back to the previous phase of establishing the service level and number of vehicles. If the vehicle fleet meets the budget, the next phase is acquiring the vehicles.

First, it needs to be proven that a better solution doesn't dominate the chosen one, like explained previously in the case study from the epigraph 4.1. If m is the optimal number of vehicles of the chosen solution, then the service level and its associated costs will be calculated for m -1, -2, -3 vehicles and will compare it to the chosen solution, if said solution is dominated by a better one the last will be chosen.

Another option is to calculate the relationship between the service level and direct costs like in the theoretical case in the epigraph 4.1, and choose the better solution for the vehicle fleet.

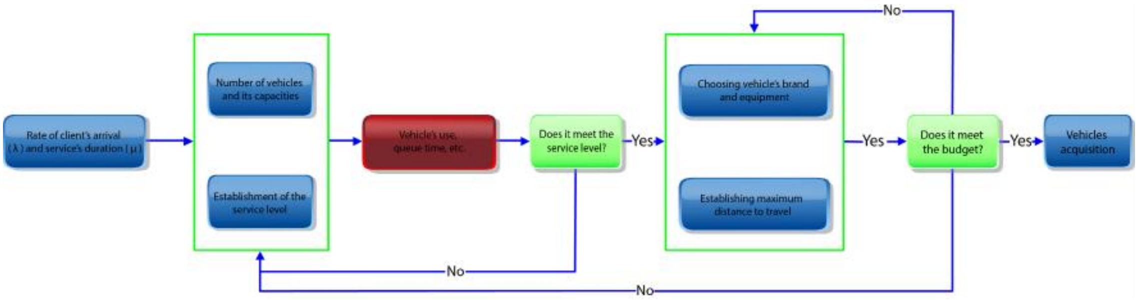
4.3.3. Aleatory demand of vehicles in the fleet

Scientific literature on operational investigation has developed methods and models for resolving this kind of fleet, such as queuing theory, simulation, or statistics.

There isn't a specific software, for which a generic software on queuing theory, simulation (Simio, http://www.simio.com/index.php), spreadsheet, or programming is used depending on how complex is each case.

The use of the vehicle's capacity is the main or secondary aspect depending on each case. In car rentals or taxicabs services, the cost of using the vehicle is the same as if one client uses it or several at the same time, the most important for the company is that the vehicle performs the service the maximum time possible, for which the use of the vehicle's capacity is a secondary aspect. In the case of incidents that demand attendance, vehicles are assigned to a crew and specific equipment, for which the use of the vehicle's capacity is a secondary aspect. In the case of a public work or mining, the use of the vehicle's capacity and the percentage used of the vehicle's capacity are the main aspect.

The graph 17 shows the process for calculating the optimal number of vehicles of the fleet in order to start its operations since the beginning for this case.



Graph 17: process for calculating the optimal number of vehicles in a fleet with aleatory demand.

The first step is to establish the service level, the approximate number of vehicles needed to meet it, and the capacity of each vehicle (m^3, passengers, tons, etc).

The service level to establish could be one of the following: that there's always available vehicles, and for this reason that there's no queue; that the queue time is shorter than a determined time, the vehicle's use rate or that several incidents can be assisted at the same time.

The results are the vehicle's use percentage, the queue time, etc. It's very important to consider what vehicles are used because it could happen that some vehicles that were originally assigned are not being use, and for this reason they aren't necessary.

With these results it can be checked if the established service level is met, and if not they need to go back to the previous phase to establish the service level or number of vehicles and their capacities, depending on the case one or the other or both will be modified.

If the service level is met, we will get the number of vehicles and their capacities (type of vehicles), and the number of drivers if the service requires it. The next step is to establish the maximum distance to travel, the vehicle's brands and equipment to calculate the vehicle's direct costs and budget for the studying period.

There needs to be an established limit of maximum traveled kilometers for the studying period, to be able to meet the direct costs or budget, since the goal is to obtain profits from the fleet. Taking this traveled kilometer limit as reference, there must be to establish policies for the client to be responsible of all or some of the vehicle's variable operational costs.

For example, renting companies would establish different rates depending on distance traveled or a rate per mile/kilometer traveled. In a taxicab company, picking-up clients can be done at a taxi station, or traveling "empty" kilometers until a client hails the cab, for which there must be an established limit for maximum "empty" kilometers to travel.

The higher the traveled distance limit is, the lower is the budget for the vehicle's acquisition, and on the contrary, the higher the budget for the vehicle's acquisition, the lower must be the traveled distance limit.

Once established the vehicle's brands and equipment, and the maximum distance to travel, one can calculate the variable operational costs using the maximum distance limit, obtaining the direct costs or budget for the studying period. Some of the direct costs and residual values require an estimate or prevision.

First, it needs to be proven that a better solution doesn't dominate the chosen one, like explained previously in the case study from the epigraph 4.1. If m is the optimal number of vehicles of the chosen solution, then the service level and its associated costs will be calculated for m -1, -2, -3 vehicles and will compare it to the chosen solution, if said solution is dominated by a better one the last will be chosen.

Another option is to calculate the relationship between the service level and total cost like in the theoretical case in epigraph 4.1, and choose a better solution for the vehicle fleet.

Queuing theory

The general model for queuing theory M/M/c (λ, μ, c), which is the most basic one of this discipline, and the rule first in-first out, are the ones proposed to calculate the optimal number of vehicles and to establish the service level.

Each vehicle fleet can have several variations for this basic model, and for this reason requires a specific model designed for the fleet's characteristics and goals.

This model M/M/c has two variants: the open model (infinite number of clients), and the closed model (finite number of clients). The formulas that characterize each one of them are different because the queue is made in a different way.

1° The open model is characterized by the following variables:

- λ is the rate of clients arrival (people, incidents, services to perform, etc.) to the system by a determined period of time (consider that it has a Poisson distribution and that two or more clients can't arrive at the same time to the system).

- μ is how long a vehicle is used by the clients (consider that it has an exponential distribution and that it's the same for all vehicles).

- c is the number of vehicles to assist the clients that arrive to the system.

For an open model to be stable and to avoid having an infinite queue, it must meet the following condition:

$$\rho = \text{Average arrival rate/System's capacity} = \lambda / c\mu; \ \rho < 1$$

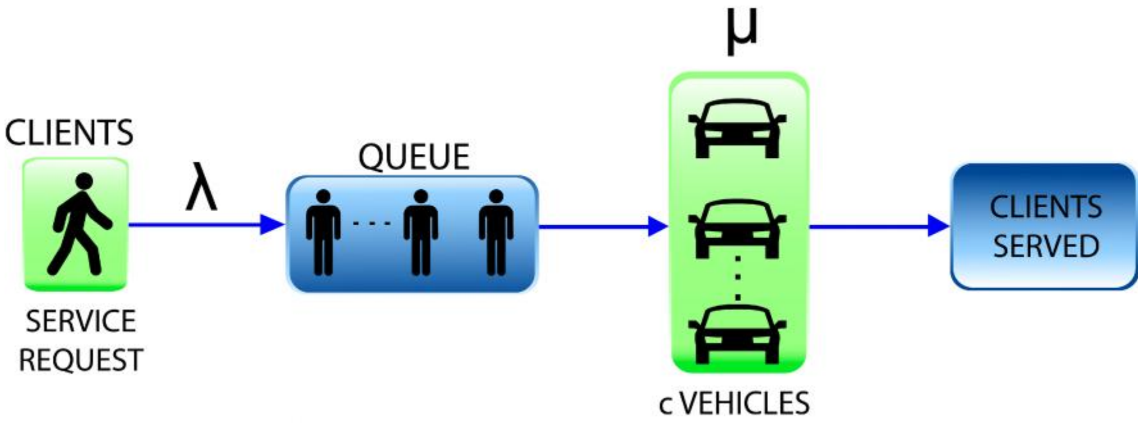
Equation 1: system's minimum capacity.

The numbers of clients in the system are the ones using the vehicles and the ones waiting in the queue.

Applying these three variables to the model's final equations, the principle attributes that characterize said model are obtained. Some of these attributes are the percentage of the vehicle's usage, average waiting time in queue, probability of queuing, average number of units in queue, average number of inactive vehicles, number of units that are being assisted by a vehicle, number of clients in the system, average time in the system, probability of having to wait in queue, etc.

The values λ and μ are established for the clients, and in order to meet the condition of the equation 1 there's a minimum number of vehicles that the fleet must hold. On the contrary, if there are a number of vehicles equal or higher than the number of clients in the system, there won't be any client in the queue, and those are the maximum service level and number of vehicles that the fleet must hold. Therefore, depending on λ and μ there's a maximum and minimum number of vehicles that the fleet must have.

Following is developed a simple applicable example of an open system for a renting company. To simplify this model, consider that it only has one operations workplace and there can't be any reservations. The model is like shown in the graph 18.



Graph 18: open system for a vehicle fleet's queuing theory

The clients' arrival to the system is of 5 people per hour (λ), the rate of usage of any vehicle is of 80 hours (μ), and there's been established that the service level is that the clients don't wait more than an hour in queue from the moment they request the vehicle.

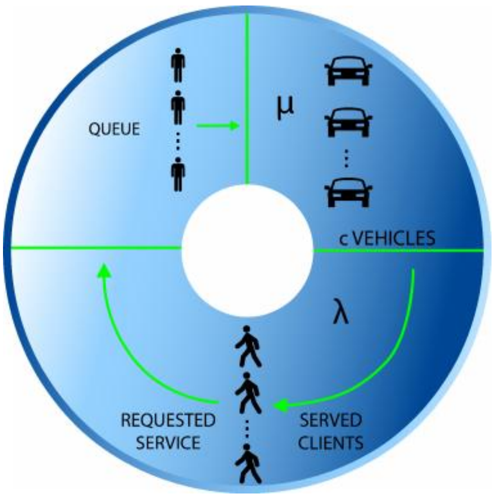
Considering this data and using the equation 1, the minimum number of vehicles for the system to be stable is 400 vehicles, and there's a maximum number of vehicles in which there's no queue and all clients are using all vehicles. Between these two limits, it's calculated the number of vehicles needed in the fleet to meet the service level previously established, using the model's final equations from the open model M/M/c.

Having more than one operations workplace, the vehicles can be picked-up from any of these workplaces, and it could happen that each workplace has the optimal number of vehicles, and for this reason for the whole fleet. However, because of how the service operates, clients would return the vehicles in some workplaces more than in others; in consequence, some workplaces would have more vehicles than others, causing that the service level isn't met in those workplaces with fewer vehicles than their optimal number, and this would cause a misbalance in the established service level.

For this reason, it must be assured that each workplace has its optimal number of vehicles by transferring vehicles among workplaces, and therefore it's recommendable to establish vehicle transfer policies among them. (Zhaolin Li, Feng Tao. 2010).

2º The closed model is characterized by the following three variables M/M/c (λ, μ, c):

- λ is the time between a vehicle's return until a new vehicle is requested (consider that it has an exponential distribution and that it's the same for all clients).
- μ is the time a vehicle is used by the clients (consider that it has an exponential distribution and that it's the same for all vehicles).
- c is the number of vehicles to assist the finite number of clients in the system.



Graph 19: closed system for a vehicles fleet's queuing theory.

The numbers of clients in the system are the ones in queue, the ones using the vehicles, and the ones that haven't request a vehicle.

The minimum number of vehicles that the system could have is one, and the maximum number of vehicles is the same as the number of clients in the system so there wouldn't have waiting time, and this is the maximum service level.

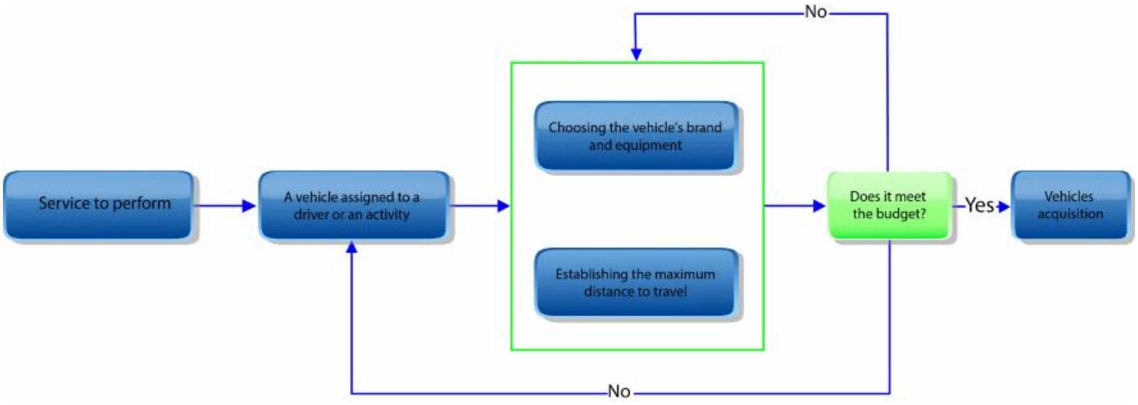
Between these two limits is calculated the number of vehicles c that the fleet needs, using the model's final equations of the closed method M/M/c in order to meet the established service level.

M/M/c is the most generic model for queuing theory, but there are also several variations, and by using the queuing theory any model could be designed to adapt to the fleet's operations.

4.3.4. An assigned driver/user/activity to a fleet´s vehicle

In this case the service level is the number of drivers/users, or the activity to perform, calculating the optimal number of vehicles is simple using a spreadsheet.

The graph 20 shows the process of calculating the optimal number of vehicles of the fleet in order to start its operations since the beginning for this case.



Graph 20: process to calculate the optimal number of vehicles with an assigned driver/user/activity to one of the fleet's vehicles.

The first step is to know how many users/drivers or activities to perform are going to be assigned to a vehicle.

Once established the service level, the results are the number of vehicles and their capacities (type of vehicles), and the number of drivers, if the service requires it. For this reason, there are two variables to establish: the maximum distance to be traveled, and the vehicle's brands and equipments.

A maximum limit of traveled kilometers need to be establish for the studying period, in order to meet the direct costs or determined budget, since the goal is to obtain profits from the fleet. From this maximum limit of traveled kilometers, there must be to establish policies for the client to be responsible of all or some of the vehicle’s variable operational costs.

For example, renting companies that are focused on sales associates or executives of other companies should establish only one change of tires, set the maximum kilometers traveled per period, or establish different rates depending on the traveled distance.

Once established the service level, there are other two variables that need to be established: the vehicle’s brands and equipment, and the maximum traveled distance in order to calculate the direct costs or budget for the studying period. The higher the traveled distance limit is, the lower is the budget for the vehicle’s acquisition, and on the contrary, the higher the budget for the vehicle’s acquisition, the lower must be the traveled distance limit.

Once established the vehicle’s brands and equipment, and the maximum distance to travel, one can calculate the variable operational costs and the residual value using the maximum distance limit, obtaining the direct costs or budget for the studying period. Some of the direct costs require an estimate or prevision

First, it needs to be proven that a better solution doesn’t dominate the chosen one, like explained previously in the case study from the epigraph 4.1. If m is the optimal number of vehicles of the chosen solution, then the service level and its associated costs will be calculated for m -1, -2, -3 vehicles and will compare it to the chosen solution, if said solution is dominated by a better one the last will be chosen.

Another option is to calculate the relationship between service level and total cost like in the theoretical case in epigraph 4.1, and choose a better solution for the vehicle fleet.

5. ADQUIRING THE FLEET´S VEHICLES

The organization has to design and implement the policy for acquiring the vehicles such as the acquiring modality, the brands and range, the equipment, the type of fuel, the type of insurance, and the vehicle's supplier.

5.1.1. How to acquire the fleet's vehicles

One of the most important decisions in fleet management is how the vehicles are acquired. There are several options, such as acquiring them as property, by renting/leasing, through a special loan destined to vehicle's fleet, or using car sharing. Which one to choose depends on the following factors:

- The organization's strategy.

If vehicle fleet management is the main activity of the organization (passenger transportation, packaging, shipping by land, mail services, etc.), the best solution is to acquire the vehicle as property, since it gives the organization absolute control over the vehicles to develop the organization's strategy.

The organization can make any modifications needed to the vehicles, repair them in their own workshops, and not having to wait for a third-party; as well as using the vehicles and dispose them from service when needed. Besides, the vehicles represent the brand image, and could have on them the organization's publicity while being used.

If vehicle fleet management is a secondary activity in the organization (using the car for particular needs of the executives or sales associates of the organization), the best solution is to acquire the vehicles through renting/leasing or car sharing.

The organization has to consider that renting/leasing contracts usually last 2 years. If we don't meet the 2 years contract, the renting/leasing company will penalize us. It usually includes other services such as maintenance, change of tires, etc. causing that the organization have less freedom to manage the fleet and develop the general strategy of the organization.

- Vehicle's characteristics and services to perform.

For special vehicles that require special equipment or fitting bodies in order to perform a determined service (land shipping services, mailing services, cleaning street, etc.) the best solution is to acquire them as property, because it allows the organization to make all the modifications needed. Besides, they are very difficult to sell because they have a limited second hand market, and their special equipment has a residual value that's almost null, which would cause the renting/leasing type of acquisition even more expensive, or may not be available at all.

The vehicles that are used to perform a service for transporting passengers/users, and that don't require any modifications like the executives and/or sales associates of a company, car rentals, etc., the best solution is to acquire them through renting/leasing.

- Financial and fiscal considerations.

The acquisition as property requires an initial investment; on the contrary, the renting/leasing type requires a smaller financial capacity, and it's considered an expense in the income statement.

Another possibility is to acquire second-hand vehicles, since vehicles with young ages have practically the same benefits and costs than new vehicles, but are more affordable to acquire. For this reason, the organization needs to establish the maximum age/mileage that these vehicles can have to be acquired.

- The market where the organization operates.

If the organization operates in a market with a very variable short-middle term demand, the optimal number of needed vehicles will vary over time considerably, and for this reason, the best solution is to acquire vehicles as property since they can be disposed from the service and sold when needed.

If the organization operates in a very stable market with a low variability in the short-middle term demand, the optimal number of vehicles needed practically won't vary over time, and the best solution to acquire the vehicles is through renting/leasing or car sharing.

In some public contents of municipality services such as cleaning or trash collection services, because of their own requirements and specifications the fleet must be acquired as property.

- Outsourced part of the fleet to a third party

An intermediate solution is to acquire part of the vehicles as property under the fleet's optimal vehicle number, and the rest of the vehicles up to the optimal vehicle number is reached, through renting/outsourced to a third party, giving to the organization flexibility to adapt to the market's demands. This practice is usually done by distribution of goods and courier companies because there's great transportation supply from independent freelance drivers with their own vehicles.

5.1.2. Choosing the vehicle's brands and ranges

A vehicle with a capacity, size, power, fuel or functionality could be acquired in different brands such as premium, medium, or low-cost; and in ranges such as high, medium or low. The organization has to establish the vehicle's brands, and the type of range to acquire, choosing which one depends on the following factors:

- Acquisition costs.

The acquisition cost is one of the key factors when acquiring a vehicle. Vehicles of premium brands and/or high-end have higher acquisition costs than those of medium-low brands and range.

- Maintenance and repairing costs.

Premium brands and/or high-end vehicles have higher maintenance and repairing costs than those of medium-low brands and range. Some vehicles brands and/or models have more alternative spare parts than others, and can lower costs up to the 30-40% if the organization has a large vehicle fleet as property with its own workshop.

- Registration fee and road tax.

In Spain, the cost over registration depends on the vehicle's emissions. The vehicles of premium brands usually have engines with higher cylinder capacity and power, which have higher contaminating emissions than vehicles with medium-low brands, and for this reason, the registration fee and road taxes are higher.

- Fuel consumption.

High-end vehicles usually have higher cylinder capacity and power than medium-low brands, and for this reason they consume more fuel for the same traveled distance.

- Vehicle's residual value.

Some vehicle's brands have more residual values than others, and this is due to several factors such as their brand image, reliability, low maintenance or repairing easiness.

- The organization's image.

Premium brand and/or high-end range vehicles represent a better image for the organization than medium-low brands and/or range.

- Vehicle's operability.

Premium brand and/or high-end range vehicles have better technology, functionality, operability, durability and reliability than medium-low brands and/or range.

- Respecting the environment.

Certain vehicles brands are more environmentally-friendly than others because their vehicles emit less contaminating emissions and many of their components can be recycled.

- The organization's targeted market.

If the organization's performed services that are directed to clients with a high acquisitive purchasing power, premium brands and/or high-end range vehicles should be acquired, and on the opposite case, medium-low brands and/or range vehicles will be acquired.

- Services provided by the organization.

If it doesn't make a difference to the clients what vehicles are used to perform the service, then medium-low brands and/or range vehicles should be acquired, since they're cheaper.

- Gratification system for the company's workers.

It is recommended to acquire premium brand and/or high-end range vehicles for the organization's executives, and for the others cases, medium-low brands and/or range should be acquired.

- The vehicle's specialization.

The more specialized a vehicle is, the fewer the number of brands and ranges available, for which there are only a few brands left from where to choose.

- Type of fuel.

Depending on the type of fuel a vehicle uses, it could only be acquired from certain brands and/or ranges. For example, electric vehicles are only available in high or low ranges, and can only be acquired in certain brands.

A particular case is the humanitarian scope, in which two brands such as Toyota and Nissan cover most of the total market and for this reason, the organization have to choose between one of these brands. Besides, these brands have a high residual value in countries where they are used by NGOs (non-governmental organization) for humanitarian services because of their easy maintenance and repairing.

A mixed solution is to acquire a set of vehicles from each brand of vehicles and/or range that are destined to different clients depending on their characteristics, use, and goals.

5.1.3. Choosing the type of equipment for the vehicle fleet

The organization has to establish which equipment options can be acquired, and that depends on the following factors:

- Acquisition costs.

The more equipment a vehicle has, the higher its acquisition, maintenance, and repairing costs.

- The equipment's specialization.

The more specialized the equipment is, the higher its acquisition, maintenance, and repairing costs, besides its residual value is almost null.

- The equipment's functionality.

The equipment to acquire must be useful and functional for the vehicle's clients/users.

- The type of vehicle.

The organization must give priority to acquiring safety equipment, over any other kind of equipment.

5.1.4. Choosing the type of fuel for the vehicle fleet

A vehicle can be propelled by one or more (hybrid) of the following fuels: fossil fuels, hydrogen, ethanol, compressed air, natural gas, or electric. The organization has to establish the kind of fuel to use in the vehicles and it depends on the following factors:

- Acquisition costs.

For the same model, the diesel or gas versions have lower acquisition costs than the rest of the fuels. However, public administrations offer tax incentives, grants, and other types of advantages to mitigate this high acquiring price.

- Maintenance and repairing costs.

The maintenance and repairing costs for the same model in the diesel and gas versions are lower than the rest of fuels.

- Fuel cost.

The costs of certain types of fuels are less expensive than others. The energy cost of electric vehicles is much cheaper than diesel or gas vehicles.

- Registration fees.

The less contaminating emissions a vehicle has, the less expensive the registration fee is in Spain. For this reason, the registration fee is more expensive in diesel and gas vehicles than for the rest of the fuels.

- Fuel consumption.

The fuel consumption in diesel and gas vehicles is higher than for the rest of fuels.

- Fuel prices.

If the prices of diesel and gas are high, it encourages the acquisition of vehicles that use alternative fuels. On the contrary, if the prices of diesel or gas are low, this discourages the acquisition of vehicles that use alternative fuels. The cost of electric power is lower than the cost of fossil fuels.

- Type of vehicle.

Determined types of vehicles can only be acquired in certain fuels like heavy vehicles that work mainly with diesel or natural gas.

- Residual value.

Some fuels have higher residual values than others. Electric vehicles have lower residual values than diesel or gas vehicles due to the battery's useful life, and their acquisition costs.

- Traveled kilometers/miles during the vehicle's life.

For the same vehicle's model, brand and power using different fuels, there is a determined number of kilometers/miles in which some fuels have lower cost of the vehicle's life (TCO –

Total Cost of Ownership) than others, and for this reason it has to be calculated how many kilometers/miles can be traveled for this to happen.

- Respecting the environment.

The non-fossil fuels are better for the environment because they emit less or none contaminating emissions.

- Intensive use of the vehicle.

If the vehicles are used intensively, the best option is to use diesel or gas vehicles since the fuel's refilling time takes a few minutes, on the contrary, the refilling time for electric vehicles is longer depending on the available facilities, and can last from 20 minutes up to eight hours depending on the type of recharging.

- The company's strategy.

The fuel used in the organization's vehicles has to develop the company's general strategy. If one of the company's pillars is respecting the environment, the vehicle fleet should have vehicles that don't contaminate such as electric cars; and if fossil fuels are used, to choose the fuel with fewer contaminating emissions or use a mix of both such as hybrid vehicles.

- Vehicle's autonomy.

This is a key factor because the organization needs to have a minimum autonomy in order to perform the service, and for this reason, we can't use electric vehicles in the fleet if they don't meet this minimum autonomy.

- Available infrastructure.

We need to have the appropriate facilities to use certain fuels. if this isn't developed enough, it limits the vehicle's use to a geographic location. Diesel and gas vehicles have a very developed infrastructure to refill with fuel in any geographic location, more than any other type of fuel.

- Type of driving

The way the vehicle is driven has a great influence in the type of energy source to use. If the vehicle is used in urban environments, where there are several stops, hybrid vehicles are recommended. On the contrary, if the vehicle is used mostly in highways, where there are barely any stops, a hybrid vehicle wouldn’t be recommended.

A mixed solution is to use a set of vehicles that use different types of fuel that are destined to different clients/users depending on their characteristics, use and goals.

5.1.5. Choosing the type of insurance for the vehicle fleet

A vehicle can mainly have three types of insurance: full coverage, franchise or third party. Which to choose depends on the following factors:

- Cost of insurance.

Full coverage insurance is the most expensive of the three, but it covers any damage the vehicle might face.

- Importance of the vehicle.

In a vehicle fleet, some vehicles are more important than others, for which it’s advisable that they have full coverage insurance, and the rest of the vehicles have a franchise or third party insurance.

- Vehicle’s value.

The higher the vehicle’s value, the highest the insurance cost, and for this reason, it’s advisable that it has a full coverage risk.

- Vehicle’s age.

The older a vehicle is, the lower the residual value, and in this case the full coverage insurance doesn’t compensate economically after a certain age, and it’s advisable to have the vehicle insurance with franchise or third-parties.

- Number of reports to the insurance.

If the organization reports a lot of incidents to the insurance company, the most advisable option will be full coverage insurance, on the contrary if the organization reports few incidents to the insurance company, the most advisable option will be insurance with franchise or a third-party. It has to be considered that some renting/leasing contracts include the vehicle's insurance.

5.1.5. Choosing the suppliers for the vehicle fleet

The organization has to choose the vehicles' suppliers. If the vehicle is acquired as property, it will be acquired directly from the manufacturer or the official dealer in the country; if the vehicle is acquired through renting/leasing, the organization has to choose the renting/leasing company that depends on the following factors:

- Contract cost.

The organization must compare the different economic options from the renting/leasing companies for the same vehicle's brand and model. Some companies are more competitive in certain brands and models.

- The contract's duration.

The organization has to consider the minimum and maximum duration of the contract, if it adapts to the organization's renovation/disposal policy, and what's the penalization for not meeting the contract's length.

- Services included in the contract.

The organization has to consider what services are included in the contract like maintenance, insurance, road assistance, tires, traffic tickets/fines management or traffic accidents management.

- Contract's flexibility.

The organization has to consider if the contract has flexible conditions like the cost of each additional kilometer/mile traveled, the number of ticket/fines management, the workshop options, the insurance or the change of tires established in the contract.

- Telematics services.

The organization has to consider if the renting/leasing company provides telematics services for the vehicles follow up, such as fuel consumption, GPS (global positioning system), or the way the drivers drive.

- Vehicle's delivery time.

The organization has to consider the time that takes between the vehicle is ordered and delivered to the organization by the supplier.

- Payment options.

The organization has to consider the payment options that the renting/leasing company offers.

5.1.6. Organizational factors

The organization has to consider the following organization factors for the vehicles acquisition:

Establishing the central for vehicles acquisition, with the following goals: acquire all the vehicles; authorize the vehicles acquisition; manage the vehicle's suppliers; negotiate the framework agreement with the vehicle's suppliers; avoid duplicating; control the vehicle's assigned budget and the acquisition process; and that the organization achieves the established optimal number of vehicles.

The organization has to standardize what vehicles can be acquired establishing the brands, models, type of fuel, and equipment with the following goals: get the best acquisition, maintenance, and repairing costs reaching framework agreements with the vehicles' suppliers.

It is advisable to have two vehicles' suppliers, manufacturers and/or renting/leasing companies at the most in order to reduce costs and get better prices due to the high number of vehicles in the contract.

Another way to acquire the vehicles is doing a contest, in which the organization presents a number of conditions and the competing companies present their offers, so the organization can choose the one that adapts better to their needs, requirements and goals.

6. VEHICLE FLEET OPERATION

The organization has to design and implement the fleet operation policy, such as maintenance management, breakdown management, spare parts management, control and reduction of fuel consumption, tires management, prevention and reduction of traffic accidents, or the use of owned or outsourced workshops.

The organization has to write and establish the operations manual for the fleet's vehicles concerning their maintenance, use, safety, fuel consumption, driving, and what to do in case of an accident or breakdown. This manual has to be given and explained to every driver and/or person in charge of the vehicle.

The goal of vehicle operations is that they operate the maximum time possible in order to meet the established service level, with the least possible variable operational costs. The main activities of vehicles operations are presented below.

6.1.1. Vehicle fleet maintenance management

Maintenance management is one of the most important activities in vehicle fleet management, because not doing the maintenance in the established period and according the manufacturer's indications has several consequences: the possibility that the motor break downs for not changing the oil or the timing belt; not detecting possible breakdowns or worn out elements that affect the vehicle's safety; the vehicle's deterioration due to use; and having a higher number of breakdowns, consumption and contaminating emissions.

The organization has to establish a system to plan ahead of time the vehicle's maintenance. In order to do that, the vehicle's traveled distance or working hours have to be known every week or month. The best solution is to use a telematic system that reports this data automatically; if the telematic system isn't available, the organization will have to establish:

- The person responsible of reporting this data every week or month. Said person could be each vehicle's driver or a person in charge of a set of vehicles.
- The way to do this is introducing the data to the system directly, or by communicating it to the maintenance manager via text (SMS), email, telephone or fax.

Once the vehicle data for the traveled distance or working hours is known, maintenance can be planned considering an average prevision of the vehicles use by week or month getting the approximate date to do said maintenance.

The maintenance planning has to be handed to the person in charge of the vehicles or drivers so they know when it's going to be done.

If a vehicle hasn't gone through maintenance in its correspondent period, it has to be communicated to the person in charge of the vehicle immediately, and this vehicle will have priority for maintenance before other vehicles.

The organization has to establish which vehicles have priority for doing maintenance and for repairing breakdowns because in the fleet there are vehicles that are more important for the service performance than others, for which these vehicles have to have priority.

The organization has to follow the manufacturer's instructions, and comply with current laws for vehicles' maintenance and breakdowns repairing.

6.1.2. Management and analysis of the vehicle's breakdowns

The organization has to implement a prevention and analysis system for breakdowns, because a breakdown causes several inconveniences: not using the vehicle for a determined period of time, which stops the service performance; some costs such as the breakdown, the towing services, and the vehicle's substitution; it could cause an accident, or that the vehicle doesn't pass the technical inspection; damage to the organization's brand image, and possible problems for the clients/users if the breakdown takes place when they're using it.

To assure the vehicle's safety and to prevent possible breakdowns the organization has to implement the following measures:

- Before and after a vehicle is used for service performance, certain mechanical and safety aspects must be checked, like the engine, tires, breaks, suspension, steering, mirrors and seatbelts. In order to do this, there must be a chart with all the things to carry out, and any defects and breakdowns will be written down. If the vehicle has a major breakdown or defect, it won't be used. Once the vehicle has been used and there's been an incident and/or breakdown, it'll be written down in the chart and handed to the person in charge of the vehicle or the fleet manager, and a copy must stay in the vehicle so the next user knows the vehicle's condition. The current defects and breakdowns in the vehicle have to be repaired immediately.

- In a vehicle fleet around 20% of the breakdowns in determined systems or components cause around 80% of the breakdowns costs (ABC analysis). These breakdowns are caused by diverse reasons like not doing maintenance at the right time and according to the manufacturer's instructions; the inadequate use of the vehicles, failure in materials, deterioration, or poor designing of the components. For this reason these 20% of breakdowns need to be identified. The organization has to classify these breakdowns and their costs by system, such as motor, transmission, steering, body, lighting, etc. and these systems by subsystems. Once classified, they must be analyzed to know which ones are the ones producing these 20% of the breakdowns, their cause and establish preventive measures to avoid them.

For example if a component breaks down frequently, a solution would be to look for another supplier for it, or if there are breakdowns because the way the vehicle is driven, the best solution is to train the users/drivers.

Breakdowns in some cases are a factor to consider in the acquisition of some types of vehicles. If the vehicle is used in urban areas with many stops while carrying heavy weight, to avoid breakdowns in the gearbox or problems with the clutch, a solution will be to buy vehicles with automatic transmission.

6.1.3. Vehicle fleet's spare parts management

The organization has to establish what types of spare parts are used in the fleet's vehicle, like the spare parts made by the vehicle's manufacturer, or by other alternative suppliers. It has to be considered if we manage a large fleet and have our own workshop.

About 80% of a vehicle's components are made by external suppliers, and they supply these components (spare parts) to the vehicle's manufacturer and the replacement market. The only difference between a spare part of an external supplier and the vehicle's manufacturer in the replacement market is the packaging; each one uses their commercial brand on the same spare parts made by the external supplier.

There are other types of spare parts manufacturers that only make and supply the replacement market, and they don't supply components to the vehicle's manufacturers.

The main advantage of using alternative spare parts is that it's less expensive than the ones supplied from the vehicle's manufacturer, and can represents up to 40% of savings.

Using alternative spare parts depends on the following factors:

- The spare part specialty.

The more specialized a spare part is, the fewer alternative spare part there is available, and for the same reason, less suppliers for said spare part. Spare parts with high rotation rate such as brake pads, filters, clutches, etc. have a large alternative market.

- Vehicle's brand.

Some brands that are big manufacturers have more alternative spare parts than smaller manufacturers.

- Alternative spare part's distribution.

Depending on the country, the alternative spare parts supplier can be present in the country, or supply the market through a commercial partner.

- Current valid legislation.

Current valid legislations control the manufacturing and commercialization for spare parts.

Around 20% of the spare parts cause 80% of the total costs for said spare parts (ABC analysis). For this reason, the organization has to classify these spare parts and their costs by system, such as motor, transmission, steering, body, lighting, etc. and these systems by subsystems. Once classified, they must be analyzed by system to know which ones are the ones producing these 80% of the total costs, and look for alternative suppliers. It's normal that there's a relationship between common breakdowns and the spare parts to fix them.

Looking for alternative spare parts suppliers can be done in different ways, like using the services of a company like Tecdoc (http://www.tecdoc.de/es/home.html), or special catalogues that are published for the components manufacturers' associations of each country, in Spain is called Sernauto (http://www.sernauto.es/), or the components manufacturers' fairs like Automechanika (http://automechanika.messefrankfurt.com/global/en/besucher/willkommen.html).

It's recommended that the spare parts are acquired in the following ways:

- Getting into a framework agreement with each alternative spare parts manufacturer, or their commercial associate in the country.

- Getting into a framework agreement with a wholesale dealer in which it is included several spare parts manufacturers, or use an online platform that puts together several spare parts manufacturers.

The framework agreement must be done by percentage discount over the public offering price (POP) for the spare parts brands and/or systems like filters, clutches, pilots, etc. and/or a rebate discount (%) for the total annual bill.

6.1.4. Control and reduction of the vehicle's fuel consumption

The organization has to design and establish the adequate measures to control and reduce the fuel consumption and contaminating emissions, because the fuel consumption can be up to 70%-80% of the variable operational costs, and 30% of the direct costs, and is also the main source of contaminating emissions if the vehicles use fossil fuels like diesel or gas.

A vehicle's fuel consumption depends on internal aspects such as the way the vehicle is driven, type of fuel, vehicle's age, characteristics of the engine, vehicle's weight, tires pressure, vehicle's aerodynamic, vehicle's schedule of use, advancement and rolling resistance, vehicle's equipment and on external aspects such as weather conditions, seasonal factors, traffic conditions; type of routes, road's condition, or fuel's quality.

The main measures have to be taken on the vehicle's drivers, because they are the ones that cause the most impacts on the vehicle's fuel reduction. The main ones are: train drivers on efficient driving, use devices that help and correct the way they drive; classify drivers who have lower fuel consumption and share their best practices with the rest of the drivers; or implement a system of incentives for the fuel's consumption reduction.

Other measures for the vehicle's fuel consumption reduction are the following: use speed limiters; use tires with low rolling resistance; do the needed maintenance in the established period of time, and under the manufacturer's instructions; use devices that turn off the motor during idle time; use aerodynamic devices; plan the route ahead of time; control the private use of the vehicles; use the right pressure for the tires; control the load weight that's being transported; avoid jamming; assign the vehicles with less fuel consumption to the longest routes; or reprogram the motor control center (MCC).

To know the fuel's consumption, it has to be measured. If we use a telematic service and/or fuel cards system, it will be automatically reported, if not, the organization has to establish:

- The person in charge of reporting this data, that could be the vehicle's driver or the person in charge of a set of vehicles

- The way to do this is introducing the data to the system directly, or by communicating it to the maintenance manager via text (SMS), email, telephone or fax

This data could be reported each time the vehicle is refueled, or every certain period of time like weekly or monthly. At the same time, the traveled distance and date must be reported too in order to calculate the fuel's consumption by liters per 100 kilometers/miles.

The data for vehicle's consumption could be analyzed and structured applying the following techniques.

- Descriptive statistics: present and characterize a set of data like average consumption, maximum and minimum consumption, consumption range, or what 20% of drivers, vehicles, routes, etc. causes the 80% of the fuel's consumption

- Lineal or multiple regression models: create a relation between a variable with one or multiple variables, such as creating the relation between fuel consumption and the vehicle's mileage

- Variance analysis: find difference between data groups like knowing if there's any difference between vehicle's brands, routes, drivers, etc. in the fuel consumption

- Multivariate analysis: analyze simultaneously a set of multivariate data, like identifying behavioral patterns such as the drivers with the highest fuel consumption are those that are 32 years old, with 3 years of experience, haven't received an efficient driving course, and drive in an aggressive way

- Operations research: use mathematical models in order to find the best optimal solution for a problem with limited resources like optimizing routes, the fleet's size, etc. to reduce the total fuel's consumption

The information obtained for the reduction and control of fuel applying these techniques are the following.

- Identify the drivers, vehicles and routes with higher fuel consumption than expected.

- Identify the drivers that don't have an efficient way of driving.

- Identify the drivers that go over the speeding limit.

- Identify if it's viable to incorporate idle time devices that turn off the engine during the stops.

- Identify if it's possible to buy a private fuel deposit where the vehicles can refuel, and for this reason the fuel price would be lower.

- It allows the organization to plan the route ahead of time, finding the shorter or with less traffic route.

- It allows the organization to control the misuse of the vehicles.

- It allows the organization to know if the fuel is used for private use.

- Assign vehicles with less fuel consumption to the longest routes.

- Identify behavioral patterns related with fuel consumption.
- It allows the organization to know if hybrid or electric vehicles meet the fleet's operational requirements in order to be acquired.

If the organization has a large fleet, it's advised to have our own fuel deposit where the fleet's vehicles can refuel, this gives certain advantages like paying less for the fuel when buying high volumes, having an easy and effective refuel control, and refuel flexibility.

Using hedging derivative financial instruments like futures and/or options on the fuel's price, the organization could get benefits of the decreases in fuel prices or have a fixed fuel's price for a determined period of time.

If the fleet uses alternative fuels, the most advisable thing will be to share recharging facilities with other organizations, due to their costs.

6.1.5. Choosing, controlling and monitoring the vehicle's tires

The organization has to design and establish the system to control and monitor the tires due to the fact they can be up to 15-20% of the variable operational costs, and between 3-5% of the direct costs through the entire vehicle's life.

Tires are one of the key elements of vehicle's safety, which can transform it from a safe vehicle to an unsafe one depending on the brand and/or model of the tires, so the organization has to establish the tire's brand, if premium or low-cost, to use in the fleet.

Tire's pressure and conditions are fundamental elements in the vehicle's safety, in the fuel's consumption and the tire's durability, and they must be checked before using the vehicle.

The goal of choosing the tire's brand and model is to minimize the cost per kilometer/mile, preserving minimum-safety conditions. The following factors have to be taken into account for choosing the tire's brand and model:

- Cost of tires.

Some brands and/or models are less expensive than others. Premium brands are more expensive than low-cost ones.

- Cost of tires per kilometer/mile.

The main indicator for control and monitor is the cost of tires per traveled distance. Some brands and/or models have fewer costs per kilometer/mile than others do.

- Initial tread depth.

Some brands and/or models have different initial tread depth. Premium brands usually have deeper the tread depth than low-cost ones.

- The tread's wear rate in the tire depends on several internal factors like the tread depth, the tire's composition, the tread pattern or the structure, and due to external factors like the way of driving the vehicle, the weather conditions, speed, and where the vehicle is used, like urban environments, highways or a mixture of both, so some tires brands and/or models have higher tire wear rate than others.

- Number of incidents.

Some brands and/or models are more likely to face more incidents like punctures, bursting, damages to the side, etc. than others do, and these incidents assume repairing costs and not being able to use the vehicle for a certain time, and in some cases, towing services too. Premium brands usually have fewer number of incident costs than the low-cost ones.

- Technical characteristics.

The tire's technical characteristics are: traction in dry and wet pavement (aquaplaning), the braking distance in dry and wet pavement, the agility in dry and wet pavement, the lateral adherence, rolling resistance, sonority, maximum speed, and maximum weight the tire can resist. Premium brands usually have better technical characteristics than the low-cost ones.

- Tire’s use.

There’s a large variety of tires depending on their use, like depending on the season, with flank reinforcement, low rolling resistance or solid.

The tire’s control and the monitoring system have to register the following information.

- The tires, punctures, and repairing costs.

The organization has to consider all the costs that affect the tire’s acquisition, repairing and maintenance, as well as the vehicle’s stops that are caused by the incidents with the tires.

- The reason why the tire is being removed.

The organization needs to establish the categories why the tires are removed and changed such as worn out, damaged, deflated, irregular wearing, rolling without pressure, damages and rubbing on the sides, and major difference between dual tires.

- Distance traveled with a tire.

The distance traveled by a vehicle must be registered when the tire is installed and removed.

- Tire’s tread depth.

The tire’s tread depth must be registered when the tire is installed and removed.

- Tire’s characteristics.

The tire’s characteristics must be registered, such as brand, model, tire profile, maximum speed, and the maximum weight it’s designed to carry.

- Tire’s position.

The vehicle in which the tire is installed, and in what position it is installed must be registered.

Based on this information, the organization can choose the tire's brands, models and profiles, and take the adequate measures to optimize their use. The main sources of information to use are the following:

- The cost per kilometer/mile by brand, model, and profile. In order to calculate it, use the arithmetic mean of all the tires that have the same brand, model, and profile.

- The percentage of usage of initial tread depth by the tire's brand, model, and profile. In order to calculate it, use the arithmetic mean of all the tires that have the same brand, model, and profile.

- Establish the main reasons to remove the tire, and take the adequate measures so the main reason to remove a tire is worn out.

- Compare if there are meaningful differences among the types of tires by routes, vehicles, drivers, etc. using the statistics technique of contingency tables.

- Know behavioral patterns like the relationship between using certain tire's brands, model, and profiles and the number of accidents or the fuel consumption. It can be done by using statistics techniques like principal components and/or logistic regression.

Collecting data and the monitoring of tires require great effort and resources from the organization. If the organization has a large fleet, they can do it only over a set of vehicles, and extrapolate it to the rest of the fleet.

Another alternative, if it's not possible to collect the distance traveled with a tire because of the type of service performed or because the organization doesn't have enough resources, they could use the cost of tread depth per millimeter used. This alternative requires measuring the tread depth when the tire is installed and once it's removed.

The low-cost tires are usually poorly designed, manufactured, and are made with bad materials, have poor technical characteristics, and for this reason they have poor safety, and normally have less initial tread depth than premium brands.

For all these reasons, the cost per kilometer/mile is higher in the low-cost tires than in the premium brands, and it's advisable to use premium-brand tires.

The organization needs to consider that the only advantage of the low-cost tires over premium brand tires is the acquisition cost is lower.

6.1.6. Preventing and reducing traffic accidents of the vehicle's fleet.

The organization has to design and establish the system to prevent and reduce traffic accidents, since around 15-20% of the vehicle's fleet has a traffic accident in a year, which represents a high cost of the organization, due to the following reasons: the vehicle won't be used for some time for the service performance; the repairing cost; the vehicle's substitution cost; the possible loss of the goods that are being transported; and the possibility of the driver/user or third-parties getting hurt.

Traffic accidents happen for several reasons such as mechanical failure (lack of maintenance or failure in materials), weather conditions (fog, rain, humidity or lighting), or road conditions (holes, cracks, sinking or obstacles); but the most important is the human factor, causing about 70% of traffic accidents.

Lack of experience, driving under the influence (DUI), driving while tired or sleepy, distractions, speeding or not following traffic signals are usually the most common causes of traffic accidents due to human factors.

The drivers and users have a great impact in the prevention and reduction of traffic accidents, for which there must be a fluid communication between the fleet managers and the vehicle's drivers/users, and they must be involved in the decision-making concerning the prevention and reduction of the traffic accidents and safety.

The organization has to establish policies concerning the prevention and reduction of the traffic accidents, and to assure the safety and health of the drivers and users of the vehicle. The company's executives must support, communicate, and enforce these policies to all the people involved in fleet management. They also need to do an audit every certain period of time to assure these policies are being known and complied.

The prevention and safety policies for traffic accidents have to establish the following guidelines, which have to be audited every certain period of time: the use of vehicles; the drivers' recruitment, characteristics and training; the bonus system for reporting traffic accidents; the system to check that the vehicles are in perfect conditions and have the maximum safety, technology and adequate safety equipment; the control and monitor of vehicles; the system for collecting and analyzing data; the scoreboard; the use of safe routes, and control of alcohol and drugs to the drivers, following each one is developed.

- The use of vehicles.

The organization has to establish when and how the vehicles are used, as well as which people are authorized to use them, maximum hours a day, schedules, safety conditions, the use for private matters, speed limits, or maximum load to transport and its distribution in the vehicle.

- Driver's recruitment, characteristics, and training.

The organization has to establish the driver's recruitment, characteristics and training such as: the drivers must have the valid driver's ID that's adequate to the type of vehicles assigned to them; check that the drivers have the needed skills and abilities before using any vehicle; and the training and testing that the drivers need to go through about preventing accidents and vehicle's safety.

- Bonus system for the traffic accidents report.

  Some traffic accidents aren't usually reported to the organization and/or insurance company for several reasons, because of this, the organization needs to establish a bonus system so the drivers or anyone in charge of the vehicle reports every traffic accidents. This can be through economic incentives, paid holidays, establish a ranking of best drivers, or use gamification.

- System to check the vehicle is in perfect conditions to be used.

The organization has to establish a system to check the vehicle is in perfect condition and has the maximum safety conditions like the planned maintenance explained in the epigraph 6.1.1 and to check the vehicle before and after it is used explained in the epigraph 6.1.2.

- Adequate technology and equipment.

The organization has to establish the safety technology and equipment for the vehicles, such as driver assistance systems, Bluetooth/hands-free, Electronic Stability Program (ESP), speed control, Antilock Brake System (ABS), xenon lights, recognizing signals, parking control, blind spot monitoring, or lane departure warning.

- Control and monitor of the drivers.

The organization has to establish the control and monitor of the drivers. Like the way they drive, the number of times the driver has passed the speed limit, number of traffic accidents, number of tickets/fines or any other incidents; this control can be done in an easy way if the organization uses a telematic service.

- Collecting and analyzing data.

The organization has to establish the system to collect and analyze data, a key aspect that has to be investigated is the cause of all traffic accidents. It’s advisable to register the following information:

- Data of chronological localization, like the date and hour of the accident.
- Data or geographical localization, like the country, state and city.
- Data of the type of road like urban or highway, speed limit, kilometer point, circulation way, name/number of the road, number of lanes, road alignment (straight, curve, intersection), and the horizontal and vertical signaling.
- The cause of the accident like mechanical failure, weather conditions, road conditions and human factors (lack of experience, driving under the influence, driving while tired or sleepy, distractions, speeding, or not following the traffic signaling).
- The consequences of traffic accidents like people being hurt, deceased, or material damages.
- The type or accidents, like mild, severe, very severe.

- The vehicles status, like if the vehicle had been through maintenance or vehicle inspection.

- Type of accidents, like getting out of the road (with or without flipping), collision (frontal, perpendicular, oblique, mirrored, reaching or scratching) with other vehicles, crashed, or run over a pedestrian.

- By the number of people involved. It could be simple or complex, if there are pedestrians, cyclists, animals or motorcycles involved.

- The weather conditions, such as rain, fog, lighting or humidity.

- The road conditions such as holes, cracks, sinking or obstacles.

- The characteristics of the other involved vehicles, such as type of vehicles (sedan, truck, etc.), brand and model, type of fuel, age or number of passengers.

- Data for the people involved, such as name, nationality, identification document (ID), date of birth, and gender.

- Use of security elements like seat belt, helmet or child safety lock.

- The data about drivers license of the involved drivers, like the type and year of expedition.

- If there were alcohol/drugs tests performed, and their results.

All the traffic accidents' costs must be collected, like the repairing cost, the vehicle's substitution cost, towing services, the possible loss of the goods, and the damages and compensations paid to third-parties.

The obtained data is classified and analyzed to find what are the characteristics of the most common accidents (ABC analysis), and take measures to prevent and reduce them. Two of the statistics techniques that could be used to find the relation among the variables involved in traffic accidents and finding behavioral patterns are the contingency tables and principal components.

- Scoreboard

The organization has to establish the scoreboard for the prevention and reduction of traffic accidents, and this has to include the following type of indicators.

- Activity indicators: they measure the accidents and their consequences due to the vehicle's use. Some established indicators have to be calculated every certain time, like the following: number of accidents every 100,000 kilometers/miles or the number of kilometers/miles that it takes before an accident occurs; number and percentage of vehicles that have had an accident; number of deceased; average cost of an accident; or total cost of all accidents.

- Safety levels of the vehicles and drivers indicator: these indicators measure the safety level of the vehicle and drivers. Some established indicators have to be calculated every certain time.

Some examples of the indicators that measure the safety levels are: the number of vehicles and percentage of vehicles that are older than 6 years (it has to be considered that after the 6^{th}-7^{th} year of the vehicle, traffic accidents increase); the percentage of vehicles that have safety elements like ABS, EPS, etc.; or the percentage of vehicles that passed the vehicle inspection.

Some examples of the indicators that measure the driver's safety are: the percentage of the drivers involved in an accident with a number of casualties; drivers penalized by speeding; drivers that have been charged for DUI; drivers that have been penalized with traffic tickets; percentage of drivers that didn't use the seat belt; percentage of drivers that are involved in road range or aggressive driving; or percentage of drivers that have been trained on safety measures.

- Using safe routes.

The organization has to give priority to safe routes, even if the traveling distance is longer. The system must be established to identify these safe routes as well as the drivers use these routes.

- Alcohol and drug control.

The organization has to establish the system to conduct random drugs and alcohol test to their drivers. This measure could be taken depending on the current laws established in each country.

6.1.7. Using owned or outsourced workshops for the vehicle fleet.

The organization has to establish if they use either their own workshops or outsource this activity to a third-party, since the investments and the operational costs are usually higher and have to be evaluated. The vehicles need to get maintenance and repairing in a mechanical workshop that complies with safety conditions, respect to environment and current laws.

The main aspects to consider for choosing between owned or outsourced workshops are the following:

- Importance of vehicle fleet management.

If the vehicle fleet management is the main activity of the organization, the best solution is to have owned workshops, since it has the following advantages: the vehicles are repaired and the maintenance is done as fast as possible, and they are available for the maximum time for the service performance; it also gives the organization more control, flexibility and safety over maintenance and repairing; and also can choose what spare parts to use.

If the vehicle fleet management is a secondary activity of the organization, the best solution is to outsource the workshops, but the time the vehicle is not available for the service performance could be longer. The organization has less control and safety over maintenance and repairing; and also can’t choose what spare parts to use.

- Economical aspect

An owned workshop requires an investment for facilities and equipment costs, workforce cost, and complying with the law. On the contrary, if the workshops are outsourced, there’s no need for said investment or workforce costs.

- Fleet size

If the fleet is small, it's advisable to take the vehicles to a third-party workshop, since the investments and costs that come with owning a workshop aren't profitable. On the contrary, if the fleet is large, the investment and associated costs of owning a workshop would be profitable.

- Type of contract.

If the vehicles are acquired through renting/leasing, the contract usually include maintenance and repairing of the vehicles, for which they have to be taken to determined authorized third-party workshops.

A mixed solution can be to have owned workshops for maintenance and subcontract third-parties for breakdowns; or having owned workshops and subcontract third-parties for specialized breakdowns such as electricity, body or diesel fuel injection.

7. DISPOSAL/REPLACEMET OF THE VEHICLE´S FLEET

The organization has to design and implement policies for disposal and renovation of the vehicles, when to renew them, choose the sales channel and suppliers, or establish the maximum time to sell the vehicles.

The maximum time a vehicle is used is established by its renovation period, for which the vehicle can be used up to this maximum time period and renewed for another vehicle, or be disposed from the service, and sold before the maximum time, because it'd no longer be needed for the service performance, like explained in the epigraph 4.3

The goal for disposal and renewing the fleet's vehicles is to sell them as fast as possible with the highest price possible, and use this income to acquire new vehicles or in any other fleet's necessities.

It has to be considered that once the vehicle is retired of service and until the vehicle is sold, the organization has to pay for transportation and storage costs, which have to be minimized.

The vehicle has to be sold in perfect use and safety conditions, and for this reason, it'd have to be repaired if needed, and in some cases the vehicle's condition has to be certified by an third company.

If the vehicle is acquired through renting/leasing, the vehicle will be taken back to the renting/leasing company during or after the end of the contract, and because of this, the vehicle won´t have to be sold by our organization.

7.1.1. Vehicles renewal policies

The organization has to establish policies for the vehicles' renewal, which could be when the vehicles reach certain kilometrage/mileage, a certain age, or whichever comes first. The main aspects to consider are the following:

- Brand image

New vehicles models in the automotive market represent better brand image than older vehicles.

- Vehicles technology

New vehicles models in the automotive market incorporate the latest technology for active and passive safety measures, fuel consumption, and contaminating emissions. For this reason they're key aspects for the reduction of traffic accidents, fuel consumption, contaminating emissions and breakdowns; they're also a good opportunity to incorporate in the fleet, vehicles that use new technologies regarding alternative fuels instead of fossil fuels.

- Traffic accidents

After the 6^{th}-7^{th} year of the vehicle's life, traffic accidents increase, and because of this, the vehicle's availability for service performance decreases, and the variable operational costs increase.

- Fuel consumption

After the 6^{th}-7^{th} year of the vehicle's life, the vehicle's fuel consumption increases, and for this reason, the contaminating emissions and variable operational costs increase.

- Breakdowns

After the 6^{th}-7^{th} year of the vehicle's life, the number of breakdowns increase, and for this reason, the vehicles availability to perform the service decreases, and the variable operational costs increase.

- The organization's market

In determined occasions, the vehicles renovation is dictated by the competition within the market in which the organization operates, and represents a competitive advantage. Car rentals have to offer their clients the newest vehicles in the automotive market to perform their services and be competitive.

- Financial restrictions

The budget destined to the vehicles renovation, limits the number of vehicles to renew each period, and for this reason the average age of the fleet.

- Information organization system

The more information about the vehicle's direct costs and residual value there is available the more precise and trustworthy are the results about the renovation period.

Total cost of ownership (TCO)

There is a wide scientific literature on fleet vehicle renovation; the most used models are the basic model of Life Cycle Cost Analysis (LCCA), the decreasing use rate with age model, or the parallel fleet replacement problem model. (Simms, Lamarre and Jardine, 1984) (Buddhakulsomsiri, Parthanadee y Charnsethikul, 2012).

Other methods based on the LCCA are the equivalent annual cost, annual cost comparison, asset repositioning, or the ones developed by Eilon, King and Hutchinson (1966), and Redmet (2009). Most of these methods use the vehicle's life cycle costs to determine the renovation cost.

The model to use in the organization is the one that meets more adequately the fleet's specifications, characteristics, operative and goals, and the data availability.

We explain the basic model because it is the most simple and widespread; the model considers that the vehicle has a constant use rate through its life.

The following ownership costs must be considering, as shows the graph 21.

- The cost of capital, like depreciation and financing, decrease with time independently of the financing choice.

- The unavoidable variable operational costs of the vehicle, like the fuel consumption, tires, maintenance, breakdowns, and accidents increase with the vehicle's age and kilometrage/mileage.

- The fixed operational costs, like insurance, taxes, and rates remain practically constant through the vehicle's life; the driver's salary has not to take into account.

Considering all these costs, the results graph a curve for the total costs of ownership in a “U” shape.

To calculate some of the vehicle’s costs of ownership, it could be included the organization’s historical data, also the vehicles manufacturer, other vehicle fleets, third-party companies, or to directly estimate them.

If the vehicle is acquired through renting/leasing, the cost of capital will be the annual vehicle’s fee.

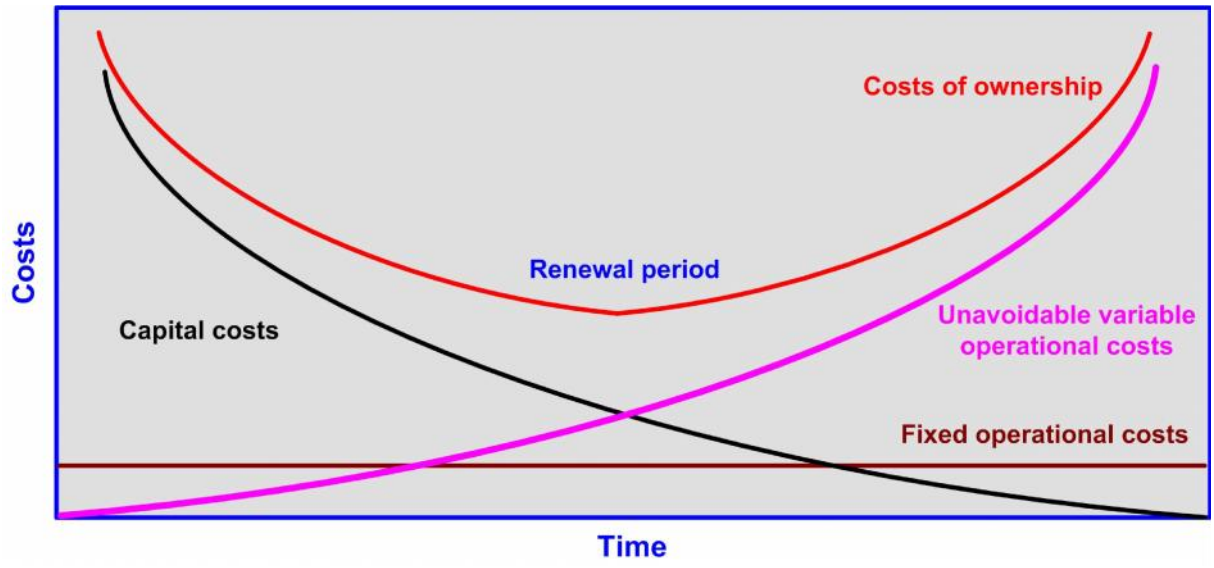
Once the total ownership costs are calculated and/or estimated, the Total Discounted Cost of Ownership (TDCO) is used to evaluate an investment project, which allows the organization to calculate the current cash flow value, using a discount rate.

$$TDCO = \sum_{t=0}^{t=n} \frac{CT_t}{(1+r)^t}$$

Equation 2: Total Discounted Cost of Ownership.

- TDCO: Total Discounted Cost of Ownership
- CT_t: Total costs of ownership
- t: period of time
- r: discount rate or cost of capital
- n: reposition period

The vehicle's renewal period is when the total cost of ownership is minimum, using the basic model shown in the graph 21.



Graph 21: vehicle's renewal period

The renewal period must be established according to the type of vehicles, they must share similar characteristics, have to have the same costs structures through their life cycle, and perform the same type of service. The renewal management is more complex the more differences are between the vehicles ages and types.

When the number of vehicles is over the optimal number, the drivers/users prefer using vehicles with lower kilometrage/mileage, causing an excess in their use, and underusing in the older vehicles. This makes that the unavoidable variable operational costs in the vehicles with less mileage/kilometrage or age to be higher than the older ones. So the basic model's hypothesis that these costs increase don't apply, which added to the fact that the costs of capital always decreases, causes the graphed curved for the total costs of ownership to not have an "U" shape, and for this reason the renewal period calculation is more complex.

If the budget for the vehicle's renewal is limited, the organization has to determine the order of the vehicles to renew. In order to do this, it has to be establish the criterion like the vehicles with higher mileage/kilometrage, higher residual value, that have higher contaminating emissions, that have priority in the fleet, or have the highest accumulated total costs.

7.1.2. Sales channels of the fleet's vehicles

The organization has to establish the sales channels for selling the disposal vehicles, such as selling them to the employees of the organization where they've been used, selling them to the second-hand market, create a sales central in the organization, use live or online auctions, or exporting them to other countries. The sales channels can be established depending on the vehicle's characteristics and type.

- The organization's employees

An interesting option is to sell the vehicles to the organization's employees where they're being used, since they have direct references on the conditions and use of the vehicles.

- Direct sales

Selling the vehicles directly is recommendable when the organization doesn't want to deal with high sales costs, and there are only a few vehicles to sell. This sale could be done to individuals, or to another company.

- Sales central

Creating the sales central within the organization is advisable when there's high rotation and large number of vehicles to be sold in a short period of time. This sales central requires an initial investment and the salary costs that have to be evaluated and not all organization are capable of it. Big car rental companies often use this channel to sell their vehicles.

- Auctions

Live or online auctions are more complicated to do, clear and advisable when there's a whole lot of vehicles to sell.

There are three main factors to maximize the total sales value, like establishing the number of vehicles in the lot, the vehicle bidding order, and the type of bid (ascending, descending, sold over the first price, sold over the second price, etc.).

Doing the bidding requires an initial investments (software and a license), and salary costs that have to be evaluated.

The game theory field has developed a vast scientific literature about bidding.

- Exporting to other countries

Exporting vehicles is an interesting option in countries where the second-hand market is strong, and can be sold for a higher price than in the countries where the vehicles have been used.

The exportation costs have to be considered, like transportation, storage, insurance, taxes and importation rates for vehicles in the destination country.

The organization can use an online website for selling the vehicles, but the organization has to consider there is an initial investment, mainly for the software that can be acquired from another company and salary costs that have to be evaluated, in this way the organization has total control over the selling process of their vehicles.

7.1.3. Outsourced suppliers for selling the fleet's vehicles

There are several specialized remarketing companies in vehicles sales through any of the type of channels previously mentioned.

Using one of these companies depend on several aspects like fees and commissions, saving all the administrative costs, and knowing the best market and channel where the vehicles could be sold.

7.1.4. Maximum time for selling the withdrawn vehicles

The organization has to establish the maximum time to sell the vehicles, which depend mainly on financial aspects, since it's advisable that the income from selling the vehicles is used to acquire new vehicles, investments, or fleets expenses. Besides, the organization may have limited space to store a determined number of vehicles.

8. VEHICLE´S FLEET INFORMATION SYSTEM

The organization has to design and establish the fleet information system with the following goals: to know the current state and tendency of the fleet management; to control and optimize the activities and service level; to control and reduce costs; to control and monitor the vehicles; and to collect important data needed to make decisions.

The organization has to establish what information to collect and how often it needs to be collected, depending on the following factors.

- Fleet's importance

If the vehicle fleet is the main activity of the organization, the information system has to be complete and developed, on the contrary if the vehicle fleet is a secondary activity, it'd be enough to have a basic information system.

- Organization's activities

Depending on the organization's activity, the information needed is different. A package transportation company needs a different information system and indicators than a company whose vehicles are used by sales associates.

- Fleet's activities

The information system has to be more complete and developed in those activities of high added value and use the most resources in the fleet.

- Level of control and analysis

If the information level of control and analysis is high, it'd be required to collect information more often, and the information system has to be more complete and developed.

- Cost

The more the information to collect, analyze and its collecting frequency, the more human and technical resources needed, for which the costs are higher.

Part of the vehicle fleet's information system is supplied with information from other departments like accounting.

The information is divided in two types depending on when it's collected:

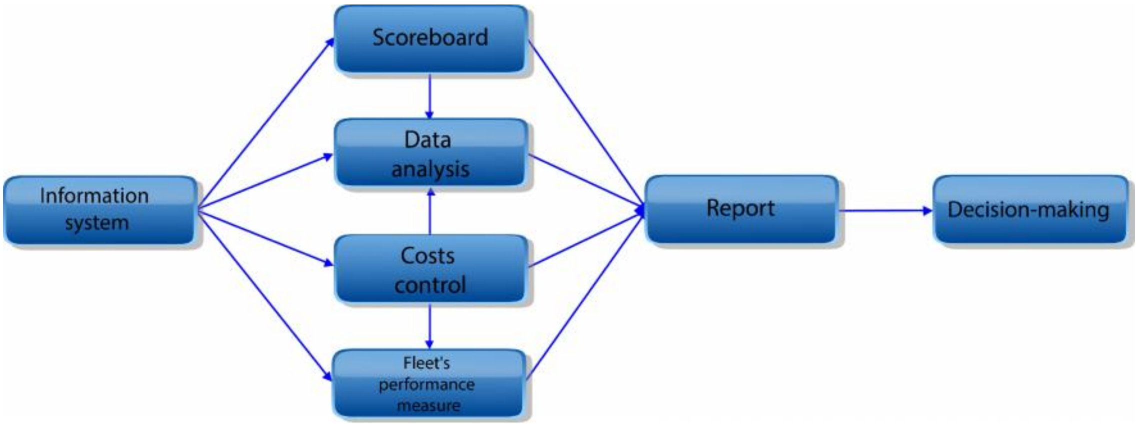
- The information is collected in the moment it's produced, and corresponds to discreet events. For example, when a vehicle is acquired, it has to be collected the cost of acquisition, the date, the model or equipment. When a vehicle is refueled, it has to be collected the amount of fuel, date, cost and kilometrage/mileage, if the vehicle doesn't have a devise (telematics) that measures the fuel consumption automatically. Or when a traffic accident occurs, the information has to be collected like explained in the epigraph 6.1.6

The organization has to establish the frequency to calculate the amount of these events in a set period of time like weekly, monthly or yearly. For example, the number of traffic accidents during a week, the number of planned maintenance per month, the number of vehicles acquired a year, or how many kilometers a traffic accident, maintenance or breakdowns occur.

- The information is collected with a frequency that has to be established by the organization, and corresponds to continual variables like distance traveled, or fuel consumption, if the vehicle has a device (telematics) that measures this information automatically this frequency period is not needed.

The information system supplies the information needed to develop each one of the following tools: scoreboard, data analysis, cost control, and measuring the fleet management performance.

With the results obtained from each of these tools, it can be done: the general report for the organization management, which has to establish the frequency to do said report. It's recommended to do it every three months, every semester, or yearly, depending on the organization's characteristics and goals. The tools mentioned before are also needed for decision-making and measures to take over the fleet management, like shown in graph 22.



Graph 22: information system for vehicle fleet management.

8.1.1. Vehicle fleet's scoreboard

The scoreboard is a fundamental tool in fleet management, and allows the organization to know and do the adequate control and monitor of the most important information in the fastest, simplest way possible. The scoreboard is made of several indicators that are calculated and/or collected from the provided information by the information system.

It has to be considered that a very wide scoreboard with several indicators could be an obstacle for the fleet operation because of the amount of information that needs to be collected and analyzed; on the contrary, a scoreboard with very few indicators don´t provide all the information needed for its management.

For this reason the organization has to establish the appropriate number of indicators, and which ones are the most valuable that adapt better to the organization's characteristics, operative, budget and goals.

For example, a basic scoreboard has the following indicators: traveled distance, fuel consumption, number of vehicles that haven't complied with the planned maintenance, the status of the vehicle (available, unavailable), the number of accidents and the service level.

The organization has to establish the frequency for the general report of the scoreboard, which is advisable to be done monthly, in order to do this, the information system's indicators have to be calculate/collected.

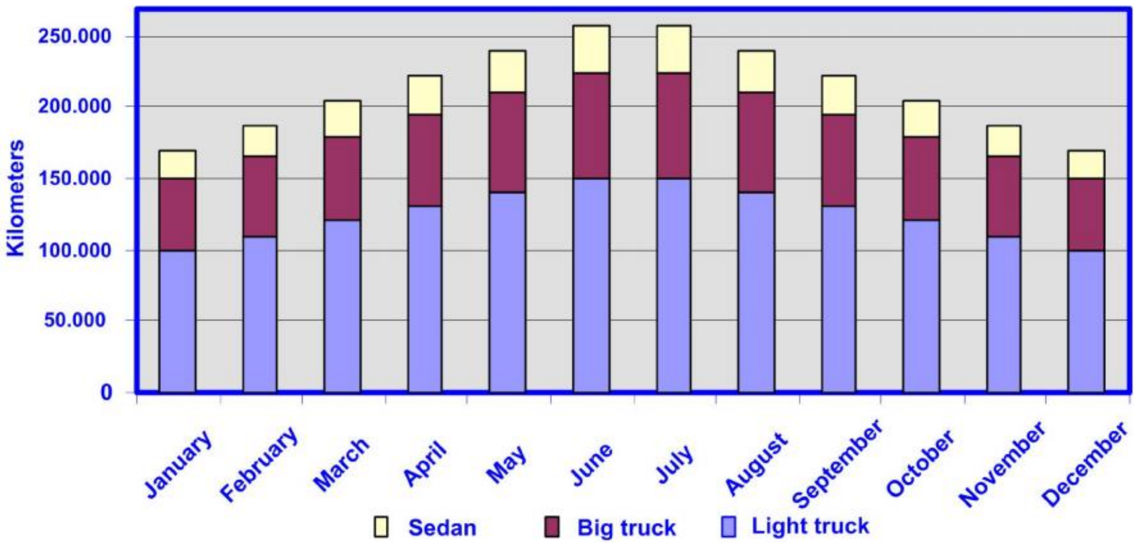
For example, if the traveled distance (km/ml) is collected weekly in the information system, all the data will have to be added together for a month if the scoreboard is done monthly.

The scoreboard is structured in a shape of pyramid, at the top there are a few basic and generic indicators that can be used in any type of fleet, and as the pyramid goes down, the number of indicators increases, getting more specific and encompasses more activities of the fleet.

Implementing the scoreboard in an organization's management requires a period to adapt, and for this reason it's advisable to establish a basic chart as already explained in the first phase, and once consolidated, spreading the scoreboard to more specific indicators and activities. The scoreboard report has to be simple and easy to understand, for this it's recommended to use graphics and charts.

The information has to be presented from the most generic to the most specific, and by types of vehicles. If the organization has several workplaces available, in different geographic locations, a chart has to be done for the whole organization, and an individual one for each workplace.

There's a variety of graphics and charts that represent the information for a scoreboard, following will be shown some examples if the vehicle fleet is made up of three types of vehicles. The graph 23 shows the total traveled kilometers per month and type of vehicle.



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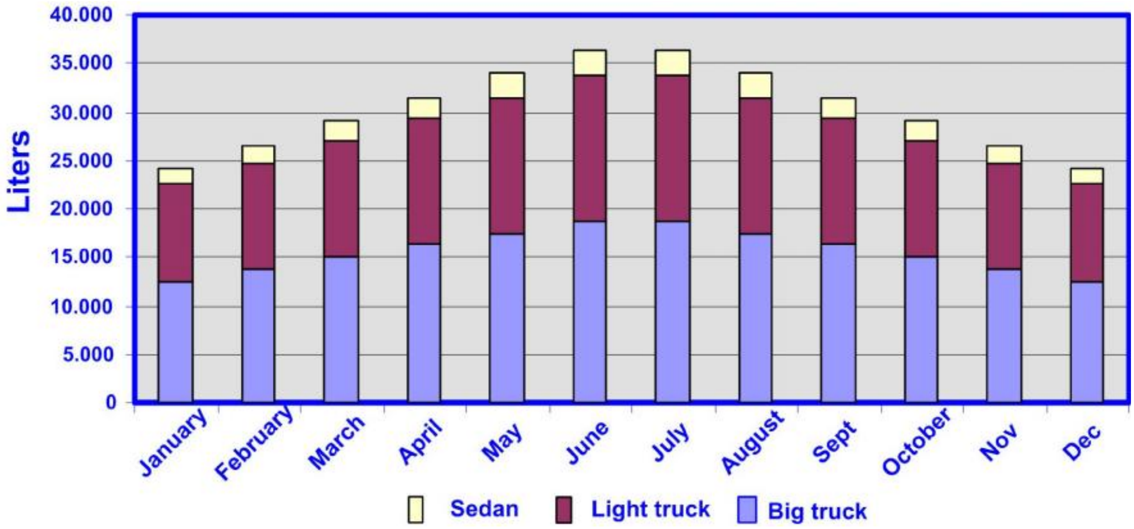
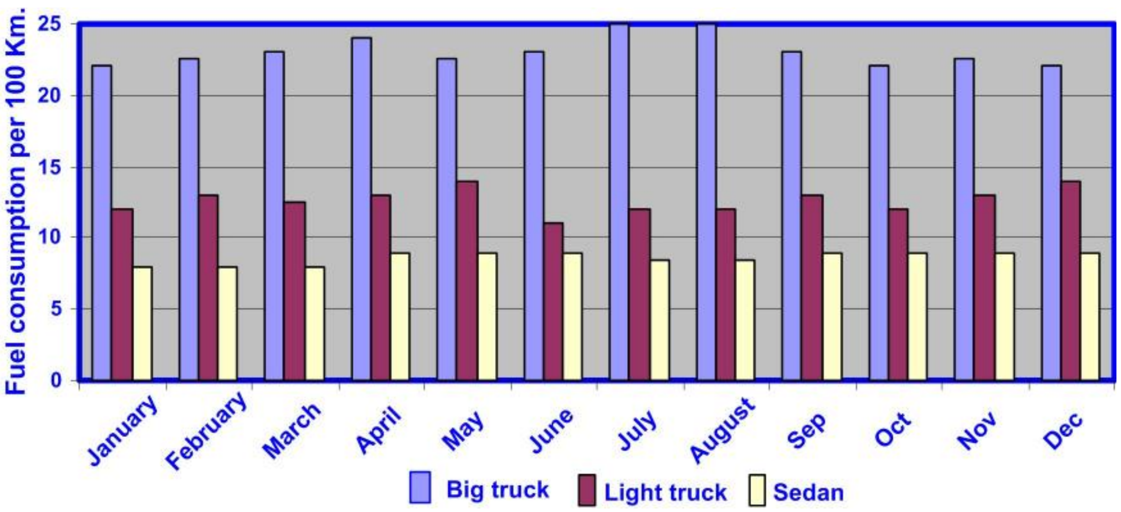
Graph 23: total traveled kilometers per month and type of vehicle

The graph 24 shows the fuel consumption per month for all the vehicles, classified by type of vehicle. The graph for the Co_2 emissions is similar to the one for fuel consumption because that calculation is based on this.



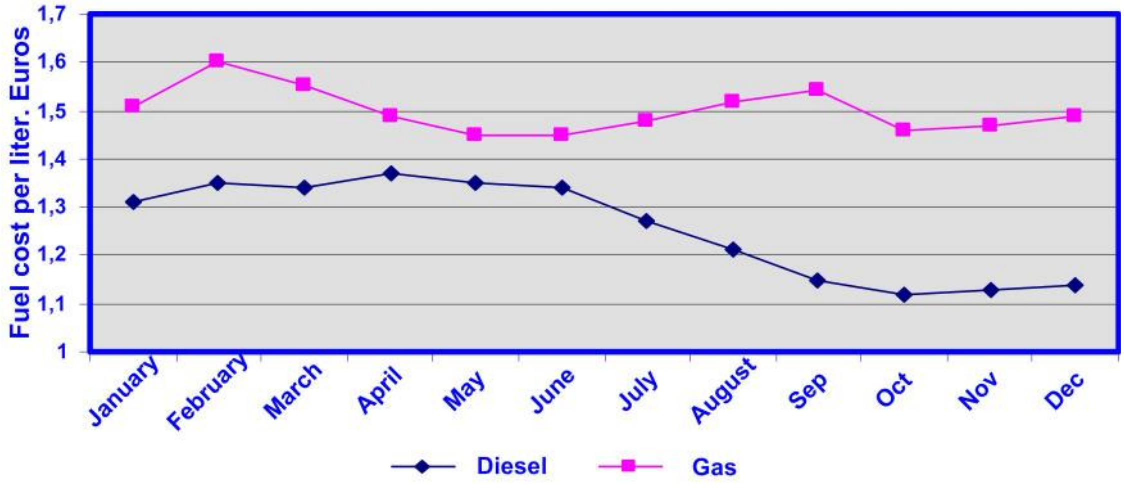
Graph 24: total fuel consumption per month and type of vehicle

Having the traveled distance and the fuel consumption, it can be calculated the average fuel consumption per 100km, by type of vehicle, like shown in the graph 25.



Graph 25: fuel consumption per 100km.

The graph 26 shows the evolution of costs of price of fuel per liters, by type of fuel per month.



Graph 26: fuel cost per liter and type of fuel per month

The status of the vehicle (available, unavailable) monthly, and per type of vehicle, if this data is collected weekly, it needs to be calculated the average status of the vehicles of the weeks of the month.

	January		February		March	
Status	**Active**	**Inactive**	**Active**	**Inactive**	**Active**	**Inactive**
Light truck	**321**	**79**	**350**	**50**	**310**	**90**
Heavy truck	**91**	**9**	**85**	**15**	**87**	**13**
Tourism	**60**	**10**	**58**	**12**	**63**	**7**
Total	**472**	**98**	**493**	**77**	**460**	**110**
%	**82.81%**	**17.19%**	**86.49%**	**13.51%**	**80.70%**	**19.30%**

Chart 13: available vehicle, unavailable vehicles

The ranking chart for type of vehicle, to represent the vehicles that consume the most, that contaminate the most, cost per kilometer, number of accidents, etc. The chart 14 shows that heavy trucks consume/contaminate more.

Top 5 heavy truck's consumption	
Identification	**Liters/100 Km.**
Vehicle 1	**33.7**
Vehicle 2	**32.4**
Vehicle 3	**31.6**
Vehicle 4	**31.2**
Vehicle 5	**30.8**

Chart 14: top 5 heavy truck's consumption

8.1.2. Fleet's data analysis

The information provided by the information system has to be analyzed and studied deeply in order to obtain valuable information for decision-making; because of this, it's advisable to use descriptive statistics, multivariate analysis or operational investigation techniques.

The organization has to establish a period in which the data analysis is done, and it's advisable to do it every 3 months, every semester, or yearly, depending on the organization's characteristics and goals.

Following are described some examples of some of the valuable information that can be obtained.

- Find behavioral patterns and take the needed measures so it doesn't happen again, Examples of behavioral patterns are the following:

45% of traffic accidents are produced between 1-5pm, the average age of the driver is 28 years old, it's a sunny day, and the type of accident is reversing into a parking space.

35% of the breakdown costs are determined by a vehicle model, in the transmission system, the vehicle has manual transmission, and travels through urban routes.

The drivers with higher fuel consumption are those that are 32 years old, have 3 years of experience, haven't received any efficient driving courses, and drive recklessly.

- Classify the information by categories and by relevance

Make an ABC analysis to classify the information by categories to detect the 20% of the events that produce 80% of the costs.

For example, the organization could know which are the main types of accidents or breakdowns that produce 80% of their costs.

- Find anomalies and misuse of the vehicles.

This information allows the company to find anomalies and misuse of the vehicles, in both cases the fleet manager has to find the reason why these situations are occurring and take the adequate measures; some of the examples to do it are the following.

If a vehicle has the same kilometrage/mileage for 4-5 weeks in a row, and it's active, several things could be the reason why it's not being used. It could have broken down or had a traffic accident, and they haven't been reported yet, or there's no one in charge of this vehicle. If the kilometrage/mileage information is collected weekly, finding this kind of anomalies is easier than if the information was collected monthly.

A driver refuels a vehicle, some of the fuel is used in the vehicles, and some is stored for his personal use, for which the cost per kilometer of fuel for this vehicle would have been much higher compared to its normal use.

If the organization uses telematics services, it could be identified if the vehicle is being used for personal use since it could be known what routes are being done, and if it's used after working hours.

9. HOW TO MEASURE THE FLEET'S MANAGEMENT PERFORMANCE

The organization has to design and implement the system to know how the fleet is managed, in order to take the adequate measures for its control, monitor and improvement, and establish the period of times to do them. It's advisable to do them each week or month, depending on the organization's characteristics, budget, and goals.

The two main key variables to know how the fleet is managed are the service level and variable operational costs, for this reason the organization has to measure these variables in each period, and their evolutions in different periods of time.

A determined service level has an optimal number of vehicles and its variable operational costs under certain conditions of use. In order to know how the fleet is managed, it has to be measured the relationship between the service level and variable operational costs for each period, and their evolution in different periods.

It's developed how the service level and direct costs vary in time, because the variable operational costs is one of the two variables that show how the fleet is managed, the proposed methodology and a theoretical and practical example to measure how the fleet is managed.

9.1. VARIATIONS IN THE SERVICE LEVEL AND THE DIRECT COSTS

Following, it's developed how the service level and direct costs can vary with time.

9.1.1. Service Level

The service level can increase for the same number of vehicles and drivers for different reasons, like optimizing the fleet management's activities, increasing the average speed, planning the routes and the service, training the drivers, using telematics services, using software for fleet management or using toll roads.

The service level can decrease for the same number of vehicles and drivers for different reasons like not optimizing and controlling the fleet management's activities, decreasing the average speed of vehicles or not planning the routes of the service.

In fleets with planned routes, it has to be considered that the service level is determined by the vehicle with the highest time from all of the fleet's vehicles, like it has been explained in the study case in the epigraph 4.1.1. For this reason, the priority is to reduce the time of this vehicle. It could happen that the organization lowers the operational time in vehicles that have lower time than the highest time of all vehicles increasing their average speed, causing an increase in the variable costs due to the increase in the fuel consumption for the same service level.

9.1.2. Direct costs

The monetary value of a cost is equal to its amount multiplied by the its price. The chart 15 shows how cost value varies depending on the price's variation and the amounts.

Concept	Price +	Price =	Price -
Amount +	+	+	+,=,-
Amount =	+	=	-
Amount -	+,=,-	-	-

Chart 15: different possibilities of variation of value cost.

Directs costs are divided according to graph 2 in fixed costs and variable operational costs.

- Fixed costs are those related to owning the vehicle, and they keep practically constant during the vehicle life, for which they have a small influence on how the fleet is managed. Following it's explained how each direct fixed cost can vary with time.

    - Depreciation could vary due to the increasing or decreasing of the residual value such as: if the vehicle is very worn out because of an accident or breakdowns that haven't been repaired; the variation in prices in the second-hand market; or if the organization acquires new equipment or does improvements to the vehicle during its life.

    - Financing costs could vary depending on the organization's characteristics or the type of interest rate.

    - The driver's salaries could vary depending on the sector's collective labor agreements, or the consumer price index (CPI).

    - Insurance can vary depending on the chosen insurance such as full risk, third-parties or franchised; and their prices.

    - Taxes and rates can vary depending on their prices, and are established by the public administration.

- Variable operational costs are related to the distance traveled and/or working hours and can vary noticeably over time. For this reason, these costs are the ones used to measure how the fleet is managed. Chart 16 shows the influence of each concept of the service level and variable operational costs, considering that the rest of the variable costs remain constant.

Concept	Increasing	Service level	Variable costs
Prices	+	=	+
	-	=	-
Distance	+	-	+
	-	+	-
Average speed	+	+	+
	-	-	-
Fuel consumption per 100 Km.	+	=	+
	-	=	-
Tires	+	-	+
	-	+	-
Maintenance	+	-	+
	-	+	-
Breakdowns	+	-	+
	-	+	-
Accidents	+	-	+
	-	+	-
Tickets/fines	+	=	+
	-	=	-
Toll roads fees	+	+	+
	-	-	-
Subsistence	+	=	+
	-	=	-
Bonuses	+	+	+
	-	-	-

Chart 16: influence of the variable direct costs.

- The traveled distance has a great impact in the direct costs, because the higher the traveled distance, the higher the variable operational costs, and lower residual value and worse service level for fleets with planned routes. For which in every type of fleet, one of the main goals is to minimize the traveled distance.

- The average speed has a direct impact in the variable operational costs and service level, because the higher the average speed, the higher the fuel consumption, and better service level in those fleets with planned routes

- Fuel cost is the main variable operational costs, and can vary considerably over time, the fuel price is determined by external reasons like free market and taxes, or by internal reasons like using financial hedges over the fuel price (futures and/or options), owning fuel deposits, getting into a framework agreement with the fuel suppliers for which the fuel's price is lower. The amount of fuel varies depending on the fuel consumption per 100 km., and traveled distance.

- Tires cost has a direct impact in the variable operational costs and service level. The price could vary because of external reasons like free market and taxes, or because of internal reasons like choosing the tires brand, or getting into a framework agreement with the tires brand/supplier, making the costs lower.

- Maintenance has a direct impact in the variable operational costs, breakdowns, traffic accidents, and service level. The price can vary due to external reasons like free market, or internal reasons like choosing the spare parts brands, using external or outsourced workshops, or by getting into a framework agreement with the spare parts suppliers, for which these have a lower cost.

- Breakdowns have a direct impact in direct costs, because the higher number of breakdowns, the higher the variable operational costs, more traffic accidents, less residual value, and worse service level. The price can vary due to external reasons like free market, or internal reasons like choosing the spare parts brands, using external or outsourced workshops, or by getting into a framework agreement with the spare parts suppliers, for which these have a lower cost.

- Traffic accidents have a great impact in direct costs, because the higher the number of traffic accidents, the higher the variable operational costs, worse service level, and less residual value. The price can vary due to external reasons like free market, or internal reasons like choosing the spare parts brands, using external or outsourced workshops, or by getting into a framework agreement with the spare parts suppliers, for which these have a lower cost.

- Traffic fines/tickets have a small direct impact in the variable operational costs, and the price is determined by the public administrations.

- Toll road fees have a slight direct impact in the variable operational costs and service level. The price is determined by the toll road management companies or public administrations.

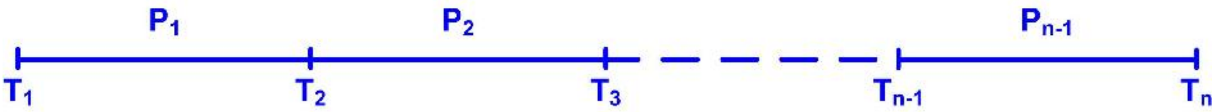
- Subsistence has a direct impact in the service costs and service level. The price is determined by the agreements that there are between the organization and the drivers and/or a collective labor agreement.

- Bonuses have a slight direct impact on the service cost and service level. The price is determined by the agreements that there are between the organization and the drivers and/or a collective labor agreement.

The increasing or decreasing in prices that are caused because of external reasons don't have to be considered to measure how the fleet is managed, because the organization doesn't have any control over them.

9.2. PROPOSED METHODOLOGY

We propose a methodology based on the planned and real service level and operational variable costs for a period of time Px. In each moment of time Tx are established the service level and variable operational costs for the period of time Px, as show in graph 27.



Graph 27: period of time for the proposed methodology

There are two main ways to measure how the fleet is managed:

- Short term: for a period Px, it is measured the increasing or decreasing of the service level and the variable operational costs planned in Tx and the real ones in Tx+1, which are usually of small quantity.

Chart 17 shows the different possibilities to know if during period Px the fleet has been managed better, the same, or worse than planned, following the increase or decrease of the planned service level and the variable operational costs, with the real ones in the short term.

Concept	Increasing costs	Same costs	Decreasing costs
Increasing service level	**+,=,-**	**+**	**+**
Same service level	**-**	**=**	**+**
Decreasing service level	**-**	**-**	**+,=,-**
+ better than planned; = just as planned; - worse than planned.			

Chart 17: different possibilities of how a fleet is managed for a period Px in the short term

The best possible situation is when the service level increases and the variable operational costs decrease in the moment Tx+1 with respect to the planned ones in Tx. The worst possible situation is when the service level decreases and the variable operational costs increase in the moment Tx+1 with respect to the planned ones in Tx. There are two specific situations: there's an increasing in the service level and in the variable operational costs in the moment Tx+1 with respect to the planned Tx; or there's a decreasing in the service level and in the variable operational costs in the moment Tx+1 with respect to the planned Tx.

In both situations it has to be done a study to know how the fleet is managed and depends on the quantity of these variations and the organization’s goals.

- Long term: for a period Px they are measured the increasing and decreasing the service level and the variable operational costs planned in Tx and Tx+1, which are of great quantity, are effective during a great number of periods, and are produced every long periods of time.

Some examples are: installing fuel deposits owned by the company, getting into framework agreements with the suppliers, using software to calculate routes or for the fleet management, train drivers, install safety or driving assistance devices.

Chart 18 shows the different possibilities to know if the fleet is managed better, same or worse than planned for periods Px and Px+1, following the increase or decrease of the service level and the variable operational costs planned in the long term.

Concept	Increasing costs	Same costs	Decreasing costs
Increasing service level	**+,=,-**	**+**	**+**
Same service level	**-**	**=**	**+**
Decreasing service level	**-**	**-**	**+,=,-**

+ better than planned; = just as planned; - worse than planned.

Chart 18: different possibilities of how a fleet is managed for a period Px in the long term.

The best possible situation is when the service level increases and the variable operational costs decrease in the moment Tx+1 with respect to the planned ones in Tx. The worst possible situation is when the service level decreases and the variable operational costs increase in the moment Tx+1 with respect to the planned ones in Tx.

There are two specific situations: there’s an increasing in the service level and in the variable operational costs in the moment Tx+1 with respect to the planned Tx; or there’s a decreasing in the service level and in the variable operational costs in the moment Tx+1 with respect to the planned Tx.

In both situations it has to be done a study to know how the fleet is managed and depends on the quantity of these variations and the organization’s goals.

There are two extreme situations, and they're the following:

- Combining the short term and long term, the best situation possible for fleet management, is when in the short term, the service level is increased and variable operational costs decrease with respect to the ones planned for each period Px, and in the long term the service level is increased and variable operational costs decrease between the periods Px and Px+1.
- Combining the short term and long term, the worst situation possible for fleet management is when in the short term, the service level decreases, and variable operational costs increase with respect to the ones planned for each period Px, and in the long term the service level is decreased and variable operational costs increase between the periods Px and Px+1.

Between these two extreme situations, there's a wide range of intermediate possible situations, and because of this the organization have to study the situation to known how the fleet is being managed.

9.2.1. Short term

Following it is proposed a model to measure how the fleet is managed in the short term. It has to be considered how to establish the planned distance to travel, and it depends mainly of the following cases:

- In the case of a fleet with planned routes, the planned distance to travel in each period Px is determined by the routes to do, like explained in the case study in the epigraph 4.1.1.

- In the case of fleets with aleatory demand of vehicles, or a vehicle assigned to a user/activity, the planned distance to travel in the period Px in the moment Tx has to be establish to meet the budget and/or the variable operational costs, like explained in the epigraphs 4.3.3. and 4.3.4.

The first step is to estimate the variable operational costs planned in time Tx per type of vehicle, since they have different values, to do this is developed the following chart 19.

Concept	Planned price	Planned amount	Planned unitary cost	Planned cost
Fuel	Pp_1	Cp_1	$Cup_1=Pp_1/Cp_1$	$Cpt_1=Cup_1*Dp$
Tires	Pp_2	Cp_2	$Cup_2=Pp_2/Cp_2$	$Cpt_2=Cup_2*Dp$
Maintenance	Pp_3	Cp_3	$Cup_3=Pp_3/Cp_3$	$Cpt_3=Cup_3*Dp$
Breakdowns	Pp_4	Cp_4	$Cup_4=Pp_4/Cp_4$	$Cpt_4=Cup_4*Dp$
Accidents	Pp_5	Cp_5	$Cup_5=Pp_5/Cp_5$	$Cpt_5=Cup_5*Dp$
Tickets/fines	Pp_6	Cp_6	$Cup_6=Pp_6/Cp_6$	$Cpt_6=Cup_6*Dp$
Toll road fees	Pp_7	Cp_7	$Cup_7=Pp_7/Cp_7$	$Cpt_7=Cup_7*Dp$
Subsistence	Pp_8	Cp_8	$Cup_8=Pp_8/Cp_8$	$Cpt_8=Cup_8*Dp$
Bonuses	Pp_9	Cp_9	$Cup_9=Pp_9/Cp_9$	$Cpt_9=Cup_1*Dp$
Total			$CupT=Cup_1+\ldots+Cup_9$	$Cpt=Cup_T*Dp$
Planned distance		Dp		
Planned Price in Euros; Planned amount in kilometers; Planned distance in Kilometers				

Chart 19: variable operational costs planned in the moment Tx.

To calculate the variable operational costs planned, first the organization has to establish the planned price, the planned amount, and the planned distance, like developed in the epigraphs 4.1.1, 4.3.3. and 4.3.4, depending on the type of fleet. Next, the planned unitary cost and the planned cost are calculated according to the chart 19.

The planned price is an average price for each concept in the moment Tx. For example, the average price of maintenance or repairing due to a breakdown. The planned amount is in how many kilometers a concept occurs, i.e. the organization has a traffic accident every 15,000km (~9,320miles), or consumes a liter (33.8oz) of gas per 13km (~8miles). The planned unitary cost of each concept is the planned price divided by the planned amount. The planned cost is the planned unitary cost times the planned distance.

The information sources needed to calculate the planned variable operational costs can be: the fleet's history, estimates, other fleets, third-party companies, official institutions, or the vehicle's manufacturer.

The second step is to gather the real variable operational costs (Crt), the real average prices (Pr), and the real traveled distance (Dr) for the period Px in the moment Tx+1. With this data, the real unitary cost (Curt) and the real amount (Cr) can be calculated as shown in chart 20.

Concept	Real price	Real amount	Real unitary cost	Real Cost
Fuel	Pr_1	$Cr_1=Pr_1/Cur_1$	$Cur_1= Crt_1/Dr$	Crt_1
Tires	Pr_2	$Cr_2= Pr_2/Cur_2$	$Cur_2= Crt_2/Dr$	Crt_2
Maintenance	Pr_3	$Cr_3= Pr_3/Cur_3$	$Cur_3= Crt_3/Dr$	Crt_3
Breakdowns	Pr_4	$Cr_4= Pr_4/Cur_4$	$Cur_4= Crt_4/Dr$	Crt_4
Accidents	Pr_5	$Cr_5= Pr_5/Cur_5$	$Cur_5= Crt_5/Dr$	Crt_5
Tickets/fines	Pr_6	$Cr_6= Pr_6/Cur_6$	$Cur_6= Crt_6/Dr$	Crt_6
Toll road fees	Pr_7	$Cr_7= Pr_7/Cur_7$	$Cur_7= Crt_7/Dr$	Crt_7
Subsistence	Pr_8	$Cr_8= Pr_8/Cur_8$	$Cur_8= Crt_8/Dr$	Crt_8
Bonuses	Pr_9	$Cr_9= Pr_9/Cur_9$	$Cur_9= Crt_9/Dr$	Crt_9
Total			$CurT=Curt_1 +…+Curt_9$	$Crt=Crt_1+…+Crt_9$
Real traveled distance		Dr		
Real price in Euros; Real cost in Euros; Real traveled distance in kilometers.				

Chart 20: real variable operational costs in the moment Tx+1

The real cost (Crt) in the instant Tx+1 can have some deviations in respect to the planned cost in the instant Tx (Cpt) because of two of the following reason.

- Real unitary cost (CurT)
- Real traveled distance (Dr)

Chart 21 shows the different possibilities on how the real cost may vary, following the high or low in the unitary cost and the traveled distance for the period Px.

Concept	Higher traveled distance	Same traveled distance	Lower traveled distance
Higher unitary cost	+	+	+,=,-
Same unitary cost	+	=	-
Lower unitary cost	+,=,-	-	-

Chart 21: variation of the real costs with respect to the planned ones for the period Px

The best situation is the one when the unitary cost and the real distance are lower than the planned ones. The worst situation is the one when the unitary cost and the real distance are higher than the planned ones. There are two specific situations: the unitary cost is lower but the traveled distance is higher, or the unitary cost is higher but the traveled distance is lower. The real cost will be higher, equal or lower than the planned one depending on the quantity of the real unitary cost and the real traveled distance.

The following analysis breaks down what part of the real cost variations come from the unitary cost or the traveled distance, as shown in the following charts 22 and 23.

Once calculated and/or gathered the planned unitary cost, the real unitary cost, the planned and real distance, per type of vehicle, the data in the following chart 22 is calculated.

Type of vehicle	Nº of vehicles	Planned unitary cost	Real unitary cost	Planned distance	Real distance
A	n_1	CupTA	CurTA	DpA	DrA
B	n_2	CupTB	CurtB	DpB	DrB
….	….	….	….	….	….
N	n_n	CupTN	CurTN	DpN	DrN

Chart 22: main variables per type of vehicle for the period Px.

With the results from the chart 22, the data for chart 23 is obtained.

Type of vehicle	Planned costs	Real costs	Total deviation	Unitary cost deviation	Distance deviation
A	CTPA=CupTA*DpA	CTRA=CurTA*DrA	DTA=CTRA-CTPA	DTCUA=(CurTA-CupTA)*DrA	DTDA=(DrA-DpA)*CupTA
B	CTPB=CupTB*DpB	CTRB=CurTB*DrB	DTB=CRTB-CTPB	DTCUB=(CurTB-CupTB)*DrB	DTDB=(DrB-DpB)*CupTB
….	….	….	….	….	….
N	CTPN=CupTN*DpN	CTRN=CutTN*DrN	DTN=CRTN-CTPN	DTCUN=(CurTN-CupTN)*DrN	DTDN=(DrN-DpN)*CupTN
Total	CTP=CTPA+...+CTPN	CTR=CTRA+...+CTRN	DT=DTA+...+DTN	DTCU=DTCUA+...+DTCUN	DTD=DTDA+...+DTDN

CTP= Total planned costs; CTR= Total real costs; DT= Total deviation between real costs and planned costs.
DT=DTCU+DTD; DTCU= Deviation due to unitary cost; DTD= Deviation due to traveled distance;.
Dr= Real distance; Dp= Planed distance; CurT= Real unitary cost; CupT= Planned unitary cost.

Chart 23: deviation between planned costs and real cost for period Px

The chart 23 shows the total deviation produced for the fleet and per type of vehicle between the real and planned costs, as well as the deviation produced due to the unitary cost and the traveled distance.

The deviation range that is produced between the planned variable costs and the real ones in absolute values is higher the more vehicles and/or planned variable costs the fleet has since the amounts are higher and for this reason, there's a wider margin to higher the service level and lower the variable costs. In a 50 vehicles fleet the deviation in absolute values of the service level and the planned and real variable costs will be lower than those for a 500 vehicles fleet.

If these deviations in absolute values are analyzed and represented in a graph, the conclusions obtained would be wrong. For this reason, there needs to be an indicator to measure the deviation and how the service level and variable operational costs evolve independently from the fleet size and variable costs.

The proposed method is to calculate the deviation percentage produced between the service level and real variable costs with the planned ones according to chart 24. With the results from the chart 23, it's obtained the data for the chart 24.

Type of vehicle	% total deviation	% unitary cost deviation	% distance deviation
Type A	(DTA/CTP)*100	(DTCUA/CTP)*100	(DTDA/CTP)*100
Type B	(DTB/CTP)*100	(DTCUB/CTP)*100	(DTDB/CTP)*100
…	…	…	…
Type N	(DTN/CTP)*100	(DTCUN/CTP)*100	(DTDN/CTP)*100
Total	(DT/CTP)*100	(DTCU/CTP)*100	(DTD/CTP)*100

% total deviation = Deviation percentage between real and planned costs
% unitary cost deviation= Deviation percentage due to unitary costs
% distance deviation= deviation percentage due to distance traveled

Chart 24: % deviation between the planned and real costs for period Px.

The chart 24 shows the total deviation percentage produced for the fleet between the real and planned costs, as well as the deviation percentage produced between the unitary cost and the traveled distance per type of vehicle.

The total operational times and the average speeds per type of vehicles are of great use to analyze the obtained results. The charts 25 and 26 show the total times and average speeds planned and real for the moments Tx and Tx+1 for period Px per type of vehicle.

Type of vehicle	Planned time	Real time	Difference	% deviation
A	Tpa	Tra	Dta=Tra-Tpa	(Dta/Tpa)*100
B	Tpb	Trb	Dtb=Trb-Tpb	(Dtb/Tpb)*100
…	…	…	…	…
N	Tpn	Trn	Dtn=Trn-Tpb	(Dtn/Tpn)*100
Total	TTP=Tpa+…+Tpn	TTR=Tra+…+Trn	DTT=TTR-TTP	(DDT/TTP)*100

Planned time is the sum of the planned times of all vehicle for period Px.
Real time if the sum of all the real times of all vehicles for period Px.

Chart 25: real and planned operational times per type of vehicle for period Px.

Chart 26 shows the planned and real average speeds for the moments Tx and Tx+1 for period Px per type of vehicle.

Type of vehicle	Planned distance	Planned average speed	Real distance	Real average speed	Difference	% difference
A	Dpa	Vmpa=Dpa/Tpa	Dra	Vmra=Dra/Tra	Dva=Vmra-Vmpa	(Dva/Vmpa)*100
B	Dpb	Vmpb=Dpb/Tpb	DrB	Vmrb=Drb/Trb	Dvb=Vmrb-Vmpb	(Dvb/Vmpb)*100
…	…	…	…	…	…	…
N	Dpn	Vmpn=Dpn/Tpn	Drn	Vmrn=Drn/Trn	Dvn=Vmrn-Vmpn	(Dvn/Vmpn)*100
Total	DPT=Dpa+…+Dpn	VMPT=DPT/TTP	DRT=Dra+…Drn	VMRT=DRT/TTR	DVT=VMRT-VMPT	(DVT/VMPT)*100

Chart 26: planned and real average speeds per type of vehicle for the period Px.

Chart 27 shows how to calculate the deviation percentage produced between the real service level in respect to the planned one for period Px. The planned service level is estimated like explained in the chapter 4. In the case of planned routes, the real service level has to be measured based on provided service, and find the average between all of them for period Px.

Concept	Planned service level	Real service level	% deviation
Total	**NSP**	**NSR**	**(NSR-NSP/NSP)*100**

Chart 27: % deviation for the real service level in respect to the planned one for period Px.

9.2.2. Long term

To measure how the fleet is managed in the long term, we apply the same method used for the short term, with some modifications. In the moment Tx+1, instead of using the real data for the period Px, it's used the planned data for the period Px+1.

A particular situation is when from the period Px to period Px+1 the number of vehicles increase or decrease provoking the traveled distance and service level to vary, like explained in chapter 4. This is due to the fact that the fleet in each period Px and Px+1 has the planned service level and traveled distance according to the number of vehicles.

For this reason, comparing the fleet in different periods with different number of vehicles it's not of great use and the conclusions can be wrong. To avoid this inconvenience, the following model is proposed. In the moment Tx+1, the service level and traveled distance are recalculated using the same conditions and number of vehicles than the organization had in Tx. The service level and distance obtained are the data that is used as the planned ones for the moment Tx+1.

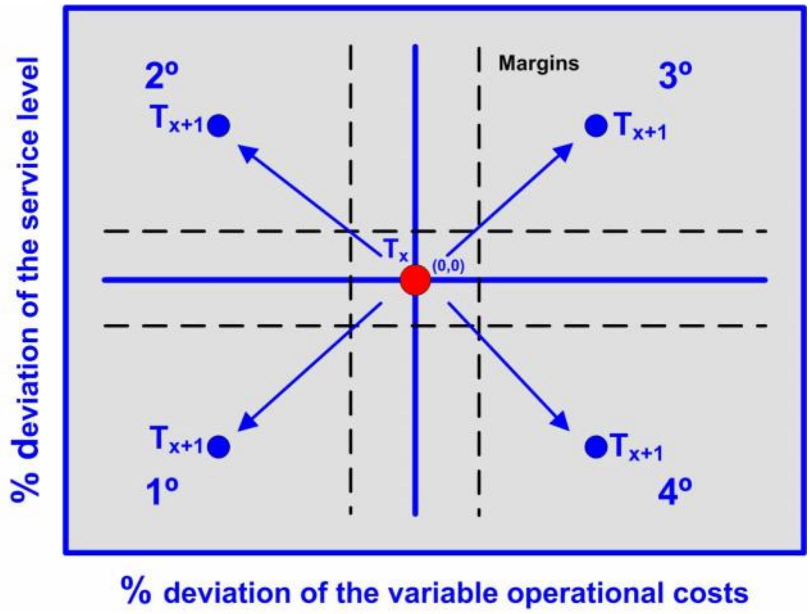
9.2.3. Results analysis

Following a methodology is developed to analyze the results for the short and long term, considering the fleet with planned routes in which the service level is the highest time of all the fleet's vehicles. A reduction in this time implies an improvement in the service level (increases) like developed in the study case in the epigraph 4.1.1.

It has to be considered that in the short period the moment Tx+1 corresponds to the deviation of the service level and the real variable operational costs in respect to the planned ones in Tx for the period Px. In the long period, the moment Tx+1 corresponds to the deviation of the service level and the planned variable operational costs in respect to the planned ones in Tx for the period Px.

The first analysis to do is the graph representation of the deviation of the service level and variable operational costs. Graph 28 shows the different scenarios of the deviation that can be produced between the service level and the planned variable operational costs in the moment Tx.

It has to be established some reasonable and realistic deviation margins in which is considered that the fleet hasn't been managed better or worse than expected.



Graph 28: possible scenarios of the variable operational costs deviations

In the 1st quadrant the service level increases and variable operational costs decrease, this is the best situation possible and it shows that the fleet has been managed better than expected in the short term, or that there's been improvement between periods (long term).

In the 3rd quadrant the service level decreases and variable operational costs increase, this is the worst situation possible and it shows that the fleet has been managed worse than expected in the short term, or that it has worsen between periods (long term).

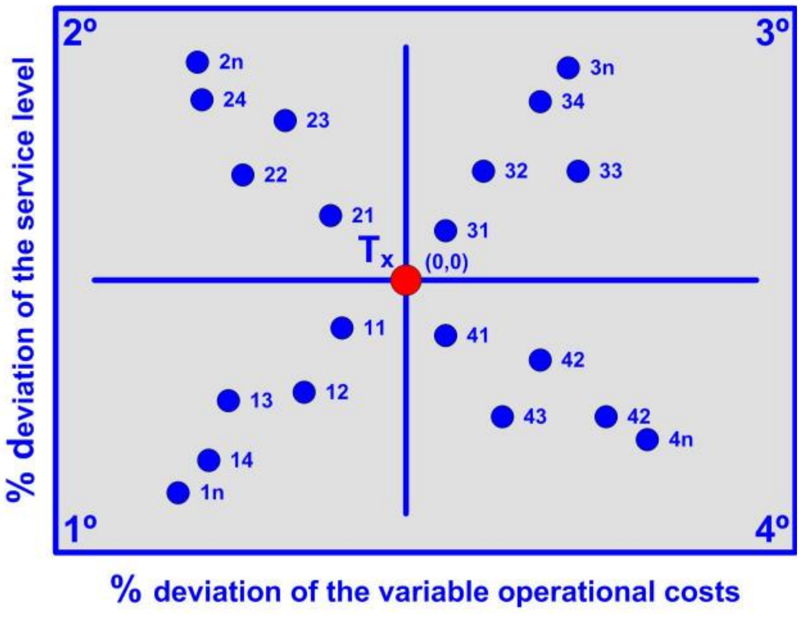
In the 2nd quadrant the service level decreases and the variable operational costs decrease, this is an intermediate situation between the worse and best situation. The fleet has been managed better or worse than expected, or that there's been improvements or declining depending on which of the two variables (the service level or variable operational costs) are more important to the organization, their values, or the operational circumstances that have been produced during the period Px (short-term) or between the periods Px and Px+1 (long term).

In the 4th quadrant the service level increases and variable operational costs increase, this is an intermediate situation between the worse and best situation. The fleet has been managed better or worse than expected, or that there's been improvements or declining, depending on which of the two variables (the service level or variable operational costs) are more important to the organization, their values or the operational circumstances that have been produced during the period Px (short-term) or between the periods Px and Px+1 (long term).

We don't have to take into account the deviations in the costs that are caused by external causes that the organization can't control to measure how the fleet is managed, since the conclusions can be wrong.

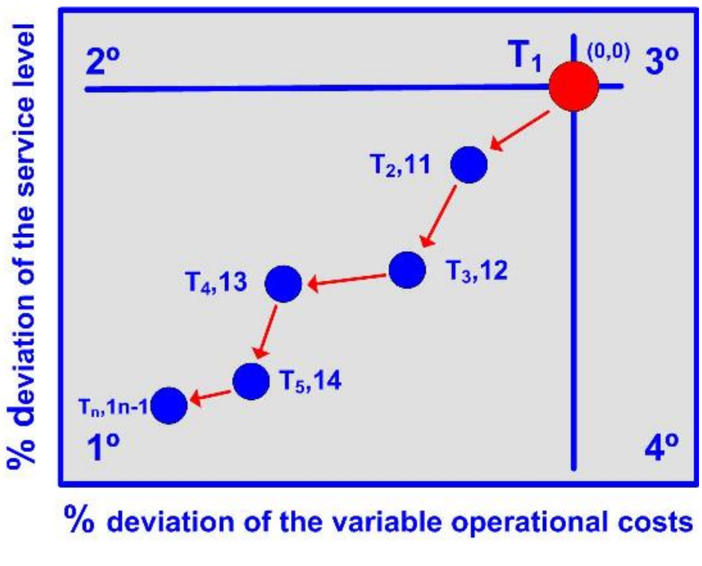
The next analysis is to do the study about how the deviation percentage of the service level and variable operational costs evolve in different consecutive periods Px, Px+1, Px+2...Pn.

Graph 29 shows an example of n possible results (four for each period) that could be obtained in the periods Px, Px+1, Px+2...Pn of the deviation percentage of the service level and variable operational costs.



Graph 29: n possible relations between the % deviation of the service level and variable operational costs.

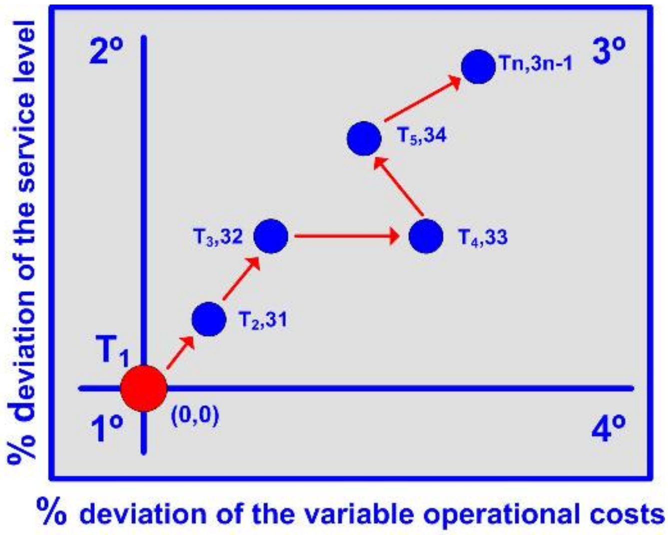
If all the values of the deviation percentage of the service level and operation variable costs in periods Px, Px+1, Px+2…Pn are in the first quadrant, the fleet has been managed better than expected and its evolution is appropriate for the short term, or there's been improvements in the long term. The ideal evolution is the one produced in the following relations (T2,11;T3,12;T4,13;T5,14…Tn,1n-1) in which in each period in the short term and between periods in the long term, the service level increases and the variable operational costs progressively decrease like shown in the graph 30.



Graph 30: evolution of ideal % deviation of the service level and variable operational costs

If all the values of the deviation percentage of the service level and the operation variable costs in periods Px, Px+1, Px+2…Pn are in the third quadrant, the fleet has been managed worse than expected and its evolution is inappropriate for the short term or there's been a declining in the long term. This could be due to several reasons, like not identifying the reasons of these variations, not taking the appropriate measures, or not planning correctly.

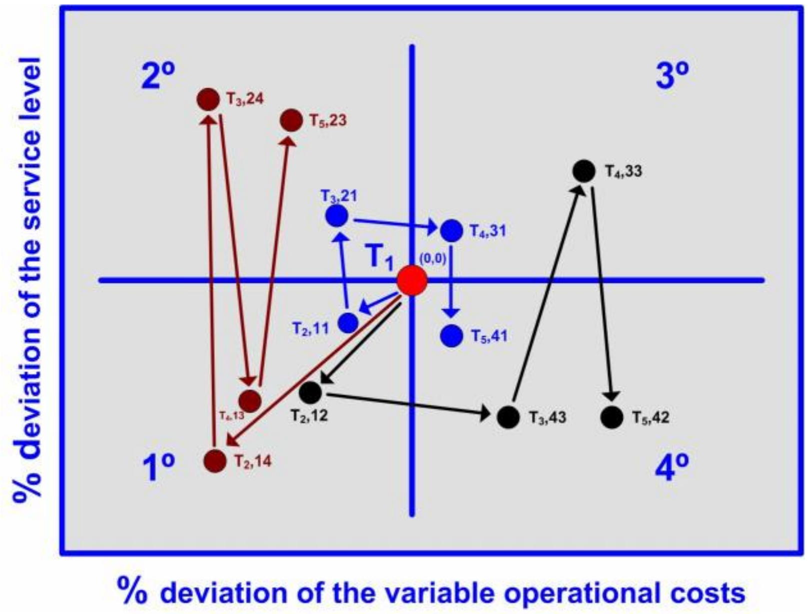
The worst evolution is the one produced in the following relations (T2,31; T3,32;T4,33;T5,34…Tn,3n-1) in which in each period in the short term and between periods in the long term, the service level decreases and the variable operational costs progressively increase like shown in the graph 31.



Graph 31: evolution of the worst % deviation of the service level and variable operational costs.

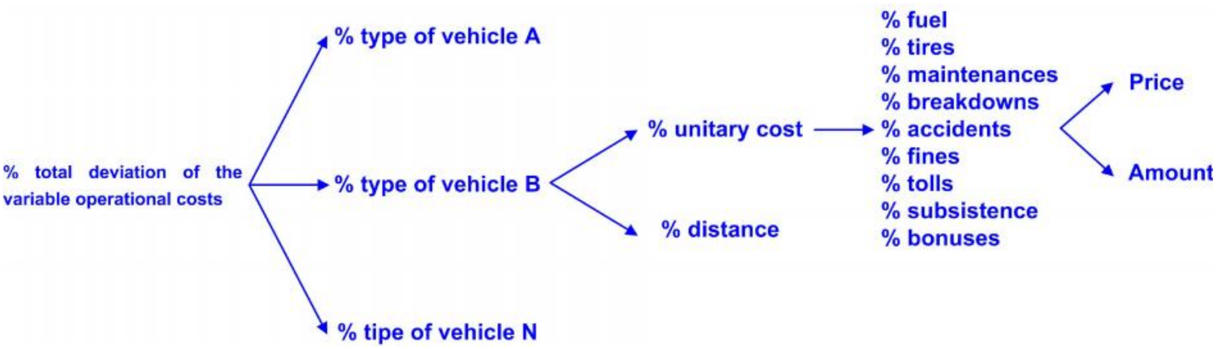
If all the values of the deviation percentage of the service level and variable operational costs in the periods Px, Px+1, Px+2...Pn are in the second and fourth quadrants, it's an intermediate situation between the worst and the best; and the fleet has been managed better and worse than expected in the short and long term depending on which of the two variables (service level or variable operational costs) are more important to the organization, their values or the operational circumstances that have been produced during the periods or between the periods Px, Px+1, Px+2... Pn.

If the values of the deviation percentage of the service level and variable operational costs in periods Px, Px+1, Px+2.. Pn are in different quadrants, the fleet hasn't been managed appropriately, because the organization hasn't controlled effectively the service level and variable costs. It could be for not identifying the reasons of these variations, not taking the adequate measures, or not planning correctly. The graph 32 shows three examples of this case considering 4 periods for the short and long term.



Graph 32: evolution of % deviation of the service level and variable costs in several quadrants

With the obtained data it has to be done a deep analysis for the short and long term with the following goals: to know the deviation causes in the service level and variable operational costs, prioritize the measure to take in those types of vehicles and concepts that are causing higher deviations; and identify the vehicles that are provoking these deviations. The analysis has to be done from the most generic aspect to the most specific one according to graph 33 for the variable operational costs.



Graph 33: structure of the deviations in the variable operational costs.

The first step is to know the deviation percentage of the variable operational costs per type of vehicle; the second step is to know the deviation percentage of the variable operational costs due to the unitary costs and distance traveled per type of vehicle, using the chart 24.

Knowing the deviation produced by the traveled distance, the organization needs to identify the vehicles that have traveled more distance than planned, study what causes this, and take the adequate measures so this doesn't occur again. In those vehicles that have traveled a distance shorter than planned, it has to be identified why this happened in order to apply it to the rest of the vehicles as a good practice and/or role model.

The third step is to know the break-down of the deviation produced by the unitary costs in its different items per type of vehicle, as shown in the chart 28.

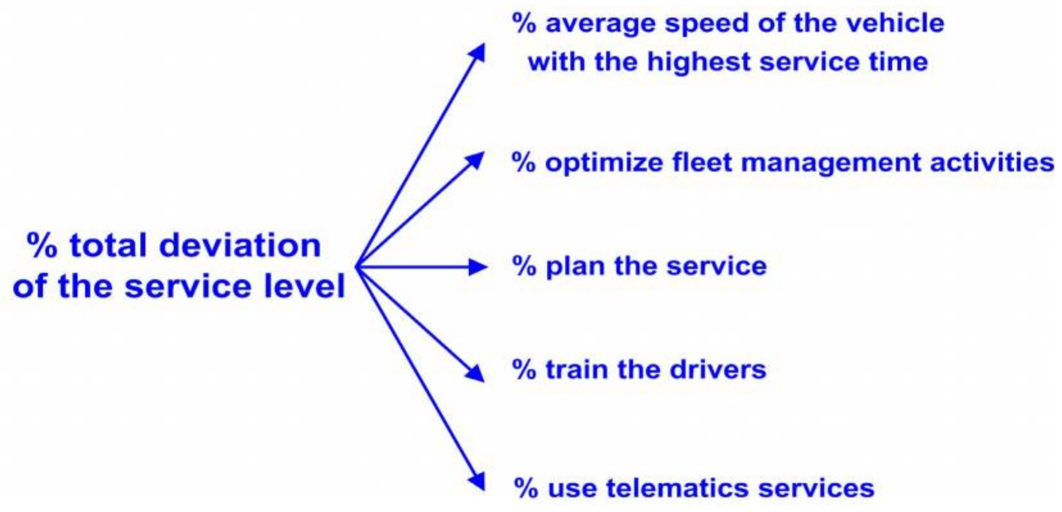
Concept	% deviation
Fuel	$((Cur_1\text{-}Cup_1)*Dr*100)/CTP$
Tires	$((Cur_2\text{-}Cup_2)*Dr*100)/CTP$
Maintenance	$((Cur_3\text{-}Cup_3)*Dr*100)/CTP$
Breakdowns	$((Cur_4\text{-}Cup_4)*Dr*100)/CTP$
Accidents	$((Cur_5\text{-}Cup_5)*Dr*100)/CTP$
Tickets/fines	$((Cur_6\text{-}Cup_6)*Dr*100)/CTP$
Toll road fees	$((Cur_7\text{-}Cup_7)*Dr*100)/CTP$
Subsistence	$((Cur_8\text{-}Cup_8)*Dr*100)/CTP$
Bonuses	$((Cur_9\text{-}Cup_9)*Dr*100)/CTP$
Dr is the real traveled distance per type of vehicle.	

Chart 28: deviation percentage of unitary costs.

With the obtained data from the chart 28, the organization knows if the unitary costs have negative or positive deviations, or no deviations. In those unitary costs with positive deviations it needs to be identified what provoked them, if it's because of prices, the amount, or both like shown in the chart 15; and identify what vehicles have provoked these deviations and take the adequate measures so it doesn't occur again.

In those unitary costs with negative deviations it needs to be identified what provoked them and the vehicles that provoked it, in order to apply them to the rest of the fleet as good practices and/or role model.

It needs to be identified the possible reasons of the deviations of the service level, and how much they correspond to each item like shown in the graph 34.



Graph 34: possible reasons for service level deviations.

A way to group the analysis from the short and long term, and measure how the fleet has been managed during period Px, is to establish a score system for the deviation percentage for the service level and variable operational costs. An example is developed on how to develop said score system.

% deviation	Costs	Service level
±0-3	0	0
±3-5	±1	±1
±5-8	±3	±3
±8-12	±5	±5
±12-17	±8	±8

Chart 29: scores depending on the deviation percentage

The chart 29 represents the score depending on the positive or negative deviation percentage produced by the real or planned service level and variable operational costs in respect to what was planned for period Px.

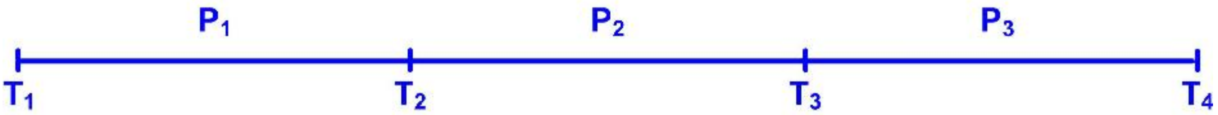
In this simple example, it's only used the total deviations, but the score system could be more specific using for example, the distance deviation and the different items of the unitary cost (fuel, maintenance, etc), and these at the same time, could be broken down by the price and amount.

In this example, the variable costs, the service level, the short and the long term have the same score percentage, however, for some organization the short term has more priority than the long term, the accidents than the fines, a certain type of vehicle, or the service level than the variable operational costs. For this reason, they need to have a different score percentage in the score system.

Because of this, scores and the level of detail of the score system depend on the characteristics and goals of the organization.

9.3. PRACTICAL EXAMPLE

A practical example is developed in a fleet with planned routes in three time periods according to graph 35, using the methodology explained in the epigraph 9.2. The service level is the highest time of all the vehicles of the fleet, and a reduction of this time implies an improvement in the service level like it is developed in the case study of the epigraph 4.1.1.



Graph 35: practical example considering three periods

Considering the fleet made of two types of vehicle that use the same fuel: the type A is a heavy truck that does interurban routes and of long distance, mainly through highways. The type B is a light truck that does mixed routes between urban and interurban and of medium-short distance.

Both types of vehicles perform the service level established by the highest time for all vehicles of the fleet, and that in this example belongs to the type B.

The charts and graphs of the following epigraphs show the initial conditions and the results of each period. Attached in the annexed is developed all the initial data and results for each period.

9.3.1. Period P_1

In the short period the planned condition in the instant T_1 and the real ones in the instant T_2 are the ones shown in the chart 30.

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2
A	20	0.502	0.520	200,000	201,000
B	80	0.195	0.193	600,000	680,000
Total	100			800,000	881,000

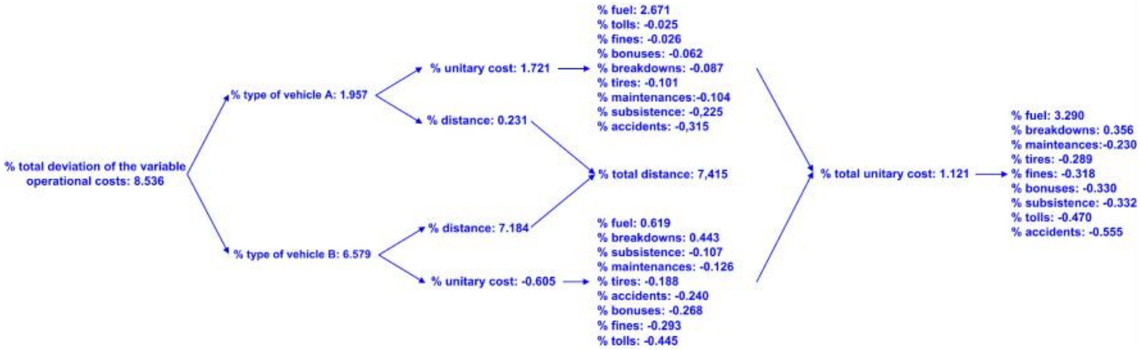
Chart 30: planned and real data for the period P_1

With the data from the chart 30 and the proposed mythology, the data in the chart 31 is obtained.

Type of vehicle	Total % deviation	Unitary cost % deviation	Distance % deviation
A	1.957%	1.726%	0.231%
B	6.579%	-0.605%	7.184%
Total	8.536%	1.121%	7.415%

Chart 31: % deviation of the real costs with respect to the planned costs for the period P_1

The graph 36 shows the % deviation broken down per type of vehicle, unitary cost, distance and item.



Graph 36: % deviation of the total variable operational costs in the short term for the period P_1

In the period 1, the deviation is 8.536% for the variable operational costs, mainly because of the vehicle type B and the traveled distance.

Analyzing the vehicle type B, the highest deviation corresponds to the traveled distance, because the vehicles have traveled more kilometers than planned. The deviation for the unitary cost has had a slight improvement, but the fuel consumption and breakdowns have worsened slightly. In the case of the fuel is due to a considerable increasing in the consumption (chart 58 and 59) because the average speed (chart 62) has increased slightly; and in the case of the breakdowns is because their prices have increased and the kilometrage/mileage for a breakdown to occur has decreased (chart 58 and 59).

Analyzing the vehicle type A, the highest deviation corresponds to the unitary cost, because the increasing of the fuel consumption, this is due to the average speed (chart 62) has increased considerably, in the rest of the items there's been slight improvements that make up partially for the fuel consumption. It could be considered that there's been no deviation in the distance for being such a small quantity.

In the long term, during the period P1, the organization has acquired their own fuel deposit of great capacity to refuel their vehicles for the moment T2, and for this reason the acquisition price for fuel is lower. The unitary costs, planned prices and amounts as well as the average time and distance, stay constant like shown in the charts 64, 66, 69 and 70.

In the long term, the planned condition in the moments T_1 and T_2 are shown in the chart 32.

Type of vehicle	Nº vehicles	Planned costs T_1	Planned costs T_2	Planned distance T_1	Planned distance T_2
A	20	0.502	0.452	200,000	200,000
B	80	0.195	0.179	600,000	600,000
Total	100			800,000	800,000

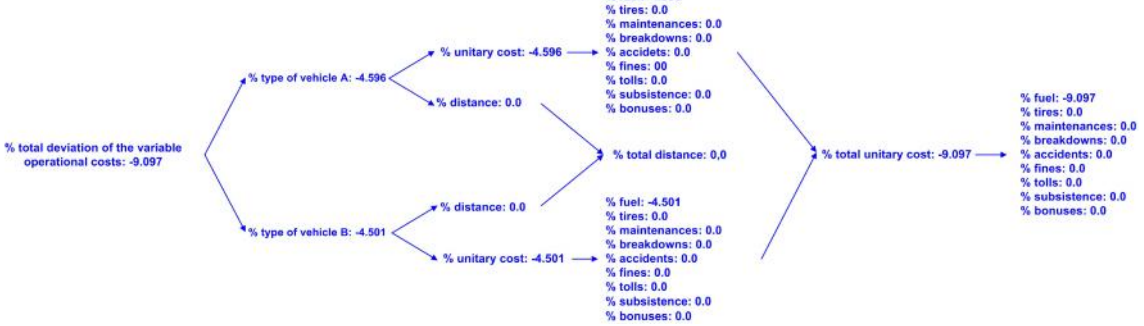
Chart 32: planned data in the long term for the period P_1

With the data from chart 32 and the proposed methodology, the data from the chart 33 is obtained.

Type of vehicle	Total % deviation	Unitary costs % deviation	Distance % deviation
A	-4.596%	-4.596%	0.000%
B	-4.501%	-4.501%	0.000%
Total	-9.097%	-9.097%	0.000%

Chart 33: % planned deviation in the long term for the period P_1

The graph 37 shows the % deviation broken down per type of vehicle, unitary cost, distance and items.



Graph 37: % total deviation of the variable operational costs in the long term for the period P_1

In the period 1 in the long term the deviation is -9.097% in the variable operational costs, caused by the fall in the fuel consumption price, and both types of vehicle have practically the same deviation percentage for the unitary cost.

The chart 34 shows the % deviation in the service level for the period P_1 in the short term.

Concept	Planned T_1	Real T_2	Difference	Increasing
Service level	8	8,5	0,5	6,25%

Chart 34: % deviation of the service level in the short term for the period P_1

In the period P1 the deviation is 6.25% of the service level in the short term, due to the fact it is established for a vehicle of the type B, and it has traveled a longer distance than planned, without any variation for the planned speed (chart 62), provoking the decreasing in the service level.

The vehicle type A has traveled the planned distance to a higher speed than the planned one (chart 62), but the service level has decreased because this type of vehicle doesn't have any influence in the service level, for this reason the only thing that has been obtained is an increasing in the variable operational costs, provoked for a higher fuel consumption.

In the long term, the organization has reduced the higher time of all the vehicles of the fleet, redesigning its route, provoking a time reduction for the service level like shown in the chart 35.

Concept	Planned T_1	Planned T_2	Difference	Decreasing
Service level	8	7.80	-0.2	-2.50%

Chart 35: % deviation of the service level in the long term for the period P_1

The main conclusions obtained for this first period are the following:

- In the long term we have obtained a considerable decrease in the variable costs of operations due to the acquisition of the fuel deposit, that has allowed the organization to lower the fuel price, and the service level stays the same.

- In the short term we have obtained an increase in the variable operational costs mainly due to the high traveled distance for the vehicle type B, and that has provoked a decrease in the service level.

- In the short term the variable operational costs has had a slight increasing because the vehicle type A has a higher speed than planned, provoking an increase in the fuel consumption, and that mainly has been made up with the improvements in the rest of the items of the variable operational costs.

- In the short term the fleet has been managed worse than expected with respect to the variable operational costs and service level. In the long term the fleet has been managed better than expected with respect to the variable operational costs, and according to what's expected in the service level since it is almost like the planned ones.

The organization has to investigate why there's been an increasing in the speed in the vehicle type A, and the traveled distance for the vehicle type B, just like identifying what vehicles has provoked the increasing with the goal of taking adequate measures to correct this situation and not happen again for the successive periods.

9.3.2. Period P_2

In the short term the planned conditions for the instant T_2 and the real ones for the instant T_3 are the ones shown in the chart 36.

Type of vehicle	Nº vehicles	Planned unitary costs T_2	Real unitary costs T_3	Planned distance T_2	Real distance T_3
A	20	0.452	0.456	200,000	198,000
B	80	0.179	0.179	600,000	630,000
Total	100			800,000	828,000

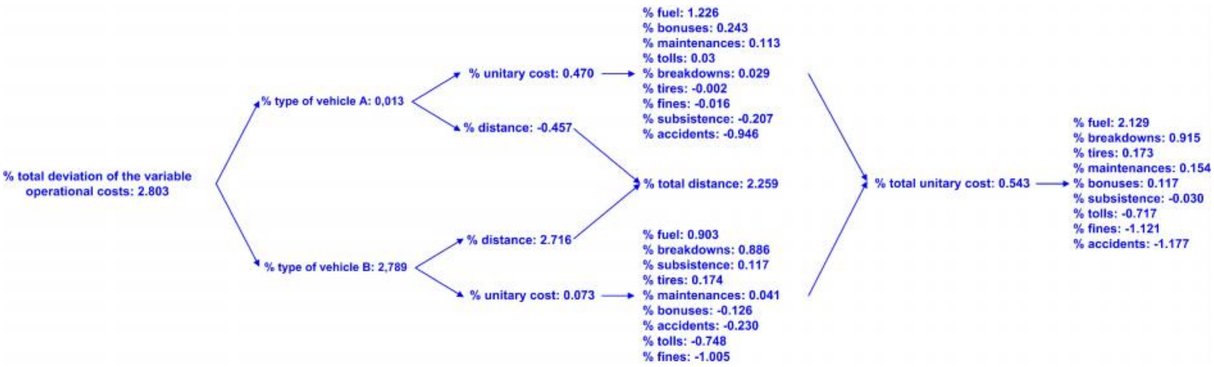
Chart 36: planned and real data in the short term for the period P_2

With the data from the chart 36 and the proposed methodology, the data from the chart 37 is obtained.

Type of vehicle	Total % deviation	Unitary costs % deviation	Distance % deviation
A	0.013%	0.470%	-0.457%
B	2.789%	0.073%	2.716%
Total	2.803%	0.543%	2.259%

Chart 37: % deviation of the planned costs in the short term for the period P_2

The graph 38 shows the % deviation broken down per type of vehicle, unitary cost, distance and parts.



Graph 38: % deviation for the variable operational costs in the short term for the period P_2

In the period 2 there's been a positive deviation of 2.803% for the variable operational cost, mainly due to the vehicle type B and the traveled distance.

Analyzing the vehicle type B, the highest deviation corresponds to the traveled distance, because it is higher than planned. The unitary cost hasn't had any deviation practically, but the fuel consumption and breakdowns have worsened slightly (charts 66 and 77). In the case of the fuel is due to a slight increase in the real price because some of the vehicles have refueled in other gas stations, instead of the company's owned fuel deposit; also due to a slight increase in the average speed (chart 70). In the case of breakdowns is because the prices have increased and the kilometrage/mileage for a breakdown to occur has decreased (charts 66 and 67). There's a slight improvement in the traffic tickets/fines because the frequency of occurrence has increased slightly (charts 66 and 67).

Analyzing the vehicle type A, there's practically no deviation in respected to what was planned. The unitary cost hasn't had any deviation practically, even though the fuel consumption has slightly worsen due to a small increase in the real price because some of the vehicles have refuel in other gas stations, instead of the company's owned fuel deposit, also due to a slight increase in the average speed (chart 70). There's a slight improvement in the traffic tickets/fines because the frequency of occurrence has increased slightly (charts 66 and 67).

In the long term, during the period P_2, an electronic device to avoid idle time has been installed, which turn off the vehicle's engine at the stops, which generates savings in fuel for the vehicle type B since it travels through urban routes (chart 76). The organization has also reached a framework agreement with a spare parts retailer that will supply alternative spare parts to the original as well as the drivers have been trained to prevent traffic accidents, so their frequency of occurrence is expected to increase (chart 74 and 76).

Due to the fact that the organization's service have a greater demand, and so we have to do more routes and/or pick-up or delivery location, the organization has to acquire three vehicles of the type B and one of the type A to keep the current service level. To calculate the long term deviation for the period P2, we consider that the fleet is the same for the instants T2 and T3 like in the charts 71 and 72.

All these measures will work in the instant T3, and for the rest of the items such as the planned unitary cost, prices and amounts they'll remain constant like in the charts 74 and 76.

In the long term, the planned condition for the instant T2 and instant T3 are shown in the chart 38.

Type of vehicle	Nº vehicles	Planned unitary costs T_2	Planned unitary costs T_3	Planned distance T_2	Planned distance T_3
A	20	0.452	0.387	200,000	200,000
B	80	0.179	0.147	600,000	600,000
Total	100			800,000	800,000

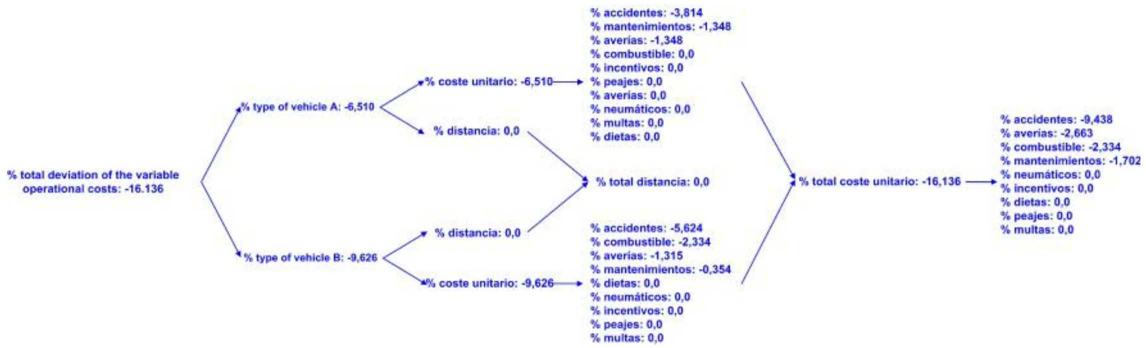
Chart 38: planned data in the long term for the period P_2

With the data from the chart 38 and the proposed methodology, the data in the chart 39 is obtained.

Type of vehicle	Total % deviation	Unitary cost % deviation	Distance % deviation
A	-6.510%	-6.510%	0.0%
B	-9.626%	-9.626%	0.0%
Total	-16.136%	-16.136%	0.0%

Chart 39: % deviation of the planned cost in the long term for the period P_2

The graph 39 shows the deviation percentage broken down per type of vehicle, unitary cost, distance and items.



Graph 39: % deviation of the planned cost in the long term for the period P_2

In the period 2 in the long term, the deviation is of -16.136% in the variable operational costs, caused mainly to the fall in the price of the spare parts that affects the areas such as: maintenance, breakdowns and traffic accidents; the introduction of the idle time electronic device to the fleet, that reduces the fuel consumption; and the prevention of the traffic accidents. The vehicle type B has a higher reduction mainly because of the idle time electronic device.

The chart 40 shows the deviation of the service level for period the P2 in the short term.

Concept	Planned T_2	Real T_3	Difference	Increasing
Service level	7.8	7.9	0.1	1.28%

Chart 40: % deviation of the service level for the period P_2 in the short term

In the period P2 there's been a slight deviation of 1.28% in the service level in the short term, due to the fact that the vehicle with highest service time has traveled a distance longer than planned, even though in the period P1 the route was redesigned. This result is in agreement with the real distance that's higher than the planned one for vehicle type B and that belong to this vehicle.

In the long term for the service level, the highest time of all vehicles has decreased, increasing the average speed of the vehicle with the highest time from all vehicles of the fleet. The chart 41 shows the deviation of the service level for the period P2 in the long term.

Concept	Planned T_2	Planned T_3	Difference	Decreasing
Service level	7.8	7.65	-0.15	-1.92%

Chart 12: % deviation of the service level for the period P_2 in the long term.

The conclusions obtained for the second period are the following:

- In the long term there's been a considerable decrease in the variable operational costs due to the framework agreement in reference to the spare parts, the traffic accidents prevention, the introduction of the idle time electronic device in the vehicles of the type B, and the service level remained the same.

- In the short term there's been a slight increasing in the variable operational costs due mainly to the higher traveled distance for the vehicle type B, and that has provoked a slight increasing in the time in the service level.

- In the short term the fleet has been managed just as expected with respect to the real variable operational costs and service level since they're almost like the planned ones. In the long term the fleet has been managed better than expected with respect to the variable operational costs, and according to what is expected with respect to the service level

The organization has to investigate why there's been a slight increase in the traveled distance by the vehicle type B, as well as identifying what vehicles has provoked this, with the goal of taking adequate measures to correct this situation and not happen again for the successive periods.

9.3.3. Period P_3

In the short term the planned conditions in the instant T_3 and the real conditions in the instant T_4 are shown in the chart 42.

Type of vehicle	Nº vehicles	Planned unitary costs T_3	Real unitary costs T_4	Planned distance T_3	Real distance T_4
A	23	0.387	0.386	207,500	199,500
B	81	0.147	0.146	614,000	605,000
Total	104			821,500	804,500

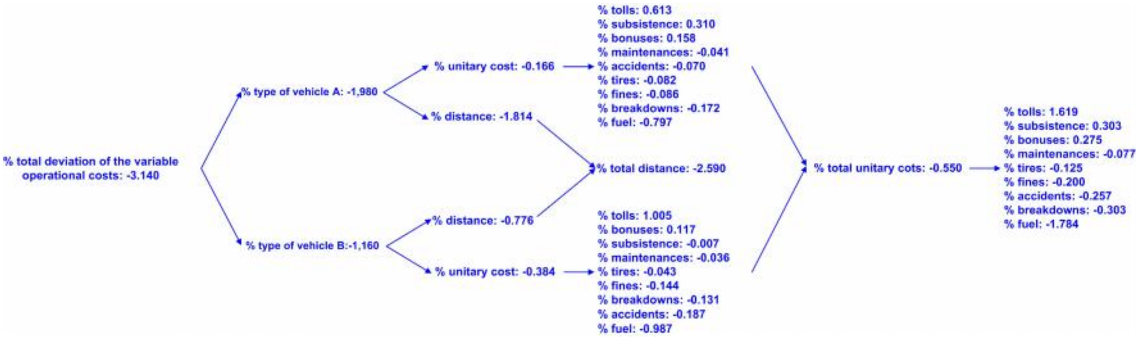
Chart 42: planned and real data for the period P_3

With the data from the chart 42 and the proposed methodology the data from the chart 43 is obtained.

Type of vehicles	Total % deviation	Unitary costs % deviation	Distance % deviation
A	-1.980%	-0.166%	-1.814%
B	-1.160%	-0.383%	-0.776%
Total	-3.140%	-0.550%	-2.590%

Chart 43: % deviation of the planned cost in the short period for period P_3

The graph 44 shows the deviation percentage broken down per type of vehicle, unitary cost, distance and items.



Graph 44: % deviation of the variable operational costs in the short term for period P_3.

In the period 3 in the short term the deviation is -3.140% of the operation variable costs due mainly to the fact that the traveled distance has been lower than planned, caused by a high in the use of toll roads like shown in the charts 74,75,76 and 77. The average speed has slightly decreased causing a decrease in the fuel consumption and an increase in the total time like shown in the chart 79.

In the long term the drivers have been trained to avoid traffic tickets/fines, for which it's expected that their frequency of occurrence increases. The organization has recalculated the routes to do in order to include toll roads provoking that the planned distance decreases, and has reached a framework agreement with a brand of tires.

All these measures will be effective in the instant T4, and the rest of the items of the planned unitary costs, prices and amounts remain constant like shown in the charts 81 and 82.

In the long term the planned condition in the instants T_3 and T_4 are shown in the chart 44.

Type of vehicle	Nº vehicles	Planned unitary costs T_3	Planned unitary costs T_4	Planned distance T_3	Real distance T_4
A	23	0.387	0.403	207,500	195,000
B	81	0.147	0.154	614,000	590,000
Total	104			821,500	785,000

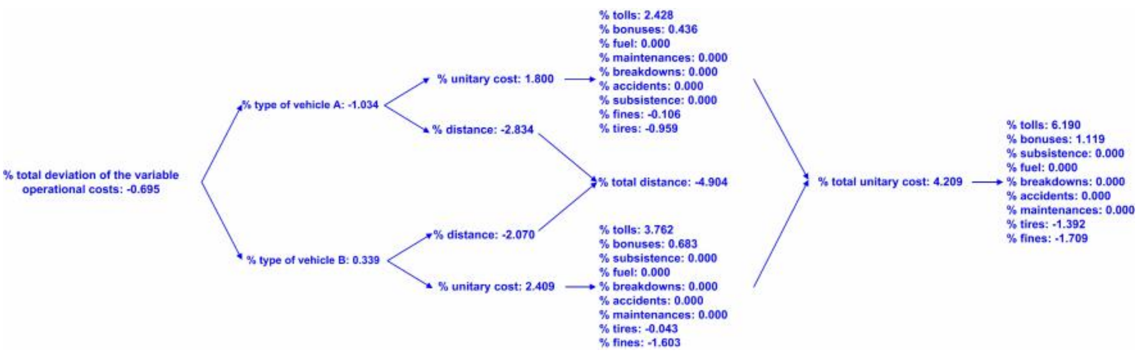
Chart 44: planned data in the long term for the period P_3.

With the data from the chart 44 and the proposed methodology the data from the chart 45 is obtained.

Type of vehicle	Total % deviation	Unitary costs % deviation	Distance % deviation
A	-1.034%	1.800%	-2.834%
B	0.339%	2.409%	-2.070%
Total	-0.695%	4.209%	-4.904%

Chart 45: % deviation of the planned costs in the long term for the period P_3.

The graph 41 shows the deviation percentage broken down per type of vehicle, unitary cost, distance and parts.



Graph 41: % deviation of the variable operational costs in the long term for the period P_3.

In the period 3 in the long term the deviation is -0.695% mainly caused for the use of toll roads that have provoked an increasing in the unitary costs, but they have been compensated by the decreasing of the planned distance. There's been a reduction in the tires cost due to the framework agreement with the tires company, and the traffic tickets/fines due to the training given to the drivers. Because of the smaller planned distance and keeping the same average speed, like shown in the chart 84 the total time decreases.

The chart 46 shows the deviation of the service level for period P_3 in the short term.

Concept	Planned T_3	Real T_4	Difference	Decreasing
Service level	7.8	7.55	-0.25	-3.21%

Chart 46: % deviation of the service level in the short term for the period P_3.

In the period P3 there's been a deviation of -3.21% in the service level in the short term, because the vehicle with highest service time has traveled shorter distance than planned due to the use of toll roads in all the performed services. In the long term in the service level the highest time of all the vehicle has decreased using the toll roads for all the performed services.

The chart 47 shows the deviation in the service level for the period P_3 in the long term.

Concept	Planned T_3	Planned T_4	Difference	Decreasing
Service level	7.65	7.2	-0.45	-5.88%

Chart 47: % deviation in the service level in the long term for the period P_3

The conclusions obtained for the third period are the following:

- In the long term there's been a considerable increase in the service level using toll roads, provoking an increasing in the unitary costs that has been compensated by the reduction in the planned distance to travel, the framework agreement with a tire supplier, and the training given to the drivers to avoid traffic tickets/fines.

- In the short term there's been a slight increase in the service level using toll roads in some vehicles, provoking a slight increase in the unitary costs that has been compensated by the reduction of planned distance to travel and the lower fuel consumption by lowering the average speed of the vehicles.

- In the short term the fleet has been managed better than expected with respect to the real variable operational costs and service level. In the long term the fleet fleet has been managed just as expected with respect to the real variable operational costs since they're almost like the planned ones and for the service level has been managed better than expected.

9.3.4. Results analysis

Grouping the results from the three periods in the short term, the charts 48 and 49 are obtained.

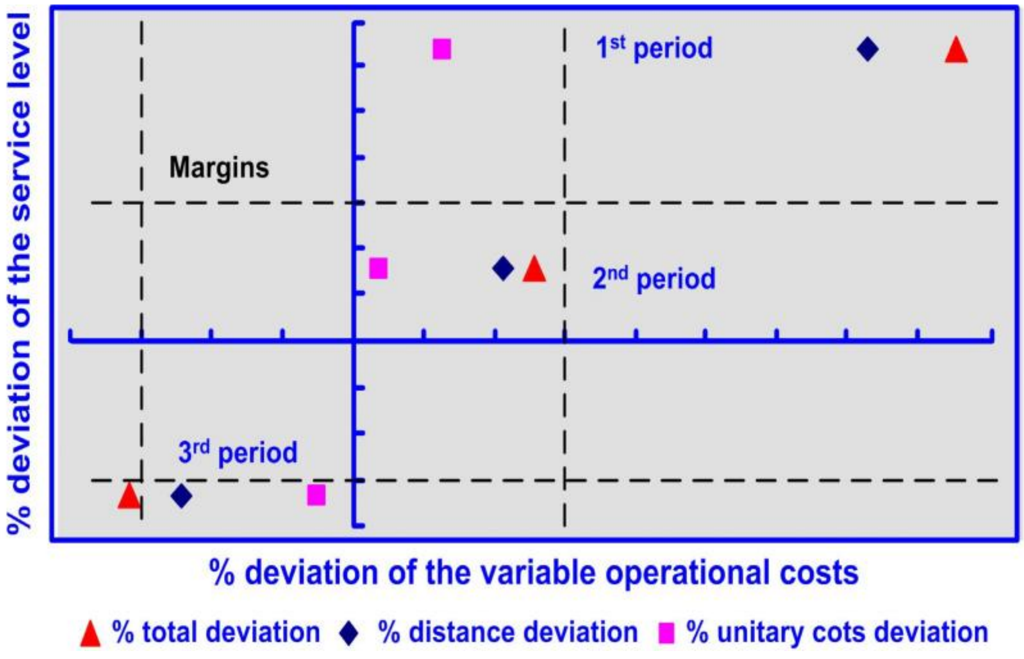
Period	Total % deviation	Unitary costs % deviation	Distance % deviation
1º	8.536%	1.121%	7.415%
2º	1.960%	-0.311%	2.271%
3º	-3.140%	-0.550%	-2.590%
Average	2.452%	0.087%	2.517%

Chart 48: % deviation of the total unitary cost in the short term

Period	% deviation
1º	6.25%
2º	1.28%
3º	-3.21%
Average	1.44%

Chart 49: % deviation of the service level in the short term

The graph 42 shows the representation of deviation of the variable operational costs and service level in the short term, using a margin of 3%.



Graph 42: % deviation of the variable operational costs and service level in the short term

In the short term, in the first period, the deviation has been positive for the service level and variable operational costs due to an increase in the planned distance. In the second period, due to a slight reduction in the unitary costs and distance traveled the deviation has been slightly positive for the variable operational costs and service level, but within the established margins. In the third period, due to a reduction in the traveled distance and unitary costs there's been a reduction in the variable operational costs and service level.

The evolution of the fleet management in the short term has gone from worse to better than expected in the analyzed periods, because the organization has taken the measures to reduce the traveled distance, which has been the most influential variable on how the fleet has been managed in the short term. Grouping the results in the long term, the charts 50 and 51 are obtained.

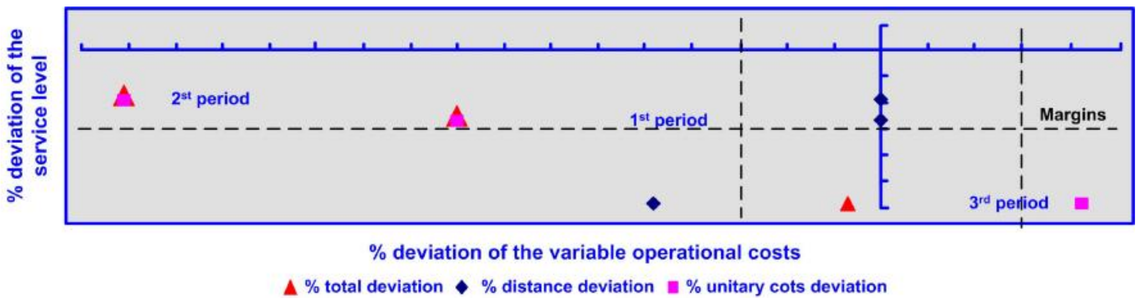
Period	Total % deviation	Unitary costs % deviation	Distance % deviation
1º	-9.097%	-9.097%	0.000%
2º	-16.136%	-16.136%	0.000%
3º	-0.695%	4.209%	-4.904%
Average	-8.64%	-7.01%	-1.63%

Chart 50: % deviation of the total unitary costs in the long term

Period	% deviation
1º	-2.50%
2º	-1.92%
3º	-5.88%
Average	3.44%

Chart 51: % deviation of the service level in the long term.

The graph 43 shows the representation of deviation of the variable operational costs and the service level in the long term, using a margin of 3%.



Graph 43: % deviation of the variable operational costs and service level in the long term

In the long term, in the first and second period, there's been a reduction in the unitary costs, obtaining a negative deviation of the variable operational costs. In the service level, there's been also a negative deviation after taking different measures. In the third period, there's been an increasing in the service level traveling a shorter distance by using toll roads; this has caused an increasing in the unitary costs that has been compensated with a shorter distance traveled.

The fleet management in the long term has been better than expected in the analyzed periods, because there's been a reduction in the unitary costs, which has been the most influential variable to measure how the fleet has been managed in the long term, and the increase in the service level taking different measures.

Grouping the data from the long and the short term, the chart 52 is obtained.

	% deviation, short term.		**% deviation, long term.**	
Period	**Unitary costs**	**Service level**	**Unitary costs**	**Service level**
1º	8.536%	6.25%	-9.097%	-2.50%
2º	1.960%	1.28%	-16.136%	-1.92%
3º	-3.140%	-3.21%	-0.695%	-5.88%
Average	2.45%	1.44%	-8.64%	-3.44%

Chart 52: deviation percentage of the unitary costs and service level in the short and long term

Using the scale from the chart 29, the following score is obtained, shown in the chart 53.

	Short term		**Long term**		
Period	**Unitary costs**	**Service level**	**Unitary costs**	**Service level**	**Total**
1º	-5	-3	5	0	-3
2º	0	0	8	0	8
3º	1	1	0	3	5
Average	-1.33	0.67	4.33	1.00	3.33

Chart 53: score obtained in the short and long term

Grouping the short and long term, the chart 54 is obtained.

Period	**Short term**	**Long term**	**Total**
1º	-8	5	-3
2º	0	8	8
3º	2	3	5
Average	-2	5.33	3.33

Chart 54: score broken down in the short and long term

Grouping per costs and service level, the chart 55 is obtained.

Period	Costs	Service level	Total
1º	0	-3	-3
2º	8	0	8
3º	1	4	5
Average	3.00	0.33	3.33

Chart 55: score broken down per costs and service level

In the fleet set, in the first period there was a negative score mainly due to the higher distance traveled in the short term. In the second period, because this issue had been resolved and due to the reduction in unitary costs in the long term, the score has been positive. In the third period, due to the shorter distance traveled and the reduction in unitary costs, the score has been also positive.

The evolution of the fleet management during these three periods can be considered satisfactory, even though in the first period due to the higher distance traveled in the short term we have obtained a positive deviation for the variable operational costs and service level. The organization identified this higher distance traveled and took the adequate measures causing its decrease and control in the second period, and its improvement in the third period.

In the long period, the organization took different measures in all the periods, which contributed to decrease the variable operational costs and increase the service level.

The variable operational costs have been reduced in the short period, reducing the traveled distance, and in the long term reducing unitary costs.

The reduction in the unitary costs have had more weight than the reductions in service level causing the measures taken in the long term to weight out the ones taken in short term for the fleet set.

9.3.5. Conclusions

The main conclusions obtained from this theoretical and practical example, and that can be applied to any type of fleet are the following:

- In the short and long term the organization could take measures in the same or different variables to control and reduce the variable operational costs and increase the service level, which depends on the fleet's characteristics, goals and operation.

- The organization has to identify if in the long or short term there's more impact on the measures to take to control and reduce the variable operational costs and increase the service level, which depends on the fleet's characteristics, goals and operation.

- The service level could increase almost at no cost by adopting several measures that need to be identified. In the case of this example, in the first period, the organization had redesigned the routes for the vehicle with more time in the fleet. In the second period, we have increased the average speed for the vehicle with more time in the fleet. In the third period, we have reduced the time of the service level increasing the use of toll roads, causing an increasing in the variable operational costs that have been compensated by the shorter distance traveled.

- The total unitary cost remains constant in some periods, if the increases in some variables are compensated by the decreases in other variables.

- During these three periods it has been applied different measures to reduce the variable operational costs and increase the service level, the organization has identified the inconveniences and the vehicles that have been causing positive deviations, and we have taken the adequate measures for their control, reduction and improvement. This is a good practice that needs to be done in every period.

- From all the variables involved in the fleet management, the organization needs to identify the ones that influence more the variable operational costs and service level in order to control and prioritize the measures to take in these variables.

- There needs to be a priority in the measures to take to reduce the variable operational costs. The analysis needs to be done from the most generic term to the most specific one to identify the causes that are provoking the highest deviations in the variable operational costs.

First, there needs to be identified the type of vehicle; second, if its due to the unitary costs or due to the traveled distance; third if it's due to the unitary costs, it needs to be identified under what concepts; lastly, once identified said concepts, if it's due to the price, amount, or both.

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10. CONTROL AND MONITOR OF THE VEHICLE FLEET

The organization has to design and implement what information and level of detail is registered for control, monitor, traceability and history of the vehicle such as the technical specifications, acquisition cost, acquisition date, delivery date, disposal date, sales date, sales price, who's in charge of the vehicle, who's the vehicle's driver, or what workplace has assigned the vehicle. Some of this information can be collected from other departments like accounting and/or financing.

The information and level of detail to register depend on several aspects like the following:

- The financial capacity of the organization: the more information to collect, the more resources needed, and the higher the cost.

- The fleet size and number of work centers: the higher the number of vehicles and/or work centers, the more complex is the information collecting, the more resources consumed, and the higher the cost.

- The information usage: it needs to be consider if the collected information is useful for decision making such as the average period of delivery for the vehicles, the average period of use of the vehicle, the average of drivers that use the vehicle, the average acquisition price, the average sales price, the average time to sell the vehicle, identify the drivers and workplaces that misuse the vehicles or are not following the general rules of the fleet management organization.

- Importance of the vehicle fleet: if the fleet's management supports the main activity of the organization it needs to have a deeper control, monitor, traceability and history of the vehicles, than if the fleet's management is a secondary activity for the organization.

- If the information is useful for other departments of the organization, like accounting or the assets control.

10.1. INFORMATION TO REGISTER OF THE VEHICLE FLEET

In order to have control, monitor, traceability and history of the vehicle, it's recommended to register the following basic information in the information system.

- Acquisition price of the vehicle and acquisition date of the vehicle.
- Delivery date of the vehicle.
- Vehicle's supplier.
- Brand and model of the vehicle and vehicle's equipment.
- Contamination emissions of the vehicle.
- Documentation of the vehicle in PDF format or copy of the original ones (technical sheet, circulation permission, insurance, etc.).
- Technical specifications of the vehicle (information hold in the technical sheet).
- Date of the last technical inspection.
- Assigned working center.
- Assigned driver or person in charge of the vehicle.
- Sales price of the vehicle.
- Date of the vehicle's disposal.
- Date of the vehicle's sale.
- Sales price of the vehicle.

Some of this information can be included in the scoreboard, like acquisition and sales price, and the date when these take place.

11. AUXILARY SERVICES OF THE FLEET

The organization has to design and implement the policy for the auxiliary services, which are those support activities of fleet management, and its main goal is to comply with the current laws in the country where the fleet operates.

The auxiliary services are the activities with the lowest added value in fleet management and are the following.

- Insurance: hiring and managing the insurance policies of the vehicles as well as choosing the provider and type of insurance.

- Accidents: managing and working with the insurance company and third-parties in traffic accidents.

- Fuel cards: hiring and managing the fuel cards as well as choosing the provider.

- Traffic tickets/fines: managing traffic tickets/fines like payment, claims, drivers identification, etc. it needs to be established in which cases the organization or the driver pays said tickets.

- Vehicles technical inspection: controlling and managing the technical inspections, with the goal of getting the vehicles their inspection on time.

- Current laws: complying with the current laws that apply to the fleet management, from the acquisition to the disposal, as well as the technical specifications of the vehicles.

- Technical modifications of the vehicles: manage all the certificates and relevant procedures with third-parties so the modifications made to the vehicles comply with the relevant law and the vehicles technical inspection.

The management of these auxiliary activities could be outsourced to third-parties, and it depends on some aspects that are reviewed in the following chapter of outsourcing.

12. OUTSOURCING AND ORGANIZATIONAL STRUCTURE

12.1. OUTSOURCING OF THE FLEET MANAGEMENT

Outsourcing is to externalize parts of the organization's productive process and/or activities to a third party. It's done by every organization in several industries due to diverse reasons.

Currently, in the vehicle fleet management market there are several third party companies to whom outsource most of the activities and/or processes like acquisition, control and monitor, sales of the vehicles or managing auxiliary services.

The organization has to establish certain criteria and guidelines for outsourcing several activities of the value chain to third parties, and which are done by the own company, just like establishing the period to review these criteria and guidelines.

There is vast scientific literature on outsourcing. Following are explained the advantages and the most important reasons for vehicle fleet management.

- Focusing on the activities with higher added value: outsourcing those activities of lower added value makes it possible for the organization to focus their most valuable resources in those activities of higher added value in order to develop higher abilities and knowledge. This gives to the organization an advantage in the market and generates more value for the clients/users, creating an entrance barrier against potential entrances in the industry.

- Flexibility to adapt to the market: the activities of the value chain increase their modularity, and the hierarchized or vertical structures of the organization become more horizontal. In addition, it requires fewer resources like staff and circulating capital causing an increase in the organizational flexibility, which is understood as the organization's ability to adapt quickly to demand and opportunities in the market.

- Costs: costs are one of the main factors for outsourcing, because of the scales economies, the outsourced providers can do the service and/or activity to a lower cost than if they were done by the organization.

- Abilities and knowledge of human capital: aside from the labor costs, outsourcing is done to add more value to the final product or service through knowledge and abilities of the third party organization's human capital.

- Mutual trust and shared values: the relationships based in mutual trust, shared values, performing similar services or making similar products, working in the same market, using the same productive service, similar supply chain and similar technologies, create competitive advantages for both organizations due to the positive impact in their abilities to adapt to the market, to solve problems that show up when they work together, and to eliminate the opportunistic behaviors.

- Co-specialization and mutual learning: outsourcing creates knowledge, abilities and a mutual experience with third parties, generating co-specialization and co-knowledge that are beneficial for the partners, allowing them to create products/services with a higher added value in a fast and flexible way and it's also a strong potential for competitive advantages. To establish a lasting and stable relationship in time, frequently organizations do strategic alliances, joint venues and other type of relationships between organizations and specialized suppliers.

Outsourcing with specialized suppliers has the following main costs: searching for suppliers, negotiating, designing the contracts, follow-up of the agreements, follow-up of the goals that are reached and the disagreements if there were any. These costs can increase considerably if the organization is working in a foreign country.

The activities of higher added value in the vehicle fleet management are: designing and implementing policies, calculating the optimal number of vehicles, vehicles acquisition, vehicles operation, scoreboard, and data analysis.

Aside from the previous advantages and costs, outsourcing requires considering the following aspects in order to outsource some activities in the value chain:

- The main activity of the value chain: if for the organization fleet management is the main activity in the value chain, they will manage the activities with higher added value already mentioned and can outsource the rest of the activities to a third party. On the contrary, if for the organization fleet management is an auxiliary activity from the main one in the value chain, they could outsource all of the fleet management activities to a third party.

- External organizations existence: It could happen that some specialized activities or processes can't be outsourced because there's no external organization that does them or because in the country there's no organization that offers the service and therefore the organization has to do the activity internally.

- External organizations ownership: an obstacle to outsource some activities is when the third party organizations belong to companies that are our competitors, and it needs to be studied if it can compensate this option.

- Fleet's operative: a fleet that has a complicated management outsources fewer activities than a fleet that's easy to manage in order to have the control of it. A fleet with planned routes outsources fewer activities than a fleet with sales associate.

- Fleet size: a fleet with many vehicles and/or work centers is more difficult to manage than those with few vehicles and/or work centers, and for this reason, we need to focus on the activities with higher added value and outsource those activities with lower added value.

In order to outsource some activities and/or processes, there needs to be met two prerequisites.

- The coordination between the different activities in the value chain has to be simplified through the reduction of the relations of interdependence between them. To do this, they need to be modularized and sequential in order to be clearly differentiated and independent among them (the coordination difficulties between the different stages of the value chain incentivize vertical integration). The activities that are part of the fleet's management shown in the graphic 1, meet this prerequisite since they're independent and sequential.

- The exchanged information among the different value chain activities needs to be standardized; this means, it needs to be universally understandable, easy to specify and transmitted in a way that information asymmetries are decreased or eliminated. Creating standard formats to define the activities and processes is needed, since it replaces the way each organization has to describe and define them, because of this, there needs to be a standard for information in syntax and grammar, so the communication is effective inside the organization and with the external company. The information that is exchanged in the vehicle fleet management is easily understandable and the standardization is simple to do.

12.2. ORGANIZATIONAL STRUCTURE OF THE VEHICLE FLEET

The organization has to design and establish the organizational structure of the fleet management such as: the departments; the job profiles; the internal activities to do and which ones to outsource; the processes; the controls; and the needed software and hardware, and depend on the following aspects:

- Fleet size to manage: a large fleet with several work centers requires more processes, resources, controls and staff than a small fleet with a work center.

- Available resources: an organization with a great financial capacity could acquire fleet management software, have a large scoreboard, hire staff for managing the auxiliary activities, have one or several fleet managers, have their own workshops, or have a department for the fleet management.

- Activities to do: the more complex are the activities to manage, the more processes, resources, controls and specialized staff are needed.

- Importance of the fleet: if the fleet management is the main activity in the value chain of the organization, the activities will be managed by specialized staff, and there will be one/some fleet manager/s. On the contrary, if the fleet management is a support activity of the main activity of the organization, the activities will be managed by several workers and/or departments of the organization.

- Who does the activities: the activities could be managed between several workers or by one/some fleet manager/s in charge of all activities.

- Outsourcing activities: some activities of the fleet management can be outsourced to third party companies.

Depending on the already mentioned aspects, there are several organizational combinations and solutions for the fleet management. Because of this, each organization has a solution that adapts better to their necessities, characteristics and goals.

13. VEHICLE FLEET MANAGEMENT SOFTWARE

The use of the fleet management software is a very useful tool for managing, storing and accessing to the fleet information from any place and device in a simple and immediate way.

For fleet management it can be used a simple spreadsheet or the most sophisticated software in the market, choosing which one depends on the following factors:

- Number of vehicles: the larger the fleet, the most difficult is to manage the fleet, and for this reason it is necessary the management software. A fleet with five vehicles can be managed with a spreadsheet, but it’s unviable for a fleet with 1,000 vehicles.

- Number of work centers: the more work centers, the more difficult is to manage the fleet, and for this reason it is necessary the fleet management software.

- Information to register: the more information to register and analyze, the more difficult is to manage the fleet, and for this reason, it is necessary the fleet management software. It’s not the same to do a simple control and monitor of the vehicles, than registering and analyzing lots of information regarding the vehicles operations.

- Cost: the more information to register, and the more functions needed, the higher the fleet management software cost.

- Fleet’s operative: the more complex is the operative, the more difficult is to manage the fleet, and it is necessary the fleet management software. It’s not the same to manage a fleet designated to sales associates, when there’s a vehicle per associate, than a fleet in which a vehicle is used for several drivers and/or work centers.

- Telematics services: if the organization uses telematic services, it’s needed to use the fleet management software to get a high performance from it.

In conclusion, if the fleet is small, it has only one work center, one driver per vehicle, the organization only needs to do a simple control and follow-up of the vehicles, a telematic service is not used, using a spreadsheet could be enough to manage the fleet.

On the contrary, if the vehicle fleet is large, with a complex operative, a lot of information is registered, there are several work centers and a telematic service is used, it’s needed to use the fleet management software.

In the market, there are many companies that create software for fleet management. Following are the key aspects that the fleet management software needs to meet.

- Adaptability: the fleet management software needs to adapt to the organization's characteristics, operative and goals, and for this reason, it can be modified to meet the organization's requirements.
- Modularity: the software needs to be integrated by modules like vehicle data, maintenance, fuel, breakdowns, accidents, etc. from which the organization can choose which ones to use, and that new ones can be developed if needed.
- Access from any device: currently, any management software can be used from any personal computer, but each time it is more important to be able to review data on the field, for which it becomes necessary that it can be accessed from tablets and smartphones.
- Flexibility and scalability: the software can be used no matter the number of vehicles and information to manage.
- Cost: the cost of the software needs to be established by modules and/or the number of users (licenses) that we use, and/or the number of registered vehicles.
- Integrate the scoreboard: with the information gathered in the software the scoreboard has to be created automatically, with all its graphics and indicators in an independent section.
- Establishing alarms: the software has to allow the organization to establish automatic alarms in those sections that the organization needs, so it goes off when the established variables are not within the established limits.
- Information extraction: the software needs to allow the organization to make cross reference searches (dynamic charts) and that these can be exported in several formats to use in a spreadsheet, business intelligence tool or statistics software.
- Matching the telematics services: the software needs to be compatible with the telematics services that the organization uses in order to get its maximum performance. Most of the

companies that offer telematics services include the software for fleet management.

- Matching the other organization's software: the software needs to be compatible and allow information exchange in an easy way with other management software of the organization, like accounting or control of assets.

An option is that an external company develops the fleet management software tailored for the fleet's needs that meet the prerequisites already mentioned. It's recommended that the software have the following sections in order to facilitate the vehicles control, monitor, traceability and history, and identify which vehicles and drivers are not being managed appropriately.

- A sheet that gathers the history and data of each vehicle like maintenance, breakdowns, work centers, drivers, acquisition prices, etc.

- A sheet that gathers the history and data of each driver like which vehicles he/she has driven, work center, accidents, traffic tickets, etc.

They're mostly all advantages when it comes to using the fleet management software, but it needs to be considered the following recommendations.

- The organization requires a period of time for the implementation, adaptation and fixes the mistakes in the management software. Because of this, it's recommended to implement a first stage with basic information to gather for the control and follow-up like the information of each vehicle, center and driver to which it belongs. Once this first stage is finished, the information to gather needs to be extended to the fuel consumption, traveled distance, etc. and so on until the organization considers which information is appropriate to gather and manage.

- The fleet management software gathers a large amount of information of the fleet, that if it isn't analyzed, the organization won't have valuable information for decision making and know the status of the fleet and its evolution and for this reason the management software will have a low performance.

- The organization needs to have the appropriate staff and with the adequate training to manage the management software.

14. TELEMATICS SERVICES OF THE VEHICLE FLEET

The use of telematics services are very useful, because it helps the organization to monitor and gather lots of valuable information of the fleet operations automatically, like fuel consumption, traveled distance, traveled routes, vehicle's localization, vehicle's driver or the way the vehicle is driven.

The goals of the telematics services are the following:

- Control and reduction of fuel consumption and Co_2 emissions.
- Control and reduction of traffic accidents.
- Know when a traffic accident occurs.
- Control and manage the vehicles safety.
- Localizing, follow-up of the vehicles, and assistance in case of a breakdown.
- Control and follow-up in traveled routes.
- Control and follow-up of the drivers.
- Control and improvement of the driving style of the drivers.
- Control of the unauthorized uses of the vehicles.
- Control and reduction of idle time.
- Improve the vehicle's use.
- Increase the vehicles productivity.
- Count the time the vehicle is being used.
- Increase the vehicles availability.

In emergency services (ambulances, police etc.), they're very useful since they identify the closest vehicle and provides with the most appropriate route to arrive in the lowest possible time to the destination.

To get a higher performance from telematics services, they need to be used with the management software and a GPS (Global Positioning System) device, or an accelerometer. On the contrary, using the management software doesn't require telematics services or other devices, even though they're recommended.

The following aspects need to be considering when telematics services are implemented in the organization.

- Cost: the more information to gather, the more resources are needed, and in consequence, the higher the cost.

- Fleet's size: the larger the fleet, the more complicated it is to manage, and for this reason, telematics services are of great use.

- Work centers: the more work centers and/or the more dispersed the vehicles are geographically, the more complicated is to manage the fleet, and for this reason telematics services are of great use.

- Data gathering: collecting data automatically avoids having to collect it manually, eliminating any problems regarding registering the wrong data, not reporting the data on time, or not to have staff assigned to the collecting activity.

- Type of fleet's operative: a fleet with a complex operative, like a vehicle is driven by several drivers or a driver drives several vehicles is harder to manage than a fleet that has an assigned driver to each vehicle, and for this reason, using telematics services is of great use.

- Flexible and scalable: It needs to adapt to the organization's necessities and characteristics, and that the gathered information can be selected and broadened in the future.

• Technology: the needed technology, and if it's available in the country for the use and implementation of the telematics services.

• Matching the management software: telematics services need to be compatible with the vehicle fleet's management software.

The organization need to establish the following guidelines to implement telematics services in the organization:

• The criteria for the telematics services selection needs to be based on the already mentioned aspects.

• Establish what information needs to be collected and reported, like the fuel consumption, traveled routes, hours of use of the vehicle etc.

• Establish a period to analyze the gathered data.

They're mostly all advantages when it comes to using telematics services for the vehicle fleet, but it needs to be considered the following recommendations:

• The organization requires a period of time for the implementation, adaptation and fixes the mistakes of the telematics services. Because of this, it's recommended to implement a first stage with basic information to gather, like fuel consumption and traveled distance. Once this first stage is finished, broaden the information until the organization considers which information is appropriate.

• Telematics services include a big amount of information of the vehicle fleet, that if it isn't analyzed, the organization won't have valuable information for decision making and know the status of the fleet and its evolution, and for this reason the telematics services will have a low performance.

• The organization needs to have the appropriate staff and with the adequate training to manage the telematics services.

15. ELECTRIC VEHICLES FLEET

The use of electric vehicles has become a feasible solution for fleet light vehicles in urban environments in the last few years, city councils have adopted several measures for the cities to be more liveable, self-sustained and respectful of the environment, and for this reason they try to minimize and reduce traffic impact, like contaminating emissions, foul smells, sicknesses, or low mobility causing new ways to manage traffic to minimize these effects, which has been called urban mobility, which agglutinates new ideas like energetic efficiency and sustainability.

The electric vehicle is a key aspect to sustainable development in urban environment mobility, since it minimizes the carbon dioxide (CO_2) emissions, which is a main cause of the greenhouse effect, and consequentially of the planet's global warming. Laws on contamination for vehicles are each time more demanding and restrictive, which has caused vehicles manufacturers to develop new technologies to meet said laws. One of these new technologies are the electric vehicle, that in the last years have evolved quickly, and doesn't emit any contaminating emissions, any noise or smell; besides, using electric vehicles reduces dependence from oil and energy costs are much lower than fossil fuels.

The advantages and disadvantages of using electric vehicles are the following:

- Advantages

  - Cost of energy: energy costs are much lower than fossil fuels.
  - Contaminating emissions: electric vehicles have zero contaminating emissions.
  - No noise, vibrations or smells: comfort levels and rolling levels are higher than in vehicles that use fossil fuels.
  - Automatic transmission: no manual transmission, with the simplification and reduction of mechanical systems.
  - Higher acceleration: higher acceleration than in a fossil fuel vehicle, due to higher torque motor in electric motors.
  - Simple maintenance: due to the simple motor and electric system, and because it has less mechanical systems than in vehicles with fossil fuels.

- Parking downtown: the possibility of free marking in downtown area of the cities that has it regulated.

- Being able to drive downtown: being able to drive downtown in the cities that have restricted the access for vehicles that use fossil fuels.

- Exempt of registration fee: not paying the registration fee.

- Exempt of toll road fees: in some regions, electric cars are exempt of paying toll road fees.

- Subventions: public administrations offer subventions for acquiring electric vehicles.

▪ Disadvantages

- Limited autonomy: The highest inconvenience for an electric car is the autonomy range that currently is of 200 km (~ 125miles).

The following chart shows the autonomy for some electric vehicles available in the market.

Model	Power (CV)	Autonomy (km.)
Citroën C-Zero	67	150
Peugeot iOn	67	150
Mitsubishi i-MiEV	67	160
Volkswagen e-up!	82	160
Ford Focus Electric	142	162
Nissan Evalia e-NV200	109	170
BMW i3	170	190
Volkswagen e-Golf	116	190
Nissan Leaf	109	199
Mercedes-Benz B Electric Drive	179	200
Kia Soul EV	111	212
Renault ZOE	88	210/240
BYD e6	122	250/300
Tesla Model S 70D	334	442

Autonomy range of some electric vehicles.

The main inconvenience of an electric vehicle is the autonomy range, which could be eliminated in a short-medium period of time due to the use of graphene that could be a real revolution for the automobile industry due the possible development of batteries, supercondensators, hydrogen deposits, painting and plastics.

Grabat Energy company, subsidiary of the Spanish company Graphenano, has created a graphene battery of high energetic density that would allow an electric vehicle to have autonomy range up to 800km (~497miles).

The battery is made of the graphene polymer, and has the advantage of being able to storage higher energy in a reduce space than the ion-lithium batteries currently used in electric vehicles, with a density of 1,000 watts-hour per kilogram (Wh/kg) and a voltage of 2.3 v.

The charging time is much lower due to the charging speed of 100 coulombs (C) in opposite to the ion-lithium of 3C. Besides, it's lighter and doesn't have the "memory effect" that ion-lithium batteries face, which is when the batteries don't charge to their maximum capacity, losing charging capacity over time.

Currently, the only issue with graphene is its high costs (1,000 euros/kg) and the difficulty of its manufacturing.

- Recharging infrastructure: public infrastructure available isn't developed enough, for this reason the organization needs to establish their own infrastructure to recharge and/or establish a share infrastructure with other organizations to save costs.

- Lower residual value: normally it's lower than the same vehicle that uses fossil fuels, even though it could vary in the market depending on their level of acceptance and the bonuses there are for acquiring the vehicle in each country. In addition, if the battery that uses the vehicle is rented the residual value will be higher, since the battery will be in perfect conditions.

- Recharging time: depending on the type of recharge used, charging could take from 30 minutes to recharge 80% of the battery level up to eight hours. The lower the recharging time, the least the battery will last.

- Battery life: the battery lasts around eight years; once this time has ended, it has to be changed, although there are some vehicles manufacturers that offer the possibility of renting the batteries during the vehicle use.

- Electric vehicles availability: currently, available electric vehicles in the market are in high and low end and in certain type of vehicles, although the available offer is expanding to any type of vehicle and end.

- Competition with hydrogen vehicles: hydrogen vehicles have been tested in the last few years with a great development, and could transform into a feasible option against electric vehicles. In some countries like Japan, they're already available in the market.

- Higher acquisition price: electric vehicles have higher acquisition price than the same vehicle model in fossil fuel.

- Lack of electric culture: The lack of electric culture in a country could be an obstacle for the implementation of electric vehicles. For example, in countries like Norway or Netherlands, they are highly welcomed, and for this reason, they're large part of the market.

Following are some recommendations to acquire an electric vehicle or change a vehicle that uses fuel fossils for an electric one in the vehicle fleet.

- Check that the electric vehicles adapt to the fleet's operative, the most important factor to check is if it has enough autonomy range for the service performance. If the vehicle travels planned routes, the distance to travel is already known; on the contrary, if the vehicle travels an undefined route, and there's no telematics services that report the traveled distance, a GPS device needs to be installed in the vehicle during the traveling period trial to know the daily traveled distance during the service performance.

- Define the type of recharge needed since this will establish the recharging time of the batteries. It could be slow (8 hours), semi-fast (4 hours) and fast (30 minutes) to recharge 80% of the battery, and each one of them has different electric power needs of installation and infrastructure.

- Where to establish the recharge location. It could be the organization’s own recharge locations, use third party ones, or public ones.

- Calculate the vehicles total cost of ownership (TCO) and the infrastructure costs to know if it´s economically feasible for the organization.

- Check that the electric vehicle has the appropriate characteristics (capacity, functionality, etc.) for the service performance.

- Establish if the batteries are bought or rented.

- Train the users on how to use and drive these types of vehicles.

- If maintenance can be done in the organization’s locations, the organization’s personnel needs to be trained and the organization must have the appropriate means.

It’s undoubted that at some point in time the organization has to change to the electric vehicle in urban environments, and for this reason, they have to be prepared with the appropriate resources and plan in time.

16. ATTACHED

16.1. EPIGRAPH 4.1.1.: CASE STUDY

16.1.1. PERIOD P_1

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	1	5	0.200	40,000.00	39.863%
Accidents	3,000	35,000	0.086	17,142.86	17.084%
Tires	700	10,000	0.070	14,000.00	13.952%
Breakdowns	2,000	30,000	0.067	13,333.33	13.288%
Maintenance	1,500	30,000	0.050	10,000.00	9.966%
Subsistence	70	6,000	0.012	2,333.33	2.325%
Bonuses	20	3,000	0.007	1,333.33	1.329%
Tickets/fines	90	15,000	0.006	1,200.00	1.196%
Toll road fees	15	3,000	0.005	1,000.00	0.997%
Total			0.502	100,342.86	100.00%
Planned distance		200,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle A.					

Chart 56: planned costs for the vehicle type A in the instant T_1

Concept	Real price	Real amount	Real unitary costs	Real costs	%
Fuel	1	4.37	0.229	46,012.26	43.989%
Accidents	2,757	33,494.78	0.082	16,542.36	15.815%
Tires	698	10,129.65	0.069	13,850.23	13.241%
Breakdowns	1,986	30,212.27	0.066	13,210.25	12.629%
Maintenance	1,450	29,673.18	0.049	9,823.56	9.391%
Subsistence	68	7,362.44	0.009	1,856.45	1.775%
Bonuses	18	3,003.59	0.006	1,204.56	1.152%
Tickets/fines	95	16,597.85	0.006	1,150.45	1.100%
Toll road fees	14	2,960.70	0.005	950.45	0.909%
Total			0.520	104,600.57	100.00%
Real distance		201,000			
Real Price in Euros; Real amount in km; Real distance in Km. Type of vehicle A.					

Chart 57: real costs for the vehicle type A in the instant T_2

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	1	13	0.077	46,153.85	39.370%
Accidents	500	13,000	0.038	23,076.92	19.685%
Breakdowns	300	15,000	0.020	12,000.00	10.236%
Tickets/fines	90	6,000	0.015	9,000.00	7.677%
Toll road fees	15	1,000	0.015	9,000.00	7.677%
Subsistence	70	6,000	0.012	7,000.00	5.971%
Tires	100	15,000	0.007	4,000.00	3.412%
Bonuses	20	3,000	0.007	4,000.00	3.412%
Maintenance	150	30,000	0.005	3,000.00	2.559%
Total			0.195	117,230.77	100.00%
Planned distance		600,000			

Planned Price in Euros; Planned amount in km; Planned distance in Km.
Type of vehicle B.

Chart 58: planned costs for the vehicle type B in the instant T_1

Concept	Real price	Real amount	Real unitary costs	Real costs	%
Fuel	1	12.67	0.079	53,654.23	40.788%
Accidents	475	12,601.32	0.038	25,632.23	19.485%
Breakdowns	305	14,241.35	0.021	14,563.23	11.071%
Tickets/fines	110	7,821.63	0.014	9,563.23	7.270%
Toll road fees	17	1,252.27	0.014	9,231.23	7.018%
Subsistence	70	6,181.61	0.011	7,700.26	5.854%
Tires	90	14,835.93	0.006	4,125.12	3.136%
Bonuses	20	3,442.93	0.006	3,950.12	3.003%
Maintenance	145	31,546.35	0.005	3,125.56	2.376%
Total			0.193	131,545.21	100.00%
Real distance		680,000			

Real Price in Euros; Real amount in km; Real distance in Km.
Type of vehicle B.

Chart 59: real costs for the vehicle type B in the instant T_2

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2	Planned total costs T_1	Real total costs T_2	Total difference	Costs difference	Distance difference
A	20	0.502	0.520	200,000	201,000	100,342.86	104,600.57	4,257.71	3,756.00	501.71
B	80	0.195	0.193	600,000	680,000	117,230.77	131,545.21	14,314.44	-1,316.33	15,630.77
Total	100			800,000	881,000	217,573.63	236,145.78	18,572.15	2,439.67	16,132.48

Chart 60: deviations of the real costs in respect to the planned ones in the short term

Type of vehicle	Planned time	Real time	Difference	% Deviation
A	3,080	2,684	-396	-12.86
B	12,320	13,728	1,408	11.43
Total	15,400	16,412	1,102	6.57
Time in hours.				

Chart 61: total planned and real time per type of vehicle in the short term

Type of vehicle	Planned distance	Planned time	Planned average speed	Real distance	Real time	Real speed	Difference	% Difference
A	200,000	3,080	64.94	201,000	2,684	74.89	9.95	15.33%
B	600,000	12,320	48.70	680,000	13,728	49.53	0.83	1.71%
Total	800,000	15,400	51.95	881,000	16,412	53.68	1.73	3.33%
Planned and real distance in km; Real and planned time in hours.								

Chart 62: % deviation of real average speed in respect to the planned ones in the short term

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2	Planned total costs T_1	Real total costs T_2	Total difference	Costs difference	Distance difference
A	20	0,502	0,452	200.000	200.000	100.342,86	90.342,86	-10.000,00	-10.000,00	0,00
B	80	0,195	0,179	600.000	600.000	117.230,77	107.438,46	-9.792,31	-9.792,31	0,00
Total	100					217.573,63	197.781,32	-19.792,31	-19.792,31	0,00

Chart 63: deviation of the planned costs in the long term

16.1.2. Period P_2

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	5	0.150	30,000.00	33.21%
Accidents	3,000	35,000	0.086	17,142.86	18.98%
Tires	700	10,000	0.070	14,000.00	15.50%
Breakdown	2,000	30,000	0.067	13,333.33	14.76%
Maintenance	1,500	30,000	0.050	10,000.00	11.07%
Subsistence	70	6,000	0.012	2,333.33	2.58%
Bonuses	20	3,000	0.007	1,333.33	1.48%
Tickets/fines	90	15,000	0.006	1,200.00	1.33%
Toll road fees	15	3,000	0.005	1,000.00	1.11%
Total			0.452	90,342.86	100.00%
Planned distance		200,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle A.					

Chart 64: planned costs for the vehicle type A in the instant T_2

Concept	Real price	Real amount	Real unitary costs	Real costs	%
Fuel	0.78	4.81	0.162	32,125.00	35.55%
Accidents	2,800	36,714.94	0.076	15,100.12	16.71%
Tires	702	10,031.30	0.070	13,856.23	15.33%
Breakdowns	2,002	29,901.13	0.067	13,256.89	14.67%
Maintenance	1,896	37,082.61	0.051	10,123.56	11.20%
Subsistence	71	7,397.20	0.010	1,900.45	2.10%
Bonuses	25	2,749.14	0.009	1,800.56	1.99%
Tickets/fines	93	15,924.66	0.006	1,156.32	1.28%
Toll road fees	16	3,016.48	0.005	1,050.23	1.16%
Total			0.456	90,369.36	100.00%
Real distance		198,000			
Real Price in Euros; Real amount in km; Real distance in Km. Type of vehicle A.					

Chart 65: real costs for the vehicle type A in the instant T_3

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	13	0.058	34,615.38	32.22%
Accidents	475	13,000	0.037	21,923.08	20.41%
Breakdowns	305	15,000	0.020	12,200.00	11.36%
Tickets/fines	110	6,000	0.018	11,000.00	10.24%
Toll road fees	17	1,000	0.017	10,200.00	9.49%
Subsistence	70	6,000	0.012	7,000.00	6.52%
Tires	20	3,000	0.007	4,000.00	3.72%
Bonuses	90	15,000	0.006	3,600.00	3.35%
Maintenance	145	30,000	0.005	2,900.00	2.70%
Total			0.179	107,438.46	100.00%
Planned distance		600,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle B.					

Chart 66: planned costs for the vehicle type B in the instant T_2

Concept	Real price	Real amount	Real unitary costs	Real costs	%
Fuel	0.80	13.22	0.061	38,132.65	33.76%
Accidents	469	13,095.01	0.036	22,563.56	19.98%
Breakdowns	308	13,323.97	0.023	14,563.23	12.89%
Tickets/fines	108	7,114.75	0.015	9,563.23	8.47%
Toll road fees	21	1,433.18	0.015	9,231.23	8.17%
Subsistence	68	5,563.45	0.012	7,700.26	6.82%
Tires	91	13,897.78	0.007	4,125.12	3.65%
Bonuses	23	3,668.24	0.006	3,950.12	3.50%
Maintenance	142	28,622.07	0.005	3,125.56	2.77%
Total			0.179	112,954.96	100.00%
Real distance		630,127			

Real Price in Euros; Real amount in km; Real distance in Km.
Type of vehicle B.

Chart 67: real costs for the vehicle type B in the instant T_3

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2	Planned total costs T_1	Real total costs T_2	Total difference	Costs difference	Distance difference
A	20	0.452	0.456	200,000	198,000	90,342.86	90,369.36	26.50	929.93	-903.43
B	80	0.179	0.179	600,000	630,000	107,438.46	112,954.96	5,516.50	144.58	5,371.92
Total	100			800,000	828,000	197,781.32	203,324.32	5,543.00	1,074.51	4,468.49

Chart 68: deviation of the real costs in respect to the planned ones in the short term

Type of vehicle	Planned time	Real time	Difference	% Deviation
A	3,080	3,036	-44	-1.429%
B	12,320	12,496	176	1.429%
Total	15,400	15,532	132	0.857%

Chart 69: total real and planned time per type of vehicle in the short term

Type of vehicle	Planned distance	Planned time	Planned average speed	Real distance	Real time	Real speed	Difference	% Difference
A	200,000	3,080	64.94	198,000	3,036	65.22	0.28	0.43%
B	600,000	12,320	48.70	630,000	12,496	50.42	1.71	3.52%
Total	800,000	15,400	51.95	828,000	15,532	53.31	1.36	2.62%

Planned and real distance in km; planned and real time in hours.

Chart 70: % deviation of real average speed in respect to the planned ones in the short term

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	5.00	0.150	30,000.00	38.73%
Tires	700	10,000.00	0.070	14,000.00	18.07%
Breakdowns	1,600	30,000.00	0.053	10,666.67	13.77%
Accidents	2,400	50,000.00	0.048	9,600.00	12.39%
Maintenance	1,100	30,000.00	0.037	7,333.33	9.47%
Subsistence	70	6,000.00	0.012	2,333.33	3.01%
Bonuses	20	3,000.00	0.007	1,333.33	1.72%
Tickets/fines	90	15,000.00	0.006	1,200.00	1.55%
Toll road fees	15	3,000.00	0.005	1,000.00	1.29%
Total			0.387	77,466.67	100.00%
Real distance		200,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle A considering 20 vehicles.					

Chart 71: planned costs for the vehicle type A in the instant T_3 for 20 vehicles

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	15	0.050	30,000.00	33.94%
Tickets/fines	110	6,000	0.018	11,000.00	12.44%
Accidents	360	20,000	0.018	10,800.00	12.22%
Toll road fees	17	1,000	0.017	10,200.00	11.54%
Breakdowns	240	15,000	0.016	9,600.00	10.86%
Subsistence	70	6,000	0.012	7,000.00	7.92%
Bonuses	20	3,000	0.007	4,000.00	4.52%
Tires	90	15,000	0.006	3,600.00	4.07%
Maintenance	110	30,000	0.004	2,200.00	2.49%
Total			0.147	88,400.00	100.00%
Planned distance		600,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle B considering 80 vehicles.					

Chart 72: planned costs for vehicle type B in the instant T_3 for 80 vehicles.

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2	Planned total costs T_1	Real total costs T_2	Total difference	Costs difference	Distance difference
A	20	0.452	0.387	200,000	200,000	90,342.86	77,466.67	-12,876.19	-12,876.19	0.00
B	80	0.179	0.147	600,000	600,000	107,438.46	88,400.00	-19,038.46	-19,038.46	0.00
Total	100			800,000	800,000	197,781.32	165,866.67	-31,914.65	-31,914.65	0.00

Chart 73: planned costs deviation in the long term for 100 vehicles.

16.1.3. Period P_3

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	5.00	0.150	31,125.00	38.73%
Tickets/fines	700	10,000	0.070	14,525.00	18.07%
Accidents	1,600	30,000	0.053	11,066.67	13.77%
Toll road fees	2,400	50,000	0.048	9,960.00	12.39%
Breakdowns	1,100	30,000	0.037	7,608.33	9.47%
Subsistence	70	6,000	0.012	2,420.83	3.01%
Bonuses	20	3,000	0.007	1,383.33	1.72%
Tires	90	15,000	0.006	1,245.00	1.55%
Maintenance	15	3,000	0.005	1,037.50	1.29%
Total			0.387	80,371.67	100.00%
Planned distance		207,500			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle A: 21 vehicles.					

Chart 74: planned costs for the vehicle type A in the instant T_3

Concept	Real price	Real amount	Real unitary costs	Real costs	%
Fuel	0.75	5,24	0.143	28,563.65	37.10%
Tires	702	10,130.45	0.069	13,824.56	17.96%
Breakdowns	1,564	30,163.66	0.052	10,345.69	13.44%
Accidents	2,315	48,830.74	0.047	9,456.23	12.28%
Maintenance	1,050	28,917.61	0.036	7,245.65	9.41%
Subsistence	75	5,237.34	0.014	2,856.89	3.71%
Toll road fees	20	1,950.57	0.010	2,045.56	2.66%
Bonuses	25	3,116.90	0.008	1,600.15	2.08%
Tickets/fines	85	16,140.01	0.005	1,050.65	1.36%
Total			0.386	76,989.03	100.00%
Real distance		199,500			
Real Price in Euros; Real amount in km; Real distance in Km. Type of vehicle A. 21 vehicles.					

Chart 75: real costs for the vehicle type A in the instant T_4

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	15	0.050	30,700.00	33.94%
Tickets/fines	110	6,000	0.018	11,256.67	12.44%
Accidents	360	20,000	0.018	11,052.00	12.22%
Toll road fees	17	1,000	0.017	10,438.00	11.54%
Breakdowns	240	15,000	0.016	9,824.00	10.86%
Subsistence	70	6,000	0.012	7,163.33	7.92%
Bonuses	20	3,000	0.007	4,093.33	4.52%
Tires	90	15,000	0.006	3,684.00	4.07%
Maintenance	110	30,000	0.004	2,251.33	2.49%
Total			0.147	90,462.67	100.00%
Planned distance		614,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle B. 83 vehicles.					

Chart 76: planned costs for the type of vehicle B in the instant T_3

Concept	Real price	Real amount	Real unitary costs	Real costs	%
Fuel	0.75	16	0.047	28,563.26	32.28%
Toll road fees	20	1,008	0.020	12,002.36	13.56%
Tickets/fines	104	5,774	0.018	10,896.36	12.31%
Accidents	326	18,660	0.017	10,569.89	11.95%
Breakdowns	234	14,970	0.016	9,456.89	10.69%
Subsistence	75	6,439	0.012	7,046.67	7.96%
Bonuses	25	3,573	0.007	4,232.65	4.78%
Tires	88	14,970	0.006	3,556.56	4.02%
Maintenance	106	29,733	0.004	2,156.89	2.44%
Total			0.146	88,481.53	100.00%
Real distance		605,000			
Real Price in Euros; Real amount in km; Real distance in Km. Type of vehicle B. 83 Vehicles.					

Chart 77: real costs for the vehicle type B in the instant T_4

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2	Planned total costs T_1	Real total costs T_2	Total difference	Costs difference	Distance difference
A	23	0.387	0.386	207,500	199,500	80,371.67	76,989.03	-3,382.64	-283.97	-3,098.67
B	81	0.147	0.146	614,000	605,000	90,462.67	88,481.53	-1,981.14	-655,.4	-1,326.00
Total	104			821,500	804,500	170,834.33	165,470.56	-5,363.78	-939.11	-4,424.67

Chart 78: deviation of the real costs in respect to the planned ones in the short term

Type of vehicle	Planned time	Real time	Difference	% deviation
A	3,234	3,188	-46	-1.429%
B	12,782	12,965	183	1.429%
Total	16,016	16,152	136	0.852%

Chart 79: total real and planned time per type of vehicle in the short term

Type of vehicle	Planned distance	Planned time	Planned average speed	Real distance	Real time	Real speed	Difference	% difference
A	207,500	3,234	64.16	199,500	3,188	62.58	-1.58	-2.46%
B	614,000	12,782	48.04	605,000	12,965	46.67	-1.37	-2.85%
Total	821,500	16,016	51.29	804,500	16,152	49.81	-1.49	-2.90%

Chart 80: % deviation real average speed in respect to the planned ones in the short term

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	5.00	0.150	29,250.00	37.21%
Tires	550	8,928.35	0.062	12,012.30	15.28%
Breakdowns	1,600	30,000.00	0.053	10,400.00	13.23%
Accidents	2,400	50,000.00	0.048	9,360.00	11.91%
Maintenance.	1,100	30,000.00	0.037	7,150.00	9.10%
Toll road fees	15	570.89	0.026	5,123.56	6.52%
Subsistence	70	6,000.00	0.012	2,275.00	2.89%
Bonuses	20	1,906.98	0.010	2,045.12	2.60%
Tickets/fines	70	13,800.15	0.005	989.12	1.26%
Total			0.403	78,605.10	100.00%
Planned distance		195,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle A. 21 vehicles.					

Chart 81: planned costs for the vehicle type A in the instant T_4 for 21 vehicles

Concept	Planned price	Planned amount	Planned unitary costs	Planned costs	%
Fuel	0.75	15	0.050	29,500.00	32.40%
Toll road fees	17	609	0.028	16,456.48	18.08%
Accidents	360	20,000	0.018	10,620.00	11.66%
Breakdowns	240	15,000	0.016	9,440.00	10.37%
Tickets/fines	90	6,573	0.014	8,078.45	8.87%
Subsistence	70	5,999	0.012	6,884.00	7.56%
Bonuses	20	2,314	0.009	5,099.89	5.60%
Tires	75	15,801	0.005	2,800.45	3.08%
Maintenance	110	30,005	0.004	2,163.00	2.38%
Total			0.154	91,042.27	100.00%
Planned distance		590,000			
Planned Price in Euros; Planned amount in km; Planned distance in Km. Type of vehicle B. 83 vehicles.					

Chart 82: planned costs for the vehicle type B in the instant T_4 for 83 vehicles

Type of vehicle	Nº vehicles	Planned unitary costs T_1	Real unitary costs T_2	Planned distance T_1	Real distance T_2	Planned total costs T_1	Real total costs T_2	Total difference	Costs difference	Distance difference
A	23	0.387	0.403	207,500	195,000	80,371.67	78,605.10	-1,766.57	3,075.10	-4,841.67
B	81	0.147	0.154	614,000	590,000	90,462.67	91,042.27	579.60	4,115.60	-3,536.00
Total	104			821,500	785,000	170,834.33	169,647.37	-1,186.96	7,190.70	-8,377.67

Chart 83: planned costs deviation in the long term for 104 vehicles

Type of vehicle	Total planned time T_3	Total planned time T_4	Difference	% deviation
A	**3,234**	**3,049**	**-185**	**-5.714%**
B	**12,782**	**12,417**	**-365**	**-2.857%**
Total	**16,016**	**15,466**	**-550**	**-3.434%**

Chart 84: total times per type of vehicle in the long term

Type of vehicle	Planned distance	Planned time	Planned average speed	Real distance	Real time	Real speed	Difference	% Difference
A	207,500	3,234	64.16	195,000	3,049	63.95	-0.21	-0.33%
B	614,000	12,782	48.04	590,000	12,417	47.52	-0.52	-1.08%
Total	821,500	16,016	51.29	785,000	15,466	50.76	-0.54	-1.04%

Chart 85: average speed per vehicle in the long term

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