A NEW ALGORITHM FOR THE DESIGN OF A TRANSPORTATION FLEET

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Abstract

In this work, a new strategy and algorithm for dimensioning transportation fleets for the delivery of consumer products from a distribution center (DC) to retailers is presented. The algorithm named CK, works on a horizon in which a delivery forecast is deployed. Given a set of vehicles and the delivery orders forecast, a volumetric optimization routine determines the optimal length of a container having a standard width and height. A set of parameters such as the desired customer service level, concentration level (i.e., expected deliveries per day), and expected growth rate, give the necessary flexibility for the decision making process. The CK algorithm simulates the behavior of costs for a finite number of test fleets and chooses the most efficient. Efficiency is measured as the best assignment of volume to a delivery in a given transport. The CK approach was implemented in a manufacturer and distributor of appliances in Santiago of Chile leading to a decrease of 25,8% of the annual spending in transportation services, an increase of 35% in utilization of the available capacity, and an increase from a historical performance of 95% in customer service level to a 99,93%.

Keywords:

Fleet sizing; logistics; supply chain; simulation.

1 INTRODUCTION

Modern organizations are not only concerned with manufacturing a final product or producing a service but they also intend to provide a high customer service. In this regard, the transportation strategy is particularly important since an efficient movement of goods contributes to increased market competitiveness, greater economies of scale in production, and lower prices along the supply chain [1].

Inefficiency in a transportation system is mainly due to the lack of knowledge about:

1. *The distribution of the volume historically transported*, since the irregularity of the demand volume of deliveries is unknown and therefore the vehicle capacity in the fleet would not have to be uniform.
2. *The suboptimal placement of products in the vehicle loading space,* since even though the irregularity of the dispatched volume is recognized, volumetric optimization of vehicles in the fleet is not applied
3. *The concentration of dispatch orders during the working period,* since if during a period the deliveries cannot be concentrated or consolidated, an adequate daily transportation scheduling will not be achieved.

A strategy for selecting a fleet must necessarily integrate the aspects mentioned above [2][3]. Figure 1, shows the efficiency of a fleet in terms of transportation costs, based on the size of the vehicle. A well designed fleet should be well behaved for a given planning horizon and badly behaved outside that horizon. This behavior is consequence of an inadequate fleet management. The fleet historically designed (dashed line in Figure 1) ignores the distribution of the transported volumes in the past period, and therefore the vehicle capacity has no relationship with the deliveries in the present period; it also misses the volumetric optimization so that vehicle capacity is not well utilized, and vehicle assignment in the daily schedule is poorly made.

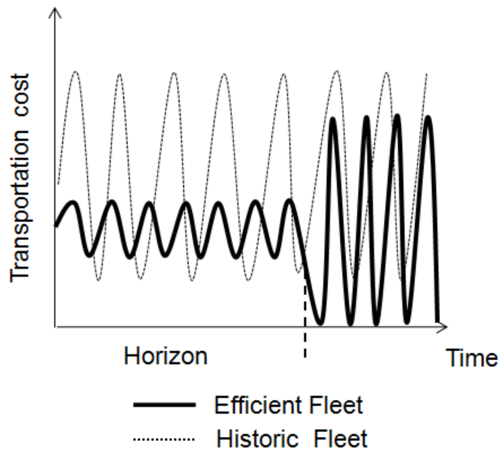

Figure 1: Efficiency of a transportation fleet

The contribution of this paper is for improving the managerial practices in the area of distribution logistics. For this purpose, it is developed a strategy which consists of five elements, as follows:

1. *Data inputs*: dispatched invoices in former periods and product dimensions for generating a forecast of the volume to be transported.
2. *Control Variables*: expected service level of transport, concentration level of deliveries, and expected growth rate of the volume.
3. *CK algorithm*: generator of a finite number of test fleets for which their behavior in transportation costs is simulated.
4. *Planner*: agent which plans the strategy by entering information inputs and handling the control variables.
5. *Information Output*: the efficient transportation fleet determined by the CK's algorithm, which satisfies the planner's requirements.

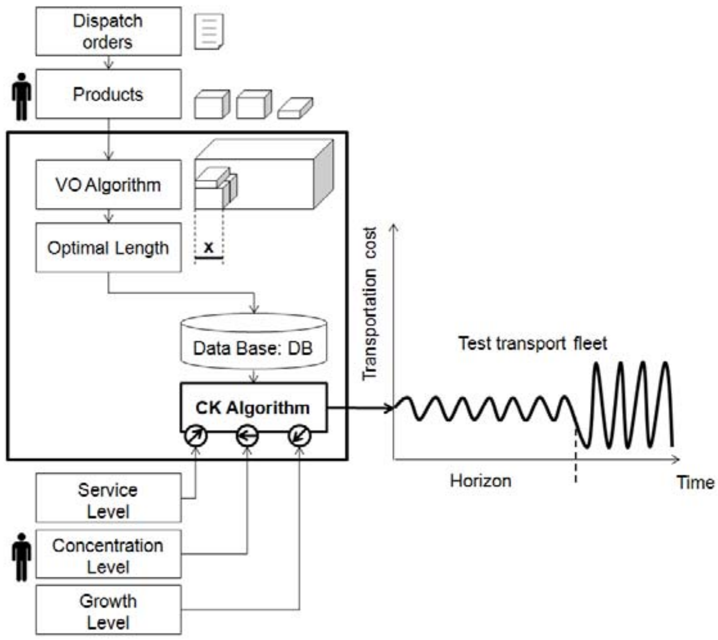

Figure 2: CK Strategy

The strategy have been implemented in the Distribution Center (DC) of a Chilean company named Sindelen S.A., which manufactures and distributes different appliances such as, stoves, refrigerators, gas heaters, hair dryers, toasters, etc. The customers are the main retail chains of the country, as well as independent stores in several cities. The fleet obtained with the application of the CK strategy helped to reduced the annual transportation cost in 25,8% (monetary efficiency), increased in 35% the utilization of the transportation capacity (process efficiency), and rose the service level up to 99,93%, as compared with the 95% of the historically designed fleet (service improvement).

2 CK STRATEGY

In order to generate the CK algorithm, some assumptions for the global strategy must be established.

2.1 Assumptions

- *The transportation cost rate depends on the vehicle container's capacity*; i.e., the greater the capacity is, the greater is the opportunity cost for the transporter and therefore the price for the dispatcher.
- *The transport capacity is determined by the length of the container,* since the front surface practically remains constant for a wide range of lengths (5,7 m^2 in average)
- *The regularity of the demand for products allows the volume demand to be also regular*, since the product size remains unchanged between periods.

2.2 CK General Procedure

Figure 2 depicts the general procedure.

1. The human planner defines the planning horizon on which the database will be generated.
2. The planner defines the set of vehicles from which the transportation fleet will be selected.
3. The planner enters all the dispatch orders in the previously defined horizon, as in step 1.
4. A software agent for volumetric optimization (VO) calculates the required volume for the product list in each dispatch order.
5. The VO software agent determines the optimal length with a standard front dimension.
6. The optimal length (OL) is recorded in the database with additional data about the dispatch.
7. The planner determines the input level of the control variables; i.e., the expected service level, concentration level, and expected growth.
8. The CK's algorithm generates a finite number of test fleets and simulates the transportation costs. Then, the least cost fleet is selected.

3 CK ALGORITHM

The construction begins with the definition of the planning horizon on which the forecasted volumes will be generated. In what follows, this section explains the notation, concepts, and relationships utilized by the CK strategy and the logic of its algorithm.

***Planning Horizon*:** Let $S = \{s_1, s_2, ..., s_H\}$ be the set of sub-periods and $I = \{i_1, i_2, ..., i_D\}$ be the index set of days per each subperiod, then the length of the planning horizon and the number of days per subperiod are defined as:

$$H = |S| \quad (1)$$

$$D = |I| \quad (2)$$

Where $|x|$ stands for the cardinality of set x .

The planning horizon will allow to collect information regarding the volume that has been transported during the period H . Then, by using a growing factor or multiplier, the fleet will be forecasted for the next year over the same defined horizon. It is recommended that H be annual and the values of S be monthly. The next step is to define a set C of existing vehicle types available from providers in the market, which will be classified by the planner according to their capacities.

***Fleet*:** Let $C = \{C_1, C_2, ..., C_N\}$ be the set of *N* classes of transporters, each with capacity C_j ; their transportation costs are denoted by $Y = \{Y_{C_1}, Y_{C_2}, ..., Y_{C_N}\}$. K_{C_j} is the quantity K of vehicles per each class C_j . Thus the p-th fleet is expressed as:

$$X_p = \{K_{C_1}, K_{C_2}, ..., K_{C_N}\} \quad (3)$$

Table 1 shows the set defined by the planner for the case study described in this paper.

Table 1: Set C

Intervals	Y_{C_j}	C_j	L_{C_j}	Front	Capacity
(m)	CLP		(m)	(m^2)	(m^3)
[0 - 4]	10,500	A	4	5.72	22.88
(4 - 5]	17,330	B	5	5.72	28.60
(5 - 7]	25,200	C	7	5.72	40.04
(7 - 8]	55,000	D	8	5.72	45.76
(8 - 13]	80,000	E	13	5.72	74.36

The planner has available vehicles of different capacities and therefore, he/she has different transportation costs to deal with. It is assumed that the cost remains constant in a small capacity range. In Table 1, C_j represent a transport class with a cost of value Y_{C_j} and capacity L_{C_j} . For instance, from Table 1 a fleet with the vector $X = \{1,7,8,4,5\}$ means that types C-D-E require 8, 4, and 5 trucks with capacity over 40 cubic meters, respectively.

Fleet size: The size *M* of the p-th fleet is given by:

$$M_p = \sum_{j=1}^{N} K_{C_j} \quad (4)$$

For instance, $M = 1+7+8+4+5 = 25$ vehicles for the vector above. Once the planning horizon and the set C are defined, the fleet design process consists of finding the capacities and quantities to be selected. That is, the values (C, K) for which the transportation costs are minimized. Efficiency in this case is measured by the best volume assignment of a given dispatch to a vehicle in the set C.

As shown in Figure 2 before data is recorded onto the database, the VO algorithm determines 1) the optimal volume for the dispatch and 2) the optimal length *OL* to contain the load. Given the value of *OL* of a dispatch *Q* in a day *i* in the period *s,* it is possible to assign an optimal vehicle C_j of length L_{C_j}

***Efficient capacity*:** Let $OL_Q^{i,s}$ be the optimal length of a vehicle of standard height and width able to efficiently serve the dispatch *Q*, in the day *i* of period *s;* then, there exists a vehicle C_j , of length L_{C_j} for which the condition (5) holds.

$$OL_Q^{i,s} \le L_{C_j} \quad (5)$$

The determination of an efficient capacity is a process for assigning optimal volumes in order to minimize transportation costs. After the efficient capacity has been assigned to each group C_j , the number of vehicles must be counted for determining the total length required as in a infinite capacity planning.

***Upper bound for fleet size*:** Let $L_Q^{i,s}$ be the total length of efficient vehicles of type C_j assigned in the day *i* of sub-period *s*; then an upper bound is defined by (6).

$$K_{C_j}^{i,s} = \frac{\sum L_{C_J}^{i,s}}{L_{C_j}} \quad (6)$$

Formula (6) states that for day i of subperiod s , $K_{C_j}^{i,s}$ vehicles of length $L_{C_J}^{i,s}$ are needed, or a relation one to one between vehicles and dispatches. This upper bound means a fleet of a size equivalent to the sum of all dispatches Q to be delivered during the planning horizon H (i.e., $M = Q$ with *M* a big number). Thus, control variables must be used to adjust the size to the actual transportation needs. One of these control variables is R a parameter that measures the number of dispatches a vehicle is able to make in a given day. This is determined by the agenda manager according to the time windows that have been agreed with the customer [4]. That is, the agenda manager is defined as the agent able to generate appointments between the supplier and the customer to sent and receive the shipments, respectively. During a day, a vehicle can make more than one dispatch or appointment. The more appointments the vehicle can make the lesser is the concentration level. The planner seeks to minimize concentration but such a decision is influenced by other external policies, such as:

- *Stock Policy:* since a poor policy with frequent stockout forces the manager to postpone a dispatch until the stock and the receiver are available.
- *Customer Policy*: since the receiver may force the agenda manager to set the time of a delivery, or else to delay the service.

Despite of the conditions that influence an agenda, it is possible for the planner to establish a concentration level as defined below.

Concentration level: Let R be the maximum number of shipments a vehicle is able to make in a day; then the concentration level α is defined by (7).

$$\alpha = \frac{1}{R} \qquad , R \in N \quad (7)$$

In a given working shift, there will be a maximum of R times to make shipments which concentrate the α % of total daily orders. The importance of this definition is that α is a control variable depending on the planner's judgment and the stock and customer policy, as mentioned above.

For each α level, fleets with different values in transportation costs will be generated. Hence, the least transportation cost is not a sufficient condition for determining an efficient fleet and therefore the expected transportation service level needs to be introduced as follows.

Expected transportation service level:*. Let* X_p be the p-th fleet generated with a concentration level α . Then, the planner is able to define the behavior of the p-th fleet by (8).

$$\delta = 1 - \frac{Unfilled \quad Dispatches}{Total \quad Dispatches} \quad (8)$$

As the planner allows a number of unfulfilled dispatches in a test fleet ($\delta \neq 100\%$), a penalty cost much greater than the cost of transporting must be assigned [5], as follows.

Penalty for unfulfilled dispatches: Let δ be the expected transportation service level with $\delta = 100\%$; then there exists a cost, say $Y_{(1\text{-}\delta)\%}$ with $(1\text{-}\delta)\%$ of unfulfilled dispatches in the planning horizon H. The penalty is given by (9).

$$\overline{Y} = Y_{(1\text{-}\delta)\%} \tag{9}$$

The determination of an efficient fleet requires a database of the historical volume that has been transported (see Figure 2). This information will allow the planner to forecast the next year, according to the sales plan; that is, a growth rate can be estimated for each period $s \in S$ .The expected growth level of the volume will be denoted by λ**.**

Expected growth level of volume: Let V_s be the total volume transported in subperiod $s \in S$, and $V_{s'}$ be the total volume to be transported during the subperiod s of the next year; thus, the growth factor for each subperiod $s \in S$ is given by (10).

$$\lambda_s = \frac{V_s}{V_{s'}} \tag{10}$$

Now, it is possible to concentrate daily dispatches by utilizing the concentration factor α and in this manner to assign a number R of shipments per vehicle. The transportation requirement B is defined next.

Transportation Requirement: Let $\mathrm{N}_0 = \mathrm{N} \cup \{0\}$, and $W_{C_j}^{i,s}$ be the requirement for transportation of type C_j in the day i of subperiod s and λ_s the expected growth factor of the volume in the subperiod s; then, for a concentration level α of dispatches:

$$W_{C_j}^{i,s} = \alpha_r \times (1+\lambda_s) \times K_{C_j}^{i,s} \tag{11}$$

Thus, the requirement $B_{C_j}^{i,s}$ is calculated by (12):

$$B_{C_j}^{i,s} = \begin{cases} W_{C_j}^{i,s} & ;\text{ if } \quad W_{C_j}^{i,s} \in \mathrm{N}_0 \\ \\ E[W_{C_j}^{i,s}]+1 & ;\text{ if } \quad W_{C_j}^{i,s} \in \mathrm{N}_0 \end{cases} \tag{12}$$

Where $E[x]$ corresponds to the integer part function of x .It is important to verify the condition for α and λ_s , since the infinite fleet $K_{C_j}^{i,s}$ breaks down the dispatches in α, passing from a relation *one to one* of vehicles – shipments to an *one to* R relation, so that vehicles ship R times during the daily working shift [4].

A factor $\lambda_s = 0$ helps to design a fleet for a given planning horizon which allows to compare its efficiency with a fleet that operated already during that horizon, whereas a value $\lambda_s \neq 0$ will project from the database a new fleet for the next year's planned horizon. The quantity in (12) may have a unique behavior throughout the periods since it involves volume requirements depending on the demand's regularity. Then, a parameter β must be defined in order to decide the quantity B of vehicles that is most representative for all the subperiods. The parameter β may follow any rule such as: mode, mean, median, maximum, minimum, or mixed rules. Even though this parameter changes the fleet composition, it is not considered as a control variable since it does not depend on the planner but on a rule that best fits to the distribution of the transportation requirements.

Test quantity: Let $\beta = \{\beta_1, \beta_2, \beta_3 ..., \beta_T\}$ be a set of T criteria defined by the planner; then the quantity of test vehicles for the group C_j is given by (13), with $B_{C_j}^{i,s}$ as defined above.

$$K_{C_j} = \beta_T \bigcup_{i,s} B_{C_j}^{i,s} \tag{13}$$

It is important to remark that the quantity in (14) is for testing since by using the CK's algorithm, by simulation different fleets will be generated with various concentration levels α, satisfying an expected transportation service level δ, with a projection λ_s, and best efficiency criteria β_T. This is formalized with the definition below.

Test fleet: Let β be a set of criteria defined by the planner; then the p-th test fleet is defined by (14).

$$X_p(\alpha,\lambda;\delta) = \{K_{C_1}, K_{C_2}, K_{C_3}, ..., K_{C_N}\} \tag{14}$$

Which has associated cost $Y_P(\alpha,\lambda;\delta)$.

For determining the efficient quantity K^* different scenarios must be evaluated, where the planner's inputs are tested one by one on the test fleets generated, as in (14). This process is made by two types of assignments: *progressive* and *regressive,* which are obtained only by simulation. Once a test fleet $X_p(\alpha,\lambda;\delta)$ has been defined, its availability during a working shift must be determined as described next.

Available fleet: With K_{C_j} as the quantity of vehicles of type C_j, and $\alpha = \{\alpha_1, \alpha_2, ..., \alpha_R\}$ the set of R concentration levels as defined by the planner, the quantity of available trips of transport type C_j is AF_{C_j} where:

$$AF_{C_j} = E \quad [\alpha_R^{-1} \times K_{C_j}] = E \quad [R \times K_{C_J}] \tag{15}$$

Even though there may be available trips in the assignment process, it is possible that the transportation needs are not covered. Then the progressive assignment is defined as follows.

Progressive assignment:. The remaining quantity, or residual quantity of transport, $RQ_{C_j}^{i,s}$, and the progressive assignment $PA_{C_j}^{i,s}$ are determined in two steps:

Step 1: $j = 1$

$$RQ_{C_j}^{i,s} = \begin{cases} K_{C_j}^{i,s} - VD_{C_j} & ;\text{ if } \quad K_{C_j}^{i,s} - AF_{C_j} \geq 0 \\ \\ 0 & ;\text{ if } \quad K_{C_j}^{i,s} - AF_{C_j} < 0 \end{cases} \tag{16}$$

$$PA_{C_j}^{i,s} = \begin{cases} K_{C_j}^{i,s} & \text{; if } \quad AF_{C_j} - K_{C_j}^{i,s} \geq 0 \\ \\ AF_{C_j} & \text{; if } \quad AF_{C_j} - K_{C_j}^{i,s} < 0 \end{cases} \tag{17}$$

Step 2: $j > 1$

$$\theta_{C_j}^{i,s} = AF_{C_j} - K_{C_j}^{i,s} - RQ_{C_{j\ 1}}^{i,s} \tag{18}$$

$$RQ_{C_j}^{i,s} = \begin{cases} 0 & \text{; if } \quad \theta_{C_j}^{i,s} \geq 0 \\ \\ -\left(\theta_{C_j}^{i,s}\right) & \text{; if } \quad \theta_{C_j}^{i,s} < 0 \end{cases} \tag{19}$$

$$PA_{C_j}^{i,s} = \begin{cases} AF_{C_j} & \text{; if } \quad RQ_{C_j}^{i,s} > 0 \\ \\ K_{C_j}^{i,s} - RQ_{C_{j\ 1}}^{i,s} & \text{; if } \quad RQ_{C_j}^{i,s} \leq 0 \end{cases} \tag{20}$$

In the assignment, the term *progressive* refers to the fact that the transportation needs are covered from the smallest fleet ($j=1$) to fleets with greater capacity ($j>1$) in a progressive manner. If in the working shift for a type of transport C_j , the available trips AF_{C_j} are insufficient to cover the needs $RQ_{C_j}^{i,s} \leq 0$ then the fleet with highest capacity in progressive order will have to cover it. Finally, if for the type of transport with the highest capacity C_N there still are needs uncovered, then the dispatch must be partitioned in vehicles of smaller capacity but with available trips.

Regressive assignment: if the number of vehicles of type C_j with free trips is $FT_{C_j}^{i,s}$, then:

$$FT_{C_j}^{i,s} = AF_{C_j} - PA_{C_j}^{i,s} \tag{21}$$

In order to break down the dispatch of a vehicle of type C_j into smaller vehicles, the free length is defined as follows.

Free length:. With $FT_{C_j}^{i,s}$ as the total free trips of vehicles of type C_j and $L_C = \{L_{C_1}, L_{C_2}, ..., L_{C_N}\}$ as the lengths of vehicles in C, then there may be a length that has not been utilized, as defined by (22).

$$FL_{C_j}^{i,s} = FT_{C_j}^{i,s} \times L_{C_j} \tag{22}$$

Thus, the number of vehicles that are needed is $RQ_{C_j}^{i,s} = -\ \theta_{C_j}^{i,s}$

Length shortage: Let L_{C_N} be the length of vehicles of type C_N , then the length shortage $LS_{C_N}^{i,s}$ is represented by (23).

$$LS_{C_N}^{i,s} = RQ_{C_N}^{i,s} * L_{C_N} \tag{23}$$

Then, the regressive assignment needs further definitions as given by (24) (25) (26).

$$\varphi_{C_j}^{i,s} = LS_{C_N}^{i,s} - FL_{C_j}^{i,s} \quad ; j=1 \tag{24}$$

$$\varphi_{C_j}^{i,s} = FL_{C_N}^{i,s} - \varphi_{C_{j\ 1}}^{i,s} \quad ; j \neq 1 \tag{25}$$

$$RA_{C_j}^{i,s} = \begin{cases} FT_{C_j}^{i,s} & \text{; if } \quad \theta_{C_j}^{i,s} > 0 \\ \\ FT_{C_j}^{i,s} \quad E \quad \dfrac{FL_{C_j}^{i,s} - LS_{C_N}^{i,s}}{L_{C_j}} & \text{; if } \quad \theta_{C_j}^{i,s} = 0 \\ \\ 0 & \text{; if } \quad \theta_{C_j}^{i,s} < 0 \end{cases} \tag{26}$$

The final assignment $FA_{C_j}^{i,s}$ in the working shift is:

$$FA_{C_j}^{i,s} = PA_{C_j}^{i,s} + RA_{C_j}^{i,s} \tag{27}$$

In the last definition (27) there still may be shortage of transport capacity since the test fleet does not assure total fulfillment, then the number of vehicle shortage is stated by equation (28).

$$VS_{C_N}^{i,s} = \begin{cases} 0 & \text{;if } \quad \phi_{C_N}^{i,s} \leq 0 \\ E\left[\dfrac{\phi_{C_N}^{i,s}}{L_{C_N}}\right] & \text{;if } \quad \phi_{C_N}^{i,s} > 0 \text{ and } E\left[\dfrac{\phi_{C_N}^{i,s}}{L_{C_N}}\right] \in \mathrm{N} \\ E\left[\dfrac{\phi_{C_N}^{i,s}}{L_{C_N}}\right] + 1 & \text{;if } \quad \phi_{C_N}^{i,s} > 0 \text{ and } E\left[\dfrac{\phi_{C_N}^{i,s}}{L_{C_N}}\right] \notin \mathrm{N} \end{cases} \tag{28}$$

Finally, for finding the pair (C^*, K^*) the costs are calculated for each test fleet, for each of the periods s , with the control variables defined by the planner, as follows:

$$Y_s(\alpha_R, \beta_T; \delta) = \sum_i \sum_j FA_{C_j}^{i,s} \times Y_{C_j} + \ \overline{Y} \times \sum_i VS_{C_N}^{i,s} \tag{29}$$

The cost over the planning horizon H of the proponed fleet is given by (30).

$$Y_H(\alpha_R, \beta_T, \delta) = \sum_S Y_s(\alpha_R, \beta_T, \delta) \tag{30}$$

The last step in the simulation is the finding of the fleets with the least cost for a given expected service level δ . The expression (31) summarizes the process.

$$\overline{\delta} = 1 - \frac{\sum_i \sum_S CF_{C_N}^{i,s}}{\sum_i \sum_S AF_{C_j}^{i,s}} \quad \text{, then for } \overline{\delta} \geq \delta \text{ :}$$

$$X_S = \{FA_{C_j}^{i}, \forall\, i, j \,/\, Y_s = \min\{Y_s(\alpha_r, \beta_t, \overline{\delta} \geq \delta)\}, \forall\, s, r, t\} \tag{31}$$

The efficient fleet is a vector $v = \{K_{C_1}, K_{C_2}, ..., K_{C_N}\}$, in terms of cost, a set gathering the best test fleets.

$$X_H = \bigcup_S X_S \tag{32}$$

Formula (33) gives the fleet with the least annual cost.

$$X_H = \{FA_{C_j}^s, \forall s, j \,\big/\, Y_H = \min\{Y_H(\alpha_r, \beta_t, \bar{\delta} \ge \delta)\}, \forall r, t\} \quad (33)$$

4 CK TESTING

The CK's algorithm was tested with data of the distribution center of Sindelen S.A. It was implemented in an Excel ™ spreadsheet and the volumetric optimization software was a free version of CubeMaster ™.In Table 2, the data entered by the planner is shown.

Table 2: Input Data

Input	Valor
H	2009
S	$\{1,2,...,12\}$ (months)
I	$\{1,2,...,31\}$ (days)
N	5 (transport classes)
C	$\{A,B,C,D,E\}$
Y_{C_j}	$\{10{,}500;17{,}300;25{,}200;55{,}000;80{,}000\}$ ($CLP)
$\bar{Y}$	100,000 ($CLP)
Q	$\{1,2,...,2712\}$ dispatches
$LO_q^{i,s}$	2712 (optimal lengths)
δ	95%
α	$\{0.5\}$
λ	$\{0.137;0.176;0.080;0.283;0.155;0.297;-0.006;$ $0.181;0.287;0.230;0.233;0.359\}$
β	{mean, mode, median, max, min, mix*}

The planner first evaluates the base period in 2009 ($\lambda = 0$ and he/she sets the control variables α and δ; only one efficient fleet is generated for each period S.

Table 3 shows the generated fleets for the best selection criteria β for the year 2009. This analysis by subperiod determined an irregular fleet with an annual transportation cost of CL$ 69,540,600 or USD 140,000. The transportation service level is 99,51% in average with a mean of 17 vehicles. However, by performing an annual analysis with variation of in 0.5 and 1, an efficient fleet for the planned with a greater service level and reduced fleet size M was determined. Table 4 shows the results of the analysis for a fleet with $\alpha = 0.5$. That is, by concentrating twice a day the 50% of the daily dispatches. Finally, it is possible to introduce a value in the growth variable λ thus generating an efficient fleet for the year 2010. The obtained fleet is $X_{2010} = \{5,2,2,2,2\}$ also with $\alpha = 0.5$. This fleet, as in 2009, concentrates vehicles of smaller capacity since the shipments in practice do not exceed 30 cubic meters.

5 CONCLUSIONS

In this work it has been presented a solution strategy for long-term design of an efficient fleet. The approach incorporates new factors that are critical to design and uses control variables determined by an expert planner in order to meet system requirements. In the future it is possible to incorporate this strategy in a higher level of aggregation within an organization to govern lowers decision levels such as daily scheduling and routing of vehicles.

Table 3: Algorithm CK for periods in 2009

S	β	A	B	C	D	E	M	$COST_S$	$NSET$
1	Máx	6	3	4	2	5	20	5,183,370	100.00
2	Máx	6	3	4	2	5	20	5,493,470	100.00
3	Med	4	2	2	2	2	12	8,783,080	98.52
4	Máx	6	3	4	2	5	20	7,592,750	100.00
5	Mix	5	3	3	2	4	17	6,261,640	100.00
6	Med	4	2	2	2	2	12	5,564,170	98.52
7	Mix	5	3	3	2	4	17	6,591,570	100.00
8	Med	4	2	2	2	2	12	5,353,090	98.52
9	Mix	5	3	3	2	4	17	4,328,480	100.00
10	Med	4	2	2	2	2	12	6,094,590	98.52
11	Máx	6	3	4	2	5	20	4,961,310	100.00
12	Máx	6	3	4	2	5	20	3,333,080	100.00

Table 4: Algorithm CK for complete horizon in 2009

	Sindelen S.A					**ACK**				
	A	B	C	D	E	A	B	C	D	E
	1	**7**	**8**	**4**	**5**	**4**	**2**	**2**	**2**	**2**
Y_H	93,582,920					69,987,580				
δ	90.00%					99.93%				
% Capacity	35.19%					54.16%				

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7 REFERENCES

[1] Ballou, R.H., 2004, Logistics: Supply Chain Management, Pearson.

[2] McGinnis,M.A., 1990, The Relative Importance of Cost and Service in Freight Transportation Choice, Before and After Deregulation, Transportation Journal, Vol. 30 (1), 12-19.

[3] Evers, P.F., Harper, D.V., Needham, P.M., 1996, The determinants of Shipper Perceptions of Modes, Transportation Journal, Vol. 36 (2),13-25.

[4] Lai, M.F., Lo, H.K., 2004, Ferry service network design: optimal fleet size, routing, and scheduling. Transportation Research, Part A 38, 305-328.

[5] Georgiadis, P., Vlachos, D., Iakovou, E., 2005, A system dynamics modeling framework for the strategic supply chain management of food chains. Journal of Food Engineering, 70, 351–364.