OPERATIONS PLANNING AND STRATEGY OF MILK COLLECTION: DEVELOPING A PROCESS FOR OPTIMIZATION

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ABSTRACT
The main goal of this study was to develop a software management program for milk collection, with regard to operations strategies (collection costs and fleeting). It was developed a mathematical model of milk collection defined through the Vehicles Path Vertices Problem**,** with each farm having specific access restrictions limiting what type of vehicle can make the collection, implying the use of the heuristic derived from the savings of Clark and Wright (CW). The data refer to producers supplying the Castrolanda Farming and Cattle Cooperative. 461 farms were entered into a database with variables: geographic position, type of cooling tank and its capacity, evaluation of conditions for vehicle access, and schedule of milking. Summarizing the optimization model, the general results were: 31 daily routes; 6.7 thousand km daily; average volume: 392.3 thousand liters; and unit cost of USD0.03/km and USD0.0068/liter. It is worth noting, as well, that the logistics management could become a strategic variable for business.

Keywords: Operations Planning; Operational Research; Brazil**.**

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INTRODUCTION

Brazil is the sixth largest milk producer in the world. Recently, the implementation of the system of bulk collection of milk occurred rapidly, to the point of being considered one of the most accelerated processes in the world. However, in current practice the process of collection is carried out in an empirical form by companies that miss out on the most important logistical benefits of the new process.

Bulk milk collection brings about numerous changes to the milk business. This system of collection reduces the costs of acquiring raw materials, eliminates cooling stations, increases the productivity of the farm, and significantly improves the quality of milk that arrives for processing at the plants. The process consists of picking up the product “in natura” cooled at the farms and transporting it directly to isothermal tank-trucks, through a flexible manifold and special self-suction pump directly from the cooler. This allows the milk gathered at the farm to preserve its properties by immediate cooling.

The introduction of logistics concepts for transport in the milk business allowed the closure of cooling stations, the reduction of collection routes, and the increase in quantity of cargo transported per vehicle, resulting in significant savings in transport costs and productivity gains. The new logistics procedures, overall, lend themselves to empirical analysis. With constant pressure from imports, almost always subsidized in countries of origin, and the distance between production centers and the principal centers of consumption, companies are recognizing the difficulty of incorporating new management tools that reduce the cost of collection and optimize the services, fleet, and location of cooling stations.

In Brazil, only the industry’s largest companies are implementing optimization processes with the use of specific softwares. Owing to the inexistence of alternatives that consider national attributes and the rural nature of the business, these companies are availing themselves of customized imported software programs, with their own original limitations of applicability to the industry. These commercial softwares were developed originally for the urban trash collection or distribution of cooking gas.

The main goal of this research is to report the procedures and the results obtained by the development and application of software management programs for milk collection at the Castrolanda Farming and Cattle Cooperative, generating an agile and safe management tool (specific software) that allowed improvement in the process of milk collection for producers with regard to collection costs and fleeting.

The next section presents the general statement of the problem and the model applied, as well as the data and heuristic used. The third section presents and discusses the results obtained in the rationalization process, elaboration of the route formation, and evaluation of some indicators related to the efficiency of routing. In addition, some possible strategies for improving results are outlined. Of course, the results themselves of collection costs are presented by region and route. Finally, the results are put into context of the effect of optimized collection and the new routing process administered with the assistance from the company’s specific software tool.

2. Material and Methods

This section presents more information about optimization process, delimiting the geographic area affected, modeling, and defining groupings and characteristics of the data used.

2.1 Castrolanda Farming and Cattle Cooperative

In 1951, Dutch immigrants founded the Castrolanda Farming and Cattle Cooperative in Castro, Paraná. Castrolanda finds itself inserted in the agricultural and livestock segment, having milk as one of its principal products. The cooperative counts on 563 associated members, 206 cattle ranchers and a herd of 13,000 head, leading to an average production around 1,200 liters per day per producer.[2]

Castrolanda participates in the ABC Pool - Arapoti, Batavo and Castrolanda, since its creation in 2001. The ABC Pool commercializes more than 400 thousand liters of cooled milk per day. The function of the pool is to collect milk in an efficient manner and negotiate the sales for its membership on the best terms possible, without industrialization or any other improvement.

The characteristics of Castrolanda's region of activity can be summarized in the elevated volume of milk and relatively short distances between farms, excellent sanitary conditions of the product, good infrastructure of rural roads, high technical proficiency of the producer, and low seasonality of production.

2.2 Process of Formatting the Problem and Modeling

The process of milk collection actually developed by the Castrolanda Cooperative is empirical. The routing is prepared weekly in a manner compatible with producers' milking process and the capacity of the cooling tanks. Collections occur daily, served by the available tank truck fleet.

The process lists the establishments that should have daily collection and those that ought to be visited in a period of 48 hours. The criterion for defining the time period for collection is the relationship between daily production and the capacity of the cooling tanks. If the volume that can be stored in the tanks is at least double the daily production, the collection will occur every two days, if not, it will be daily.

Routes were developed, considering the time for collection and the total quantities collected at the properties on each route. Some routes are fixed service and others are variable in order to meet the necessities of collection and availability of vehicles (transport capacity).

Milk is sold under free-on-board terms (FOB), in average daily volume of approximately 500 thousand liters. Castrolanda notifies the market about the quantities to be delivered to their clients and their respective locations. The companies make decisions on

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[2] Company information is available at www.castrolanda.coop.br.

how much to collect from the farms. In this process, the collection is organized by service providers as an activity to aid the buyers. This effort has no specific remuneration, as the buyer pays by the kilometer relative to the transport from deposit to processing plant with an additional 100 km added for the transport cost between farm and deposit.

The destinations are regular, as there are contracts that guarantee determined quantities per period that are delivered to their own Batávia Cooperative, located in Carambeí, member of the pool, and locations such as Londrina, Lobato and Toledo (Paraná): Araçatuba, Guaratinguetá, Itararé, Araras, Ribeirão Preto and Buri (São Paulo), Araquari (Santa Catarina), Poços de Caldas (Minas Gerais) and Itumbiara (Goiás). Nevertheless, there are sales to clients that are not regular.

The vehicles used are light trucks with a capacity of 8,500 liters, compared to a truck (12,300-13,500 liters) and heavy truck (19,000-26,500 liters). The routes are basically fixed with slight alterations for the peak period of collection.

Each farm was entered into a database with relevant variables established for each case, such as geographic position, type of cooling tank and its capacity, evaluation of conditions for vehicle access, and hours of milking. Exactly 461 establishments were surveyed for these data.

Another important factor for the planning of milk collection lies in the fact that the scale of production varies widely among producers. The variation registered was between 70 liters and 27 thousand liters daily. In terms of mathematical modeling, these heterogeneities can have repercussions in the process of route formation for vehicles with large differences in transport capacity.

It is worth noting, as well, the occurrence of a differentiation in quantities produced during the harvest periods (May-October) and the non-harvest periods (November-April). The increase in production during the harvest period brings about the need for the routes to be restructured, as many producers go from collection every 48 hours to daily pick-up.

Finally, the fact that some producers need daily collection, while others can have collections every 48 hours as a consequence of their cooling tanks' capacities and daily production is a factor for consideration in the routing of the milk collection

2.3 Optimization Model

The optimization of milk collection requires definition of the mathematical model to be studied. In this case, it is called the Vehicles Path Vertices Problem**,** which has an objective function of minimizing the route of the fleet serving the producers (vertices).

The Vehicles Path Vertices Problem can be described as the problem of determining an optimal set of collection/delivery routes departing from multiple points over a number of scattered clients in a geographic region, subject to a set of lateral restrictions (maximum demand carried in vehicles, collection/delivery time, maximum distance, hours of operation, etc.) (Gomes 1996). The generic formulation of the Vehicles Path Vertices Problem can be established as follows:

$$\text{Minimize } \sum_{v=1}^{nv}\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} x_{ij}^{v} \qquad (1)$$

Subject to (2)

$$\sum_{v}\sum_{j} x_{ij}^{v} = 1 \quad (i = 2, \dots, n), \tag{3}$$

$$\sum_{i} x_{ip}^{v} - \sum_{j} x_{pj}^{v} = 0 \quad (p = 1, \dots, n) \ (v = 1, \dots, nv), \tag{4}$$

$$\sum_{i} q_i (\sum_{j} x_{ij}^{v}) \le Q^{v} \quad (v = 1, \dots, nv), \tag{5}$$

$$\sum_{i} t_i^{v} \sum_{j} x_{ij}^{v} + \sum_{i}\sum_{j} t_{ij}^{v} x_{ij}^{v} \le T^{v} \quad (v = 1, \dots, nv), \tag{6}$$

$$\sum_{i} x_{i1}^{v} \le 1 \quad (v = 1, \dots, nv), \tag{7}$$

$$\sum_{j} x_{1j}^{v} \le 1 \quad (v = 1, \dots, nv), \tag{8}$$

$$X = (x_{ij}^{v}) \in S \text{, e} \tag{9}$$

$$x_{ij}^{v} \in \{0,1\} \quad (i,j = 1, \dots, n) \ (v = 1, \dots, nv). \tag{10}$$

in which:
n= number of demand vertexs including the deposit;
nv= number of vehicles;
c_{ij}= cost of the route of vertex i to vertex j;
Q^v = capacity of vehicle v;
q_i = demand of vertex i, where $q_1 = 0$ e $q_i \le Q^v$, $\forall\ i, v$;
T^v = maximum time permitted for vehicle v;
t_i^v = time necessary for vehicle v to deliver or receive in vertex i (time of service in i by v);
t_{ij}^v= time of route of vehicle v between vertexs i and j, $t_{ij}^v = \infty$;

$$x_{ij}^{v} = \begin{cases} 1, \text{if the link ij is used by vehicle v} \\ 0, \text{otherwise.} \end{cases}$$

S = set formed by the restrictions of breaks in illegal subroutes that do not include the origin vertex.

The objective function (1) seeks to minimize the total routing cost for a set of equal or distinct vehicles. The restrictions (2) and (3) define each demand vertex to be served by exactly one vehicle. The equation (4) considers the continuity of the route. In other words, if a vehicle enters in a demand vertex, it should exit same. The equation (5) restricts vehicle capacity. Similarly, equation (6) is related to total route time. Equations (7) and (8) guarantee that availability of vehicles will not be exceeded. Restriction (9) represents the prohibition of illegal sub-routes. Finally, restriction (10) defines the decision variables of the model.

For the specific case under analysis, there are some peculiarities that need to be defined and that, if they do not radically change the model to be developed, at least, they alter the manner in which it is employed. One of these concerns the application of the time restriction, which was not applied since practice demonstrated that the routes are short enough for vehicles to run within the forecasted limits.

Another issue comes with respect to the choices of vehicles in the fleet: light truck, truck, and heavy truck with capacities of 8,500 liters, 12,700 liters, and 22,000 liters respectively. Each farm has specific access restrictions limiting what type of vehicle can make the collection. Some can handle any type, others accept light trucks or trucks, and, some only light trucks. This happens on account of road infrastructure conditions (rural roads and internal roads within the farm) and the area available for vehicle maneuvers.

The collection plan was also observed. Some producers require daily collections while others can have collection on alternate days, as their storage tanks have sufficient capacity to stock product for two days.

In light of such restrictions, it was necessary to find a heuristic that could be modified with the ends of serving the peculiarities without there being a considerable loss in the final result.

The heuristic applied derives from the savings of Clark and Wright (CW). According to Novaes (2001), this heuristic is well known and still very much used as part of other procedures. It was originally developed to resolve the classic problem of vehicle routing. It bases itself on the notion of savings, which can be defined as the combined cost or union of two existing sub-routes. It is treated as a constructive iterative heuristic based on a maximizing function of insertion. The algorithm is sufficiently appropriate for the problem in question as it permits the limitation of vehicle type and does not require great computation capacity, making it easy to apply.

It is assumed, initially, that each client is served by one vehicle, constituting round trips between the deposit and the client. Given that c_{ij} is the function of the trip between client *i* and client *j*, impedance can be defined, in addition to distance traveled, displacement time, cost, or a combination of these, for example. According to the definition offered by Liu and Shen (1999), two routes containing clients *i* and *j* can be combined, since *i* and *j* are either in the first or last position of their respective routes and that the total demand of the combined routes does not exceed the vehicle capacity.

For each iteration, all combinations of possible routes are analyzed through:

$$\boldsymbol{T_{ij} = c_{id} + c_{dj} - c_{ij}} \tag{11}$$

where *d* represents the operational base and T_{ij} the gain obtained by the union of the two routes. For always having chosen the greatest savings among possible routes, the choice function is said to be maximized. For each new combination of subroutes, the savings are recalculated and updated for the next combination of sub-routes. Thus, the method is said to be iterative (Liu and Shen, 1999).

In order to better understand this method, it can be stated that in the choice of two points for constituting the routing sequence, it is desired a pair with the greatest value of gain $T_{i,j}$. There are combinations, therefore, that violate the restrictions of time, capacity, etc., thus becoming unviable. The method explores this concept, outlined as follows:

1. Calculate the gains $T_{i,j}$ for all pairs *i, j* ($i \neq j$, $i \neq d$ e $j \neq d$);

2. Rank pairs *i, j* in decreasing order for values of gain $T_{i,j}$;

3. Begin with pair *i, j* with greatest gain $T_{i,j}$ and continue in the sequence obtained in;

4. For the pair of nodes *i, j*, corresponding to *K-th* element of the sequence (2) verify if *i* and *j* are included or not in the existing route:

a) If *i* and *j* were not included in any of the routes already open, then create a new route with nodes *i* e *j*;

b) If exactly one of the points *i* or *j* already belong to a pre-established route, verify if this point is the first or last point of the route (adjacent to the deposit node *d*). If this occurs, add the arc *i*, *j* to this route. Otherwise, pass to the following stage, skipping pair *i*, *j*;

c) If both nodes *i* and *j* already belong to two pre-established routes (different routes), verify if both are extremes within their respective routes (adjacent to node *d*). In this case, join the two routes into one. Otherwise, go to the next stage, skipping pair *i*, *j*;

d) If both nodes *i* and *j* belong to the same route, go to the following step;

e) Continue the process until the complete list of "gains" is exhausted. If some remaining point is not included in any route, individual routes should be formed linking the deposit to each point and returning to the base.

This is the algorithm for identifying if the points i and j are included in a route.

```
If i and j are not in any route Then
    Create a route with i and j
Otherwise
    If i or j is in a route Then
        If this node is an extreme point of the route Then
            Add i and j to the route
        Else
            Abandon the pair i and j
    Otherwise
        If i and j are in different routes Then
            If i and j are extreme points of their routes Then
                Join the two routes
            Else
                Abandon the pair i and j
        Otherwise
            Abandon the pair i and j
```

2.4 Data

The geographic dispersion of the farms and the absence of a geo-referenced system of rural roads bring additional difficulties that add to the problem at hand. Moreover, the specific nature of dairy farmers dispersion prevented the experiences of other known problems, such as trash collection from contributing to solve the problem.

The set of farms was tested using the methodology of p-medians, but the results obtained for the groupings presented high dispersion in the number of producers. In this form, the routing obtained was damaged considering the alternatives of up to three types of trucks for collection in each grouping, resulting in many trucks circulating with idle cargo capacity in many cases.

Moreover, within these adversities, the grouping process was done on a geographical basis, having as a reference some cities of the research area. These were defined as: Ponta Grossa, Carambeí-Castro, Piraí, Castrolanda and Carambeí, with the last two with capabilities for permitting access to heavy trucks for collection. The groupings Piraí and Ponta Grossa are characterized as being composed of small producers; Carambeí and Castrolanda assemble producers with large average daily volumes and with small geographic dispersion; the grouping Carambéi-Castro brings together the greatest number of producers, and, therefore, has the largest technological diversity and daily production, characterized by diverse means of vehicle access to the establishments.

For each grouping, a matrix of distances was generated among the producers, based on the Euclidian distance. While the literature had indicated highway distances and urban means, parameter 1.3 states that, by the comparison of the results with the distances (km) drawn empirically, the local specificity of some regions, such as relief and features of the rural road, do not corroborate such parameters. Moreover, for regions with urban features, in which the farms are located very close to or in urban centers, the indication of 1.3 from the literature is maintained, which prevailed in the cases of Castrolanda, Carambeí and Castro-Carambeí. In other cases, the parameters used refer to the empirically observed values in comparison with the Euclidian distance initially estimated, having been 2.0 for Piraí do Sul and 3.0 for Ponta Grossa.

The collection process starts with the departure of the vehicle from its operational base, the collection at the farms and terminates with the return to the point of departure. The operations base was located in the city of Carambeí, headquarters of the largest service provider since Castrolanda does not actually provide logistics services and sells on a free-on-board (FOB) basis.

The values used in this simulation relative to daily farm production represent the average between minimum and maximum values registered during the year 2003. These data were furnished by the cooperative.

The remaining relevant information, such as location of the farms, capacity of the cooling tank, and evaluation of transport access, were surveyed by the research team involved in the project.

3. Results

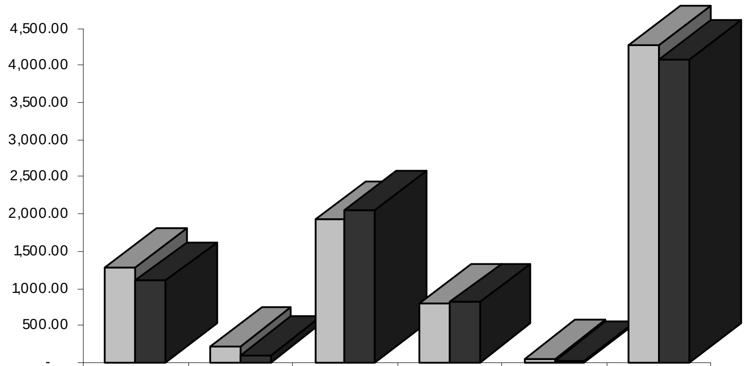
In this section, results obtained in this optimization process are presented with the formation of routes and the other indicators produced relative to the efficiency of the collection routing. This section also presents the results of the models considered as possible strategies for improvement and the results themselves in terms of collection costs, by region and route.

3.1 Optimization Results

Considering that the product has to be collected within 48 hours of milking, the model developed generates data for two days of collection, which requires visiting all the properties over that time period. It is worth calling attention to the high stability of the results, which has important logistical implications in terms of forecasting the collection and making investments in fleet size.

Organized into 31 daily routes, the collection would require traveling 6.7 thousand km daily (Figure 1), collecting an average volume of 392.3 thousand liters of milk (Figure 2).

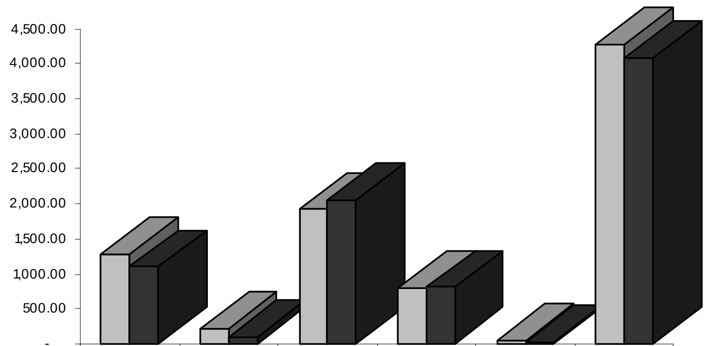
Figure 1 – Distance traveled for milk collection, Castrolanda Cooperative, according to the groupings



	Piraí	Ponta Grossa	Tronco	Castrolanda	Carambeí	TOTAL
Day 1	1,277.42	220.63	1,922.93	803.97	52.21	4,277.16
Day 2	1,104.15	98.82	2,054.07	809.82	24.86	4,091.72

Source: Research results.

Figure 2 – Liters of milk collected, by grouping, days 1 and 2, Castrolanda Cooperative



	Piraí	Ponta Grossa	Tronco	Castrolanda	Carambeí	TOTAL
Day 1	1,277.42	220.63	1,922.93	803.97	52.21	4,277.16
Day 2	1,104.15	98.82	2,054.07	809.82	24.86	4,091.72

Source: Research results.

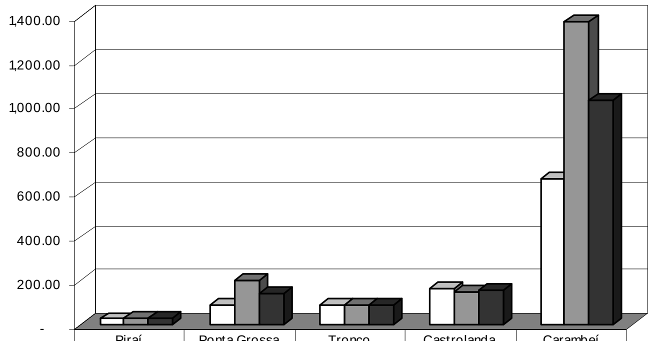
The routes cover reasonably short distances, signaling the economicity of the collection compared to other Brazilian regions, particularly in regions of recent expansion such as Goiás, Mato Grosso and Pará. As the average volume of milk collected on the farms is also high given the level of specialization of the producer, the average density is extremely elevated to the Brazilan reality notably for the results of the "Carambeí" grouping (Figure 3).

3.2 Simulations

By way of elaborating scenarios for evaluating strategies, some simulations were realized, with the objective of discussing forms for optimizing the collection process, with alterations in vehicles and collections needs.

In conceptual terms, the reference models for the results refer themselves to the simulations. The so-called **original model**, refers itself to the results obtained by the modeling process in a real form. The **truck model** refers itself to a simulation, considering that collection could occur just with the utilization of trucks and heavy trucks (therefore, without use of light trucks), seeking to delimit the economic advantages of increasing average capacity of vehicles used. The **light truck model** refers to another simulation, considering that the collection could occur just with the use of light trucks and heavy trucks (thus, without the truck model), seeking to outline the economic advantages of optimizing some services that resulted in collection with large idle capacity of the vehicles. The **48-hours model** considered that all the producers had cooling tanks with capacity equal or superior to two days' production, resulting in the viability of milk collection every two days (48 hours), which could present significant advantage for the costs of collection.

Figure 3 – Density of Collection (liters/km), by grouping, days 1 and 2, Castrolanda Cooperative

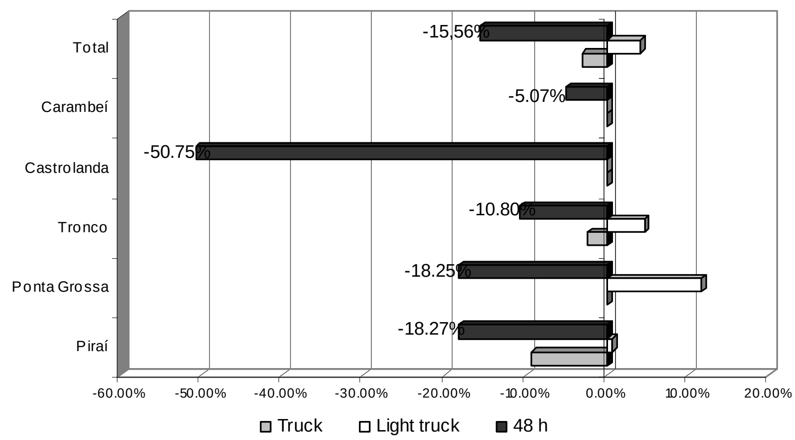


	Piraí	Ponta Grossa	Tronco	Castrolanda	Carambeí
Day 1	27.05	91.51	88.22	167.34	665.82
Day 2	31.23	199.09	88.37	149.43	1,375.70
AVERAGE	29.14	145.30	88.29	158.39	1,020.76

Source: Research results.

The results are presented (Figure 4) with a base in the differentials of average daily distance covered for the different groupings. Advantages of 48-hour collection were reported over all the measures, such that this result reflects the weight of savings offered along specific heavy truck routes (Castrolanda and Carambeí), even though the negative result is consistent for all groupings and for large groupings to the other simulated models. As a result, the viability of this system involves a high capital cost for the acquisition and preparation of installations for increasing the storage capacity on the farms. On the other hand, the collection with light trucks added distance traveled to the system.

Figure 4 – Comparisons of distance traveled (%) with the original results



Source: Research results.

3.3 Estimates of Milk Transport Costs

The cost structure adopted in the implementation phase of the new logistics process was standard costing. This system aims to determine or establish comparative measures that permit the effective control of costs. The standard costs are predetermined costs that should be reached in efficient operations. They serve to compare performance standards in order to create useful budgets, guide prices, obtain a significant product cost and for bookkeeping savings.

The objectives of standard costing are:

- Evaluation of performance and operational efficacy of the company, through comparison of estimated and real costs;
- Verification of responsibilities via identification of causes of variations;
- Opportunity for cost reductions through corrective measures taken on the occurring variations;

Standard costing should be carefully calculated, in light of the repercussions that it could represent inside the company. Its correct estimation is of fundamental importance, as well as its constant revision and fitting for the ends of incorporating technological or operational changes for establishing future standards.

For the case of costing provision of transportation services, the application of standard costing can be of great importance as an instrument for controlling and monitoring costs. As a result, it is necessary that standard costing reflects the reality of the company or the business and that, in fact, it monitors the results by way of budgeted costs (standard) and actual costs (real costs), leading to the eventual corrections that may be needed.

It is worth considering, initially, that standard costing budgeted for milk collection considered the following vehicles to be used for the examination of costs: Volkswagen 23.210 truck (12,700 kg), the Volkswagen 15.180 light truck (8,500 kg), and the Mercedes-Benz line of heavy truck (beyond of 22,000 l). Standard costing (and this research) relied on these vehicles' performance and maintenance needs as verified in the market and in their respective vehicle manuals.

The average daily distance traveled by the vehicles and the average cargo carried were estimated, based on the fact that during nearly half the month, the vehicles carry out two routes per day, according to the following values:

- light truck: 300 km and 7.8 tons
- truck: 250 km and 10.6 tons
- heavy truck: 250 km and 22 tons

Table 1 shows the costs of milk collection (USD/km, USD/ton and USD/liter references), according to different vehicle types. In accordance with what can be observed, the volume transported and the distances traveled exert a significant influence in the reduction of transport costs, with respect to the contribution to the apportionment of the activity's fixed costs.

Table 1 – Costs, distance traveled and volume transported of monthly milk collection, according to vehicle type

Costs/ Vehicle	USD/month	km/ month	USD/km	ton/ month	USD/ton	USD/liter
Light Truck		**8,235**		**356**	**9.58**	**0.00958**
Fixed	2,029.01		0.2464			
Variable	1,383.29		0.1680			
Total	3,412.30		**0.4144**			
Truck		**6,992**		**478**	**6.80**	**0.00680**
Fixed	1,638,20		0.2343			
Variable	1,613.03		0.2307			
Total	3,251.23		**0.4650**			
Heavy truck		**6,992**		**990**	**5.26**	**0.00526**
Fixed	2,130.66		0.3047			
Variable	3,079.07		0.4404			
Total	5,209.73		**0.7451**			

Source: Research results.

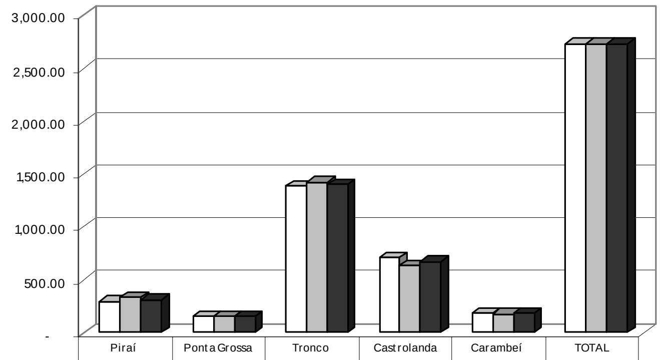
In the vehicle comparison, the collection savings with heavy trucks stands out. The principle of scale in collection per vehicle is quite significant as the truck had a gain of 29 percent in relation to the light truck. The possibility of further improvement is more favorable in the use of heavy trucks resulting in a cost reduction of 25 percent in relation to truck and almost 50 percent with regard to light truck. Nevertheless, many times reality prevents the application of this economic logic as a result of additional factors, such as the quality of the roadways in rural milieu and vehicle access at the farms.

It also must be considered that these heavy truck advantages only occur, as well, in the case there is a quantity to be collected compatible with the vehicle capacity since, on the other hand, the costs of operating (USD/km) are unfavorable.

Based on these costs, the daily collection of nearly 392 thousand liters of milk is estimated on a basis USD per kilometer and USD per liter, converted to USD/km and USD/liter. The average costs (among days 1 and 2) estimated for the collection with the remuneration for distance traveled was USD2,117.08 (Figure 5), which signifies a unit cost of USD0.03/km.

In case the payment occurred on a USD per liter basis, the daily collection cost would be USD2,732.00 (Figure 6), equivalent to a unit cost of USD0.0068 per liter. This cost would be 23 percent less than the freight rates actually in practice in the regional market (USD0.0089 per liter). As a result, in practice, these costs will be even lower because the collection already reached almost 500 thousand liters per day, nearly 65 thousand above the total volume that was used in this model’s operational simulation.

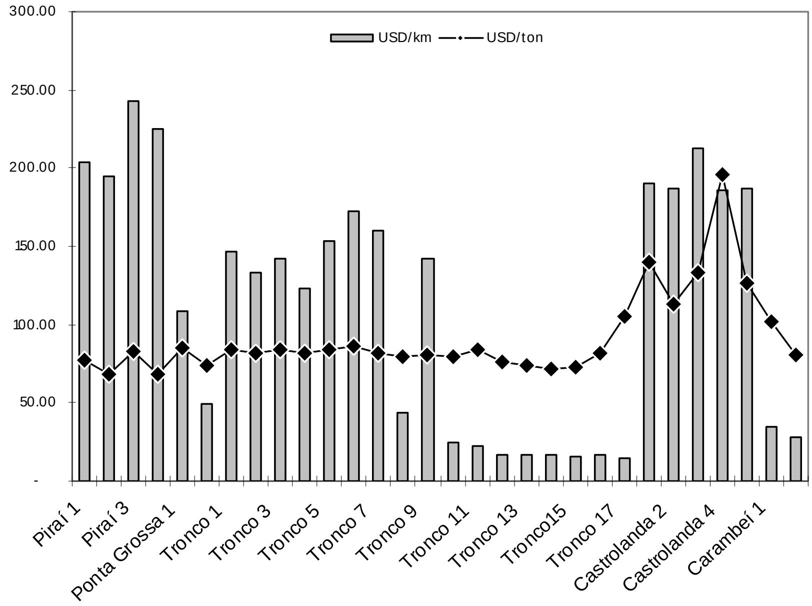
Figure 5 – Total Collection Costs, arranged by groupings, in USD/km



	Piraí	Ponta Grossa	Tronco	Castrolanda	Carambeí	TOTAL
Day 1	297.27	158.87	1,386.91	707.99	182.92	2,733.96
Day 2	330.58	156.27	1,426.40	636.82	179.97	2,730.03
AVERAGE	313.92	157.57	1,406.65	672.40	181.45	2,732.00

Source: Research results.

Figure 6 – Total Collection Cost, by groupings, in USD per liter



Source: Research results.

In addition, it is understood that the increase in distance traveled will be minimal. This results in the collection occurring in areas of higher density (liters of milk per km), where vehicles will reduce their level of idle capacity, leading towards a convergence of the costs based on USD per km and USD per liter. For example, in case the cost of milk collection reaches the value of USD2.117,08, based on remuneration USD per liter, the unit cost of milk collected would be USD0,005 per liter, 38.46 percent lower than the current market rate.

4. Final Considerations

The goal of this research was the development of a logistics management tool (software) for milk collection in the Castrolanda Farming and Livestock Cooperative. The emphasis on the process of optimization was evidenced in aspects of collection costs and in rationalization of fleet.

The results present the possibility for an efficient logistics management, while collection costs and fleet size are optimized. The daily optimization of routes allows for transparency regarding the economic results of the fleet, making possible management alternatives with respect to the allocation of vehicles, search for complementary business during the non-harvest periods, and the use of partnerships with independent truckers in order to reduce the amount of capital immobilized in highly specialized assets (isothermic tank trucks).

Fundamentally, the optimization of milk collection provides for the better management of the most relevant variables involved in the cost of collection, such as the volume of milk collected, the distance traveled during the collection, the density indicator (liters of milk per km), and the number of vehicles suitable for conditions of collection.

The principal advantages that the customized software offers over the empirical systems and the imported commercial models can be enumerated as follows:

1. The software was specifically developed to solve the problem of milk collection at the farm level.
2. It permits optimization with a diversified fleet.
3. It permits the specific evaluation of conditions of the farms; and,
4. It generates specific reports tailored to the interest of Castrolanda.

Considering that the previous process in use was based on the FOB criteria, where the milk buyer assumed the responsibility of the collection costs, Castrolanda did not have precise and systematized data on the most relevant parameters of the collection: the cost (USD per liter) and the transport density (liters per km). As a result, attempts to compare the efficiency of the results are meaningless.

However, as an illustration, this research presented some results constructed from company and service provider data. It should be stressed that an optimized process can obtain even better real results while improving transport efficiency, increasing the volume of milk collected without an equal increase in distance traveled. In this case, the company strategy of adding new producers located in areas already served and promoting the increase in milk production of producers already integrated in the collection could lead to even more significant improvements.

It is worth noting, as well, that the management could become a strategic variable for business. For example, changing the terms of sale of milk to cost, insurance and freight basis (CIF), would build in the price of delivery to the buyer, thus internalizing the logistics.

The dissemination of the use of softwares with this profile can be a landmark in the logistics of Brazilian agribusiness and for milk, particularly, taking into account the immense potential for cost reductions.

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