INFIELD ROUTING NETWORK AND REDUCING TRANSPORTATION COSTS ON A SUGAR MILL IN COLOMBIA

TRABAJO DE GRADO

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SANTIAGO DE CALI
2012

ABSTRACT

Globalization and free trade agreements are factors that affect the world's economy. For some industries they can be beneficial and for others not so much. Additionally customers are ever more and more demanding, they want better products, with better quality and at a lower price. To stay competitive in the market it is necessary to give the customers everything they want and to supply all the client's needs.

Being competitive is hard work to maintain and also expensive if the costs are not taken into consideration. Sugar mills are gigantic industries in Colombia and have been around for long time, generating thousands of jobs and social benefits to the community.

However, no matter how large a company is, it cannot disregard cost structure and cost reducing. One of the biggest costs sugar industry has, is transportation cost. They have to transport cane from the fields to the factory, to process sugar and derivatives every day. Some mills do not have a schedule on reducing this transportation time and spend lots of resources on labor, maintenance and fuel for trucks. Creating a specific route with measured times and a specific process will allow a mill to reduce this cost and gain more benefits for the entire company.

Key Words: sugar, mill, truck, trolley, tractor, route.

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I. Introduction

Sugar industry in Colombia is one of the biggest industries in the country in terms of production, sales and revenues. Worldwide, the Colombian sugar industry is amongst the 15 best countries in terms of production and among the first 10 exporters representing 1.4% of production and exportations on sugar in the entire globe.

Sugar mills are huge companies with an overall of 25.000 employees with a major sense of corporate social responsibility not only in terms of employment but also on generating better life standards to nearby population, building schools, recreational centers, supermarkets, city halls and so on.

Price on sugar is set by market values on the New York and London stock markets, for exportation and there are internal policies and regulations to control the price in Colombia so there are some specific rules to sugar mills in order to fulfill internal market needs. The international market is getting tougher because of free trade agreements between different countries, this means that there is more competition on sales and the tradeoff will be on service times instead of price.

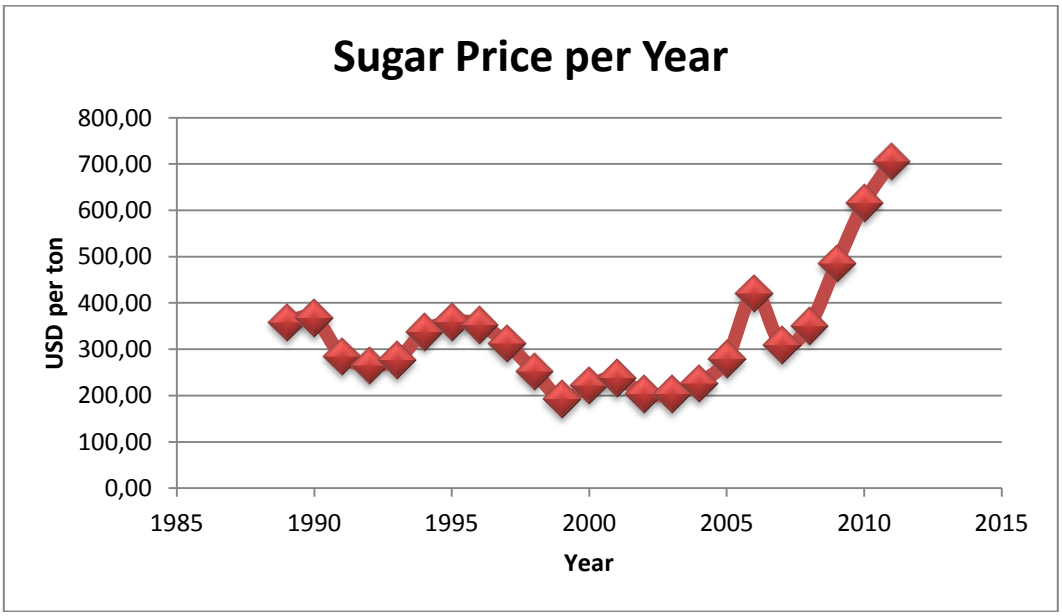


Figure 1: Sugar price per year of London Stock Market
Source: ASOCAÑA

For past times the concerns of the sugar mills where only on sales, sales and how to sell more, leaving aside any cost infrastructure. With globalization and free trade agreements, Colombian mills are starting to make investment on software and creating processes planning to reduce costing and increase revenues.

In the past the only concerns of the sugar mills where only on sales, and how to sell more, leaving aside any cost infrastructure. With globalization and free trade agreements, Colombian mills are starting to invest in software and creating planning processes to reduce costs and increase revenues.
With this perspective of increased sales and prices, why are sugar mills earning less money than before? Question addressed to a General Manager in a board meeting, the answer was costs, production and selling more induce a higher cost and since there is no cost control, increased sales and price are not going to balance and at the end the company will earn less money selling more instead of selling less and optimize earnings.

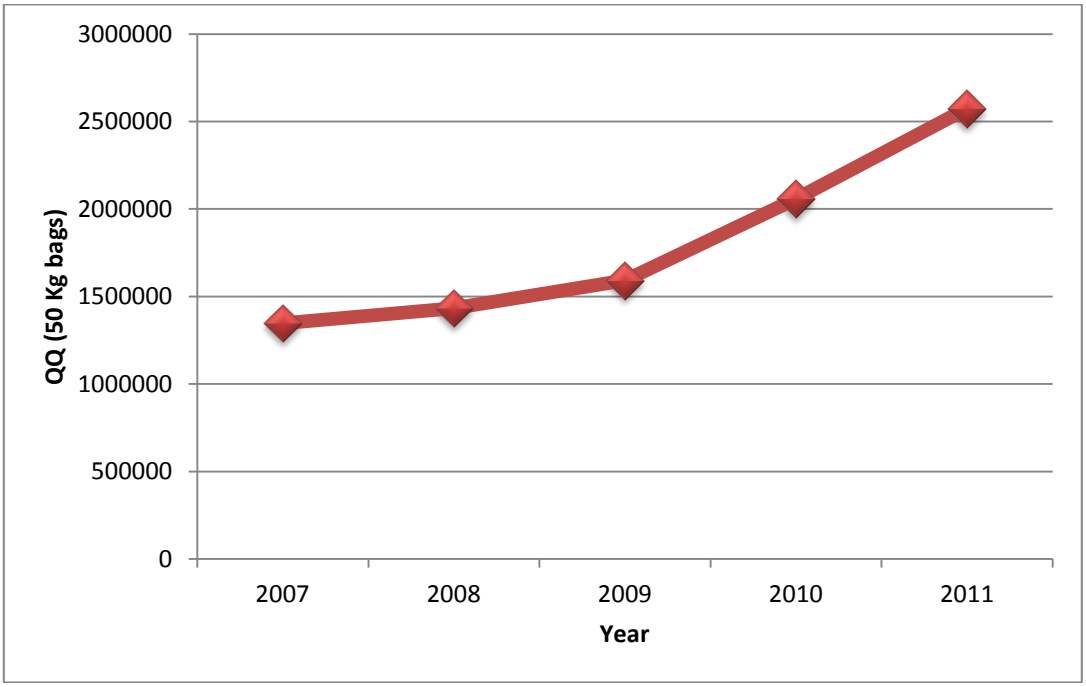


Figure 2: Mill quantity exportations per year
Source: Mill

One operative complexity in sugar cane industry is the transportation of the sugar cane from the fields to the factory with vehicles, known as sugar cane trains. These are trucks that pull different kinds of trolleys depending on their capacity. The transportation of the sugar cane in Colombia is approximately 33% of the harvesting cost. Besides the

transportation cost other harvesting costs are constituted by preparation costs of the raw material and rising cost meaning the load of the vehicle on the field. In past years there has not been a major breakthrough on how to reduce the transportation cost and that´s what this project is about, to find an alternative on reducing transportation cost.

II. Key Research Question

The goal of the project is to find an alternative on reducing transportation cost of a sugar mill creating infield routing.

III. Project Description

The data and information was provided by a sugar mill located in Colombia, since they provide the data, the resolution of the project can apply to this specific company, however if another industry has similar conditions the approach can be applied.

The project will approach a specific response to reduce transportation cost; the approach was made possible by different meetings with mill employees which led to a concrete problem of wasted time on the cane recollection. To understand the impact on costing, it was necessary to make a financial analysis of the previous years, to foresee what would be the future of the company in financial terms, and the money cash flows so the results of the project be beneficial.

IV. Literature Review

Costing is a continuous struggle for all companies; every single cost affects the price of the product. When a company fails to control all cost associated to the cost of sold goods, the company will lose money, and cost control has been an issue for a long time. Companies have been trying to control the costing and different strategies already exist, one strategy started in 2002 ABC costing (Activity Based Costing) or DPP (Direct Product Profitability); ABC costing will let a company know the entire cost structure divided by activities this will clarify which activities are the most demanding on costing but does not present a formal alternative to cost reduction activities; and DPP which is the profit earned by a product unit.

An attempt on reducing cost was approached by Virgilio Ramon (2002) who made a summary on how costing is found and a human approach to reduce costing effects. To effectively reduce cost different techniques must be used on the activities of the company, Kaizen, statistics control, six sigma, are techniques which help reduce cost, however none of these techniques have been used on transportation costing.

However these techniques did not match the problem to be addressed, so the thesis creates a routing network on vast plantation to reduce transportation costing, using routing techniques such as: network flow, shortest path, maximal flow or a traveling salesman problem. A network flow is used to model a flow which needs to be balanced by the sum of flux entering must be equal to the exit flux; shortest path is to create a route which will consider the shortest distance or lower cost for transit; maximal flow is to find a feasible flow through a single source and the TSP is to find the shortest path on a route that must visit every node at least once and come back to the point of origin, all of this can be found on any text book from different authors such as Ronald Ballou and D.M. Lambert.

For vast plantation there is no routing technique per se to be used, in theory a TSP will work however there are lots of restrictions to be filled. Networks are used on different scenarios such as a traffic, communications or wireless networks which can help model a network on vast plantations. Scellato, Fortuna, Frasca, Gomez-Gardeñes and Latora created a model to study the flow of vehicles on urban streets network taking in consideration traffic and intersections so the agents will modify their route. Their results show that agents can easily organize their motion based on their local congestion knowledge, however the model was not suitable for a big load of vehicles, this is intriguing because the model was used on big cities with hundreds of roads and restrictions, such as intersections, traffic lights, drivers tendencies, speed limits and it was a feasible solution found, nevertheless it cannot be used for vast plantation since the need is to go to point A through other nodes and return to point A, but gave an idea how a big network can be addressed too.

Ali, Verlinden and Van Oudheusen created a model for “Infield logistics planning for crop-harvesting operations” (2009), they used two routing techniques which led to the same results reducing harvesting time significantly, the model was to have a combined harvester (harvester pass to tractors). The first model they create a VRP model combining bin packing model and a travelling sales person problem to minimize the distance and the capacities of the harvesters; converting the model to a CVRP due to vehicles capacities. The result created a path on the field which met all the restrictions created but the issue with this model was the solving time which only let them calculate small fields and not on vast calculations. The second model was based on MCNFP to solve bigger problems. A change on the initial formulation specially creating the balance equation to ensure the arc

flow and the vertex they could solve the same problem in lesser time and could model the route to a 5 hectare field.

This last model would work fine, however the technologies used are different, they use a combined harvester while in this thesis the cane is already cut and needs to be loaded and shipped. Another issue is the field, the algorithm created let them find the route for at most 5 hectares, in this thesis it is needed to collect 40 hectares daily
Also Eduardo Figaro and Freddy Hernandez wrote a thesis on "Characteristics of sugar cane transportation in Colombia", and they made an effort approaching transportation costing, however the strategy proposed, talks about different scenarios such as sub-contracting fleet or owning only trolleys but no trucks. The scenarios proposed could be interesting however none of these where quantify and there is not a conclusion if the scenarios will work or not.

V. Methodology

Since the objective of the thesis is to attack directs costs, the first thing to do is to make a financial analysis of the company. The reason is simple; sometimes to control any process there is a need to invest (software, machinery or personnel) and cost control is not an external situation, although the final objective is to reduce transportation cost with what the company owns.

After analyzing the financial situation of the company, cost factors can be taken into consideration, and with the factors analyzed, the problem can be more specific to attack. With the factor analyzed, a brainstorm with employees of the mill takes place, the reason is to mix different points of view, and discover what the employees think could be raising the transportation cost, this way insightful information of the process will be taken in consideration.

After analyzing the results of the brainstorming factors such as scheduling and wasted time, were important factors that made costing go higher and a final solution was to consider routing method to schedule the recollection of cane on the fields and to create assignment for the trolleys.

All the information and data was supplied by the mill and all questions on procedures and technologies they use where asked directly to them, so the assumption on creating routes models are were as minimal as possible.

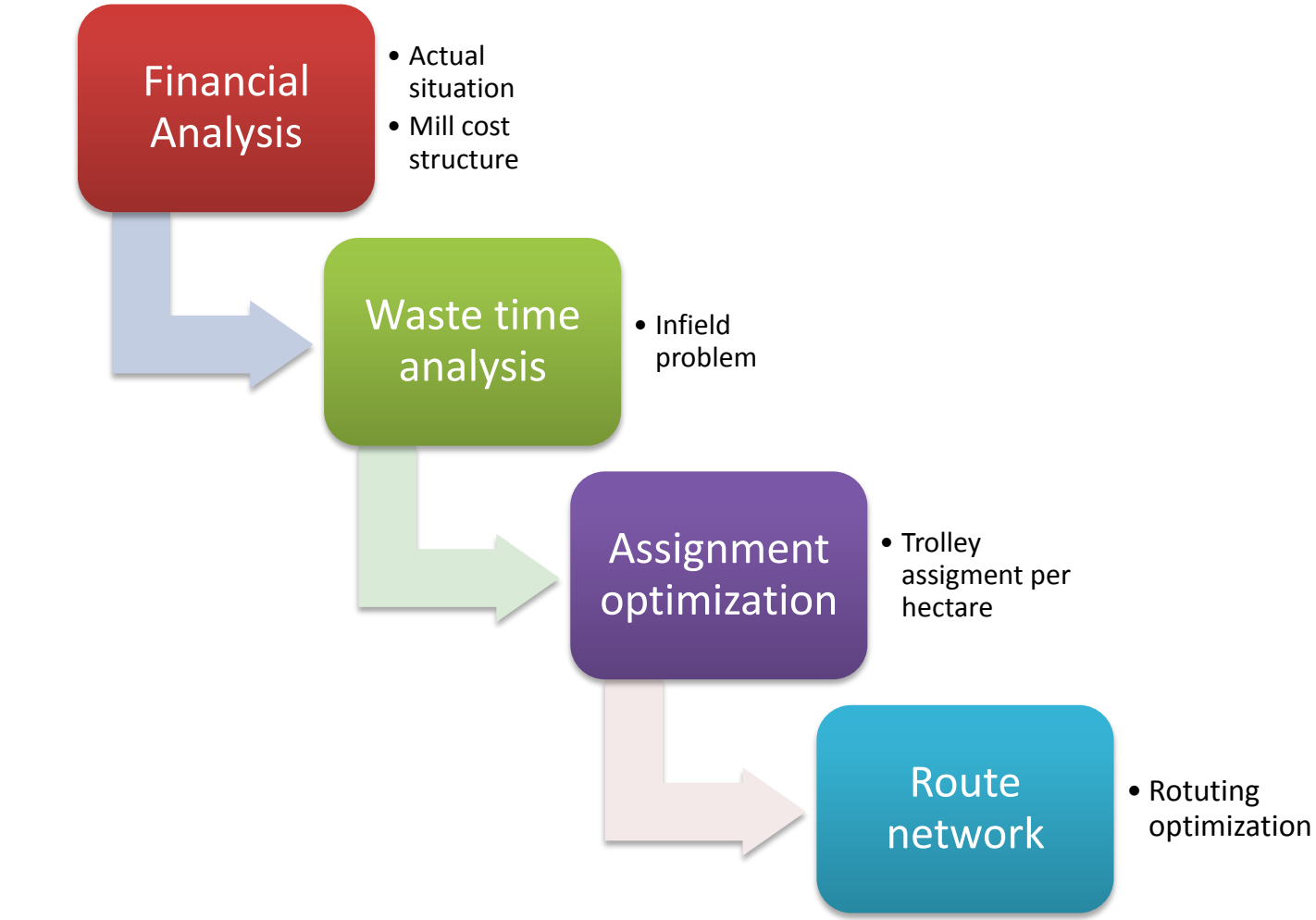


Figure 3: Methodology

CHAPTER 1 CONTEXT AND BACKGROUND

1.1. Sugar Cane History

Sugar cane in Colombia arrived in 1493 with Cristobal Colon (Christopher Columbus) but it was not until 1510 that the first crop was seeded in the Atlantic coast. In 1541 Sebastian de Belalcazar seeded the first crop in Valle del Cauca near the later city of Cali. In 1550 the first cane industry was founded near rivers to be transported to Panama. Alexander Humboldt during his visit in 1800 introduces the Tahiti cane which replaces the Spanish cane and spread out over the department during 1802.

Technology reaches de country in 1867 and the first mill worked with 3 horizontals masses action an iron wheel with the force and impulse produced by river water. However in 1901 was the first breakthrough with the opening of the first factory of white sugar with machinery functioned by water vapor which had the capacity of grinding up to 50 tons every 12 hours

In 1926 started the big bang in the sugar industry with the opening of Providencia mill with grinding capacity of 500 tons every day. In 1928 opened Riopaila mill and in the next decade 5 new mills started production. By then the area became in the biggest sugar production in the country and still the country kept importing sugar. By the 1940´s other mills started operations and the import ceased becoming sugar one of the most profitable business in Colombia and becoming and having important share on the GDP every year.

1.2. Social Impact

The chart below shows the description in territory of the sugar cane fields by 2001, the field covered are from the whole department of Valle del Cauca and the north of the department of Cauca and Risaralda covering over 187,987 hectares:

AREA PLANTED IN SUGAR CANE – YEAR 2001	
Sugar mills:	14
Daily grind capacity	70.000 tons
Total sugar production by year 2000	2.240.820 tons
Sugar exports by year 2000	56% of total production
Direct employment	30.000
Indirect employment	200.000
Beneficiary population	1.200.000

Source: Procaña

Table 1: General information on sugar cane production on 2001

For the purpose of this project it is necessary to consider the social impact that can become the implementation of technology, because if there is technology implementation, there is a great percentage of population that can become unemployed, since the sugar mills produces a major labor percentage on the population of the little towns near to mills.

Since the mills are far away of populated areas they have constructed small towns for the workers and their families, in these towns besides the houses the people who live there have everything that they need as if they lived in any town or city, they have supermarkets, shops, schools, libraries, parks and sports centers, even some of the mills have churches for religious practice with clerics to offer Sunday services.

By the year 2008 the CSR (corporate social responsibility) was 21.12% of the total utilities of the sugar mills. The most common investment on CSR was:

1. Education: scholarships for the workers children, contribution for workers studies, value and contribution for schools inside the mills.
2. Housing: contribution on loans for construction, buying, mortgage coverage or improvement on workers houses.
3. Recreational and cultural activities
4. Other major contribution where redirect on environment on cleaning the waters of the rivers that would benefit over a million people of the region.

1.3. Description Of The Company

The Sugar mill object of study in this thesis is an agro industrial company, located in Colombia in the Department of Valle del Cauca, dedicated on the production and commercialization of sugar and derivatives, it has around 20.000 hectares dedicated only to sugar cane crops and 200.000 square meters assign to production plant and administrative office. There are 1.700 direct employees and 1.500 contractors.

Production plant is mainly equipped with mills, turbines, boilers, clarifiers, heaters, filters, evaporators, vacuum pans, crystallizers, centrifuges, dryers, conveyors and technical and humans elements necessary for the performance of the manufacturing function.

All the products manufactured in the mill belong to the line of raw sugar such as: special white sugar, white sugar, refined sugar, virgin honey and final honey which with the exception of final honey, earn the seal for quality given by ICONTEC (Colombian institute of technical norms and certifications)

CHAPTER 2 TRANSPORTATION ECONOMICS

Cost refers to the trade-off between uses of resources. This can involve time, money, land or loss of an opportunity to enjoy a benefit. A feasible approach is proposed by Douglas Lee (2004) "The economist's notion of cost is the value of resources (used for a given input) in their best alternative use . . . If less time were used in travel, how valuable would the time be for whatever purpose travelers chose to use it? If clean air were less consumed in dispersing vehicle pollutants, how much would society benefit from using the air to disperse non-highway pollutants or from breathing cleaner air? This concept of costs depends, then, on benefits foregone; there is no separate measure of cost that is distinct from valuation of benefits." In this case it will be defined as in less cost in transporting the raw materials to the factory how much will the benefits of the whole company increase.

Transport cost is merely the cost involved in relaying goods to and from a plant, including payments to transport firms for their services and any cost incurred by a plant using and maintaining its own fleet of vehicles.

2.1. Transportation Cost Attributes

Transportation cost can be categorized by the following attributes:

- Distribution (internal and external impacts) costs and benefits are accrued directly by a good´s consumer. External costs and benefits are borne by other. Social costs are the total of both internal and external impacts.
- Variable and Fixed Variable costs increased with consumption. Fixed costs do not. Depreciation is often considered a fixed cost because car owners make the same payments no matter how many miles a year they drive, but car´s operating life and resale value are affected by how much it is driven, so depreciation is partly variable over the long term.
- Market or non-market costs involve goods that are traded in a competitive market, such as vehicle, land or fuel. Non-market costs involve goods that are not regularly traded in markets such as clean air, crashes injuries and quiet.
- Perceived or actual costs are different and need to be considered, motorist tend to perceive immediate costs such as travel time, stress, parking fees, fuel and transit fares, while costs that are paid infrequently such as insurance, depreciation, maintenance and repairs are often underestimated.

In the study the factors to be considered if the final decision is to own the fleet are divided in fixed and variable cost:

VARIABLE COST	**FIX COST**
Fuel	Depreciation
Taxes	Insurances
Tolls	Maintenance
Tires	Finances charges
Parking	Licensing and registration

Table 2: cost factors on transportation.
Source: Mill

CHAPTER 3 COST STRUCTURE OF SUGAR MILL

Income on sugar cane industry is basically on the sale of sugar and ethanol. The costs and expenses are categorized as production costs, indirect production cost and administration expenses.

1. Production cost: these costs include all the operation since the growth to the production of final product. It is also divided into field costs, fabrication costs and depreciations. Field costs are those involved in the growth, harvesting, cut, transportation of sugar cane from fields to factory. Fabrication costs include from receiving the sugar cane in the factory until the final products are ready to sell in the warehouse. Depreciations refer to that recognition of use to all the assets and equipment necessary to the operation.

2. Indirect production cost: all of those costs related not directly to field and production costs but is necessary to each operation. The Salaries of production or field managers are related to indirect production cost.

3. Administration Expenses: All other expenses as support area, managers salaries (accounting, purchases and warehousing, IT, Human resources, controlling).

Because of the social impact analyzing Indirect Production Cost would not create a supply chain problem; instead it would be a project with a social emphasis and would not work as a project. Administration expenses are not directly related to supply chain and it is not a topic of interest.

The production cost includes many activities where it would be interesting to go deeper and analyze any possible problem that create an opportunity to improve and current process. It also is responsible for the 80% of cost of sales of the mill. For these reasons it is necessary to analyze each activity that belongs to production cost:

- Cost of cane from a third party: this is the cost of labor of non-direct employees which are the farmers on the fields.
- Cost from renting land: this are some of the lands that are not own and have to pay rental use.
- Field Cost: cost from the own fields maintenance, such water and burn.
- Harvest Cost: cost involvement from all the activities related to harvest the cane, it is subdivided in:
    - Cut: labor of direct employees who cut the cane
    - Lift: cost of loaders who lift the cane to load on trolleys
    - Transportation: cost of truck and trolleys maintenances and repairs.

- Administration: administrative cost of the operation
- Fabrication Cost: white sugar production cost
- Refined Process Cost: cost of the process to convert white sugar into refined sugar.
- Packaging Cost: standard packaging cost for white sugar.
- Refined packaging cost: packages for refined sugar
- Depreciations: machine and land depreciation

Cost of cane from third party	36.7%
Cost from not own land	5.2%
Field Cost	14.5%
Harvest Cost	24.0%
Fabrication Cost	11.2%
Refined Process Cost	1.5%
Packaging Cost	0.7%
Refined Packaging Cost	0.7%
Depreciations	5.5%

Table 3: Production cost partition
Source: Mill

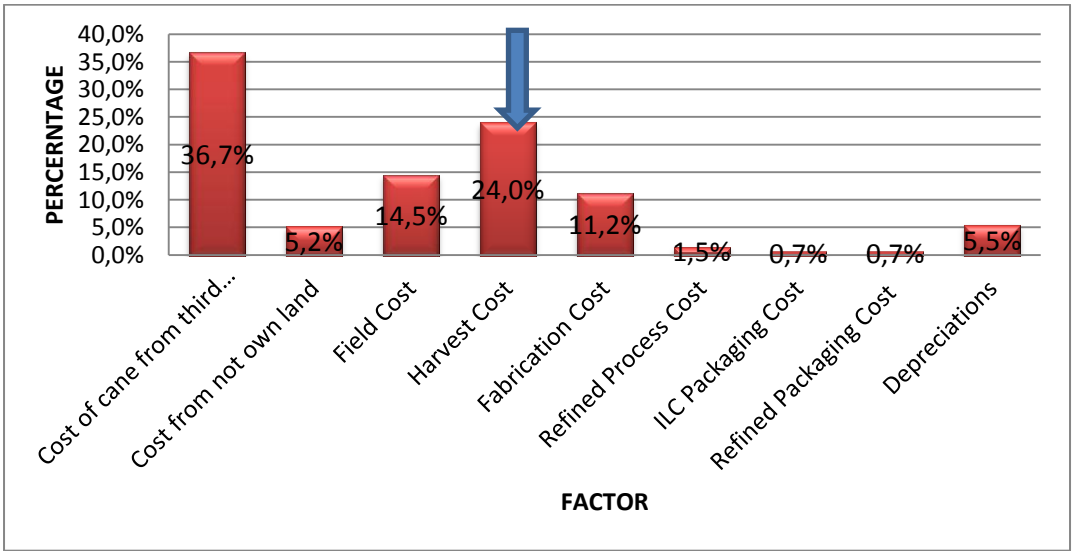


Figure 4: Production cost percentage
Source: Mill

The highest factor is the cane from a third party, since it is merely labor cost, it cannot work with it directly. However harvest cost definition includes transportation costing from trucks and trolleys in the fields. So getting deeper in the cost structure it is necessary subdivide harvest cost:

Cut	54.0%
Lift	8.0%
Transportation	34.0%
Administration	4.0%

Table 4: Harvest cost partition
Source: Mill

As figure 4 shows the highest harvest cost is cut, however it is a labor cost of employees who cut cane, but the second highest is transportation cost.

Transportation cost is basically the cost of the vehicles which bring cane from the fields to the production plant. This costs associates fuel consumption, maintenances and repairs, new wheels, wheels repair, labor (driver's salaries and wages), filters and lubricants.

The cost for each truck according to data given by mill, engineers is $32,772,120 Colombian pesos each month. Multiplying this value by 35 trucks they own, the transportation expenses in the harvesting cost are $1,147,024,212 Colombian pesos.

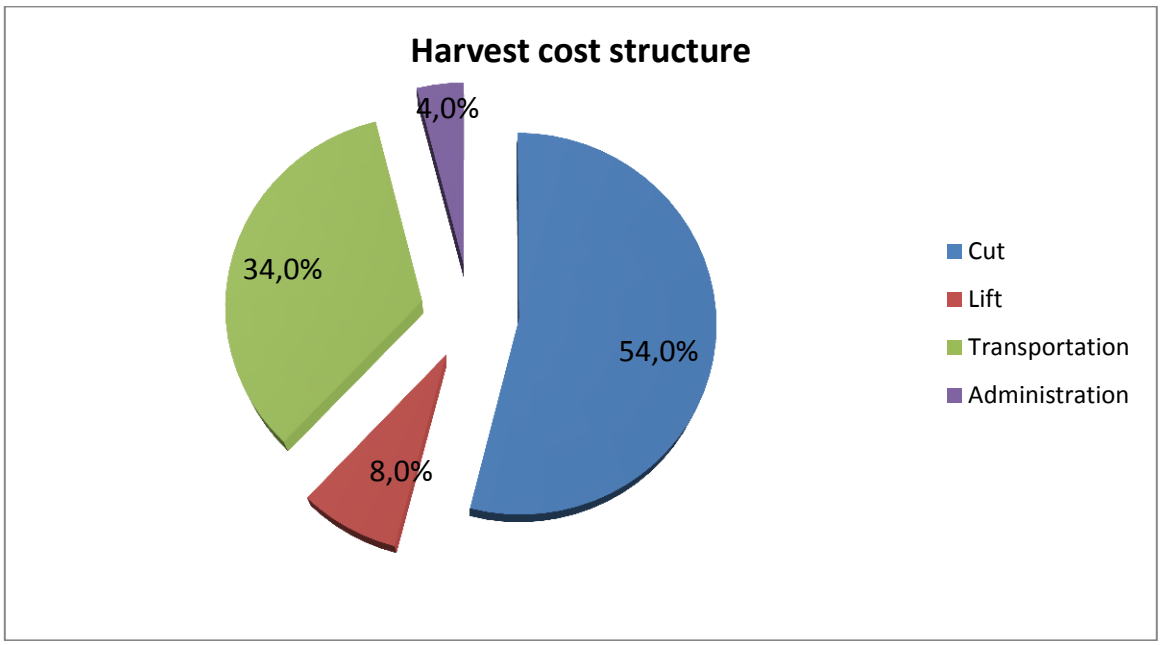


Figure 5: Harvest cost percentage
Source: Mill

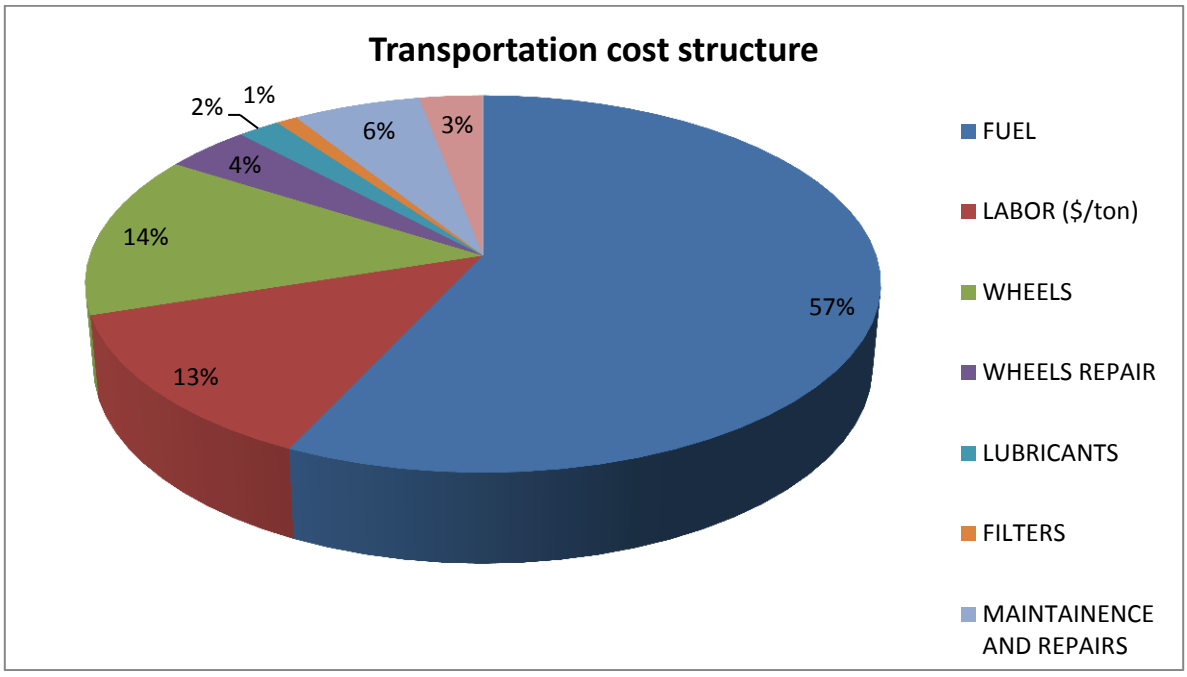


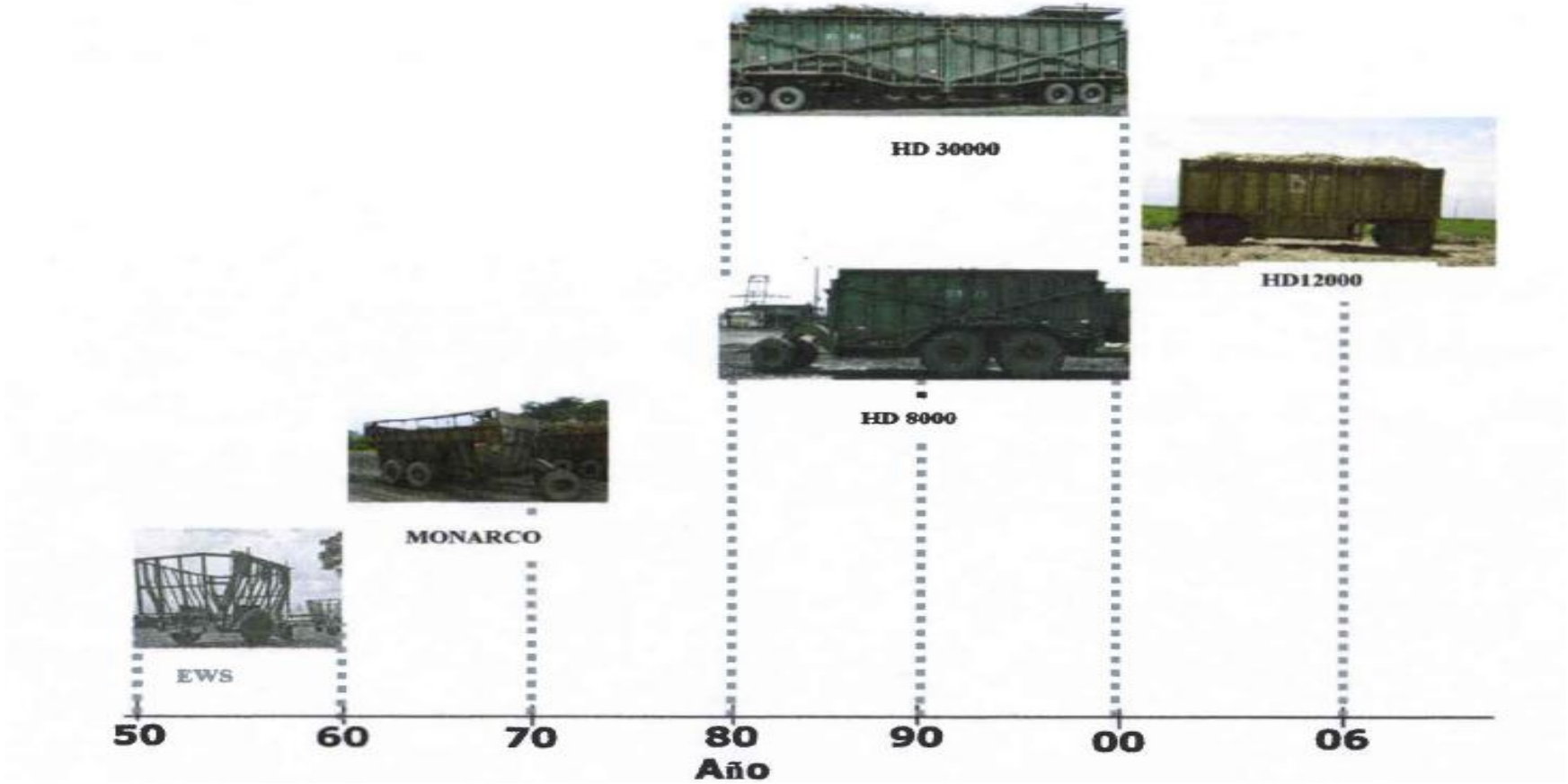
Figure 6: Percentage distribution on truck cost by truck
Source: Mill

CHAPTER 4 TRANSPORTATION BACKGROUND

The transportation on the sugar cane industry in Colombia has evolved since 1990, the main reason is because the harvest fields have being growing far away from the factory result on the increasing demand of sugar and its derivates. This situation has made the industry on transport bigger volumes of cane, and the consequence on equipment modernizing, developing new and efficient methods on cane transportation. Also the raise of the fields has made a huge impact on little towns, because it brings development on little towns, constructing roads and more transportation systems for people.

The transportation on sugar cane is basically constituted by two types depending on the length of the field: tractors for short distances (between 0 to 10 km), and trucks for long distances (between 10 to 80 km). Now days, truck is the vehicle most commonly used because of the distance it has to cover. This is the main reason why the factors on the trucks must be determined and analyzed, and each of these factors are to determine a solution of the main problem.

On the other side, the trolleys used on the transportation have had modifications over time, since the 50´s according to the needs of each time for the cane transportation, according to quantities and peculiarity of the preparation conditions, cut, raise and transportation.



Source: International forum of harvest and transportation of cane.
Figure 7: Evolution of trolleys.

On these days the transportation has evolved on having sugar cane trains, they consist of 4 to 5 trolleys with a capacity of 35 tons max each. These trolleys have been the preference in Colombia for their versatility, and how easy can get them on the fields and stay until being filled out and then the trucks go and pick them up.

CHAPTER 5 FINANCIAL ANALYSIS

The following analysis was made with the balance sheet and income statement from the years 2008, 2009 and 2010. The methodology used was vertical and horizontal normalization and the results of the economics rates presented on the spreadsheet. The values presented are in Colombian pesos in thousands, express otherwise.

5.1. Economic Background

The beginning of 2009 was marked by the uncertainty of the economic world crisis, generating not only actions and reactions from the governments but also the inner policies of all the companies. A few sectors of the economy were not affected and it is the case of oil, mining and some commodities like sugar which had good operational results in 2009. Still the recession is not to be taken lightly, because it affects market development and a decrease on exportation due to an economic deceleration of the product. The impact in Colombia was not as strong as in other countries, in line for the strength of the economic sector with low interests rates, good savings and international reserves.

GPD growth was slow at the beginning of 2009, at the end it rose 0.5% by the end of the year. Even with the world crisis, Colombia and Peru where the Latin American countries with the highest growth. The inflation took a big hit and it went down over 5 points reaching an historic minimum of 2% comparing a 7.67% from 2008.

5.2. Sugar Balance in Colombia

Statistics (source procaña) in the industry show an estimated cane seeded of 205.664 hectares; the total area increases from 2008 in 193.000 hectares, in 2008 were seeded 157.000 hectares. This significant increase was due to the fact that in 2009 the new areas seeded where supposed to be seeded in 2008 and did not occur since the workers were on a strike. The total amount of ground cane was 24 million tons, over 23% comparing from last year. Tons of cane per hectare (TCH); which measure the field productivity increase in 1.5% from 2008. The commercial performance reaches a high record figure, reaching 11.96%.

In 2009 the total production raw sugar reached 2.6 million metric tons increasing 28% from 2008. Also the white sugar increased by 22% and raw 71%. Ethanol production reaches 326 million liters increasing 26% from the last year. In 2009 the inner sugar

consumption was reduced in 5.9%, and the total sales of sugar in the national market reduced by 4.4%.

The future of the sugar mills is prominent with the production of ethanol which is estimated to increase 11% yearly with the use of ethanol as a fuel which reduces carbon emissions on the atmosphere. Big oil companies are investing money on sugar mills on research and development to produce ethanol.

5.3. Exportations

Exports increased 120% in 2009 ending the year exporting over 1.000.000 million metric tons. The main destinations where Caribbean islands, Chile, Peru and USA, however Colombian sugar made new appearances in Canada, Mexico and Sri Lanka among others. The total value of the exportation in 2009 reached US$429.3 million, increasing 157% from 2008. This increase was represented mostly on the price of the sugar that it was an average of 16%.

International price of raw sugar in the New York stock market reached and average of 17.9 US cents per pound generating one of the biggest rises of history of sugar, in 2008 the price was 12.1 US cent per pound. On the London stock market white sugar went from an average of 351.3 US dollar per ton in 2008, to 485.6 US dollar per ton in 2009 an increase of 38%.

The increase of the price of the sugar was merely because India the world largest exporter had to fulfill their own internal use of sugar which occurs to a world sugar deficit leading to other countries to compete and sell sugar. Also the European Union kept their down trend in sugar production, passing from 18 million in 2006 ending 2009 producing 15.5 million tons. Brazil, one of the largest and biggest sugar productions, increased from 33 million tons to 36.5 million tons from 2008 to 2009, however their increase did not match the deficit created by India and the European Union.

5.4. Financial Situation of sugar mill

Balance Sheet

To 31 of December of 2008, 2009 y 2010
(amount in thousands of Colombian pesos)

				HORIZONTAL		VERTICAL		
	2008	2009	2010	2008 - 2009	2009-2010	2008	2009	2010
CURRENT ASSET								
Available	$ 2,783,190	$ 3,796,718	$ 226,594	36%	-94%	0.5%	0.6%	0.0%
Investments	$ 4,560,767	$ 6,246,157	$ 7,157,252	37%	15%	0.8%	1.0%	1.1%
Account receivable	$ 116,454,296	$ 116,863,695	$ 144,521,467	0.4%	24%	19.9%	18.6%	21.6%
Inventories	$ 25,064,136	$ 30,911,681	$ 37,649,188	23%	22%	4.3%	4.9%	5.6%
Diferred	$ 3,084,851	$ 5,754,162	$ 1,583,096	87%	-72%	0.5%	0.9%	0.2%
TOTAL CURRENT ASSET	**$ 151,947,240**	**$ 163,572,413**	**$ 191,137,597**	8%	17%	25.9%	26.0%	28.5%
NON CURRENT ASSET								
Account Receivable	$ 8,461,971	$ 59,686,616	$ 57,856,100	605%	-3%	1.4%	9.5%	8.6%
Permanent Investments	$ 68,488,029	$ 72,233,067	$ 76,955,358	5%	7%	11.7%	11.5%	11.5%
Property, plant and equipment	$ 87,592,158	$ 88,246,448	$ 88,056,808	1%	0%	14.9%	14.0%	13.1%
Intangibles	$ 15,155,541	$ 13,065,859	$ 17,473,659	-14%	34%	2.6%	2.1%	2.6%
Diferred	$ 2,519,373	$ -	$ -	-100%		0.4%	0.0%	0.0%
Credit	$ 90,196	$ 90,196	$ -	0%	-100%	0.0%	0.0%	0.0%
Valorization	$ 251,720,065	$ 231,396,426	$ 238,210,143	-8%	3%	43.0%	36.8%	35.6%
TOTAL NON-CURRENT ASSET	**$ 434,027,333**	**$ 464,718,612**	**$ 478,552,068**	7%	3%	74.1%	74.0%	71.5%
TOTAL ASSET	**$ 585,974,573**	**$ 628,291,025**	**$ 669,689,665**	7%	7%	100.0%	100.0%	100.0%
CURRENT LIABILITIES								
Financial Obligation	$ 82,306,915	$ 134,788,610	$ 115,353,683	64%	-14%	14.0%	21.5%	17.2%
Account payables	$ 55,651,024	$ 54,436,398	$ 50,682,086	-2%	-7%	9.5%	8.7%	7.6%
Work Obligation	$ 2,263,362	$ 2,383,130	$ 2,593,492	5%	9%	0.4%	0.4%	0.4%
Taxes	$ 2,393,818	$ 1,582,451	$ 1,563,333	-34%	-1%	0.4%	0.3%	0.2%
Other liabilities	$ 5,321,713	$ 9,433,686	$ 6,420,191	77%	-32%	0.9%	1.5%	1.0%
Portafolio	$ 500,000	$ -	$ -	-100%		0.1%	0.0%	0.0%
TOTAL CURRENT LIABILITIES	**$ 148,436,832**	**$ 202,624,275**	**$ 176,612,785**	37%	-13%	25.3%	32.3%	26.4%
NON-CURRENT LIABILITIES								
Financial Obligation	$ 16,335,588	$ 15,949,173	$ 72,223,932	-2%	353%	2.8%	2.5%	10.8%
Long term account payable	$ 224,109	$ 304,516	$ 1,371,052	36%	350%	0.0%	0.0%	0.2%
Long term portafolio	$ 39,500,000	$ 38,500,000	$ 38,500,000	-3%	0%	6.7%	6.1%	5.7%
TOTAL NON-CURRENT LIABILITIES	**$ 56,059,697**	**$ 54,753,689**	**$ 112,094,984**	-2%	105%	9.6%	8.7%	16.7%
TOTAL LIABILITIES	**$ 204,496,529**	**$ 257,377,964**	**$ 288,707,769**	26%	12%	34.9%	41.0%	43.1%
EQUITY								
Shareholders Equity	$ 381,478,044	$ 370,913,061	$ 380,981,896	-3%	3%	65.1%	59.0%	56.9%
TOTAL EQUITY	**$ 381,478,044**	**$ 370,913,061**	**$ 380,981,896**	-3%	3%	65.1%	59.0%	56.9%
EQUITY + LIABILITIES	**$ 585,974,573**	**$ 628,291,025**	**$ 669,689,665**	7%	7%	100.0%	100.0%	100.0%
BALANCE	**$ -**	**$ -**	**$ -**					

Figure 8: Balance sheet 2008-2010
Source: Mill

Income Statement

To 31 of December of 2008, 2009, 2010

(amount in thousands of Colombian pesos)

				HORIZONTAL		VERTICAL		
	2008	2009	2010	2008 - 2009	2010	2008	2009	2010
Inflation	5.69%	7.67%	2%					
Operational Income	$ 174,663,249	$ 203,244,674	$ 245,813,728	16%	21%	100.0%	100.0%	100.0%
Operational Income (less inflation)	$ 174,663,249	$ 191,680,052	$ 226,959,815	10%	18%			
Cost of sales	$ (143,806,537)	$ (171,689,125)	$ (196,924,665)	19%	15%	82.3%	84.5%	80.1%
GROSS PROFIT	**$ 30,856,712**	**$ 31,555,549**	**$ 48,889,063**	2%	55%	17.7%	15.5%	19.9%
OPERATIONAL EXPENSE								
Administrative Expenses	$ (11,513,755)	$ (17,079,617)	$ (14,738,615)	48%	-14%	6.6%	8.4%	6.0%
Sales Expenses	$ (7,419,474)	$ (7,978,054)	$ (10,140,265)	8%	27%	4.2%	3.9%	4.1%
OPERATING INCOME	**$ 11,923,483**	**$ 6,497,878**	**$ 24,010,183**	-46%	270%	6.8%	3.2%	9.8%
Other income	$ (2,018,389)	$ 9,438,909	$ (2,852,396)	-568%	-130%	1.2%	4.6%	1.2%
Utility previous years	$ 9,905,094	$ 15,936,787	$ 21,157,787	61%	33%	5.7%	7.8%	8.6%
Previous years adjustment	$ (637,306)	$ (148,645)	$ (94,224)	-77%	-37%	0.4%	0.1%	0.0%
UTILITY BEFORE TAXES	**$ 9,267,788**	**$ 15,788,142**	**$ 21,063,563**	70%	33%	5.3%	7.8%	8.6%
Taxes	$ (1,660,806)	$ (2,062,535)	$ (4,664,454)	24%	126%	1.0%	1.0%	1.9%
NET INCOME	**$ 7,606,982**	**$ 13,725,607**	**$ 16,399,109**	80%	19%	4.4%	6.8%	6.7%
Net income per asset	$ 406.42	$ 733.98	$ 909.32	81%	24%			

Figure 9: Income statement 2008-2010
Source: Mill

2009 was a year full of economic challenges, the US dollar instability and the increase of the price generated increments in future operations of sugar such as ethanol, figure in 2009 which reaches $38 billion, makes an increase in the financial obligations.

In 2010 the mill closed the year with net profit of $16.339.109 thousands, which represents $909.32 per share, that was higher than 2009 with a net profit of $13.725.607 thousand with a represents $733.98 per share.

Operational income rose to $246 billion in 2010, overcoming 2009 in $43 billion. The main reason on the growth was the increase production that was a little bit over 12%, and the price of the quintal (50 Kg bag) on the local market rise close to $66810 per quintal.

Gross margin went from 15% in 2009 to 19% in 2010, mainly because the increase in sales at a better price in local and international markets in 2009. Operational profit was lower in 2010 than 2009 due to diminish on administrative expenses which went from $17 billion to $14 billion from 2008 to 2009.

Profit before taxes increased to $21.064 million increasing from 2009 over $5.537 million. During 2010 total assets increased in $41 billion, in 2009 was $628 million, the main reason was the increase in receivable accounts, both short and long term, that went from $176 billion in 2009 to $202 billion in 2010, and the increase in inventories which went from $30.911 million to $37.649 million. Financial obligation went from $150.737 million in 2009 to $187.577 million in 2010.

Since the main idea of the project is reducing transportation cost, this might mean that the company also needs to make some investments, and this financial analysis will give an idea on how strong or weak the company is and how urgent the implementation is needed

5.4.1. Horizontal Normalization

This kind of analysis will help determine trend between accounts of the same report on the same years, this will help know financial state of the company and which accounts need to be taken into consideration for finance reviewing and costing.

5.4.1.1. Income Statement

Analyzing revenue operations without taking into account the effect of inflation is noted that the company has increased its sales in the 2008 to 2010 in 16% and 21%. It is important to exclude the effect of inflation, because the measure will be more accurate and it will only affect the business performance. According to the analysis the mill achieved an increase of the operational income in 10% between the years 2008 and 2009 and 18% between the years 2009 and 2010. It is important to notice that the company has a growth in sales which concludes with good sales dynamics and sales force.

Cost of sales has increased a little more every year than the proportion of sales growth, which can be rescued in 2009, it achieved a 10% increase in sales with a 19% increase in cost of sales, in 2010 an increase of 18% in sales with a 15% in cost of sales, namely an increase in sales was achieved reducing the cost of sales and it is shown in the growth of gross profit by 55% between 2009 and 2010.

It is really notable the increase on administrative expenses between years 2008 and 2009 of 48%, in turn between 2009 and 2010 the decrease was 14% which was due to the economic crisis concluding fired personnel. Because of these changes and reduced administrative costs and increased selling expenses operating profit shrank in 2009 but significantly overcame in 2010 with an increase of 270%.

Finally it is remarkable the financial development of the business during the 3 years of analysis which achieved an increase of the net profit in 2008 and 2009 of 80% and an increase of 19% between 2009 and 2010

5.4.1.2. Balance Sheet

Accounts available had a major decrease of 94% between 2009 and 2010, which indicates a limitation on cash flow of the company, also the accounts receivable increase which explain the low cash flow. Increase on inventories is constant each year, which indicates a good inventory policy in the company according to the sales forecast. Between 2008 and 2009 the long term receivables increased in 605% which indicates that the company is funding its clients and there is another explication on the low cash flow.

Total assets were constant on 7% in each period of time, which benefits the company with the increase on sales, especially in 2010, which indicates that the company can increase sales in bigger proportion than the growth of those assets sales, represent. In 2008 and 2009 the company made loans to banks which are noted in the increase of its financial obligations in 64%, in 2009-2010 it decreases by 14% which generates trust and optimism on internal policies and overall performance on the leverage. During 2009 and 2010 accounts payable increased by 350% which indicates that the company is changing policies on leverage and it is turning to its providers. This situation made an increase on non-current liabilities by 105% on 2009-2010.

On the equity there was a decrease in the period 2008-2009 of 3% and the same amount increase on the next period which indicates loss and recovery from period to period

5.4.2. Vertical Normalization

This analysis pretends to compare figures of the same document. The base figure is the total asset with the rest of the figures, and see the behavior of each year and try to understand fluctuations.

5.4.2.1. Income Statement

Market share has been constant during the 3 periods of time and there is no representative fluctuation. In 2009-2010 gross margins has increased from 15% to 19% which is accurate according to the decrease on cost of sales. Operational profit has also increased significantly during the 3 periods, 6.8% in 2008, 3.2% in 2009 and a major increase in 2010 of 9.8% due to the diminish on administrative expenses and the relation between the increase on cost of sales and total sales. Net margin has increased between 2008 and 2009 and has been constant from 2009 to 2010.

5.4.2.2. Balance Sheet

During these periods the most significant participation in the current assets of the total assets are accounts receivable; this indicates that the assets are invested on what the clients owe to the company. Year after year it has been a constant of 20% of the total company assets which is a constant company policy. The assets distribution is balanced by 30% on current assets and 70% on non-current assets, which indicates a vast participation on long term assets which results on a deficit on cash flow affecting short term commitments.

Financial obligations mostly represented by short term are 18% constant of the total assets, which means that the company has enough resources to cover its financial obligations. Long term financial obligations increase in 2010 by 10% after being constant by 2.5%, it was due to increase and loans in 2010 to fulfill sales goals. During these periods total liability has increased on the total assets by 34%, 41% and 43% by 2010, this indicates that the company has greater obligations with providers. Even though it is not half of total assets this incremental tendency is harmful to the company because it will jeopardize the relationship among providers.

The participation of the assets has diminished in part of the equity; the providers are getting the investment instead of the shareholders. Even though the investment is still in hand of the shareholders to continue with this trend will be harmful in the future.

5.4.3. Financial Ratios

Financial ratios are measure to compare year after year on how the company´s performance was and help understand providers, banks and shareholders the financial situation.

5.4.3.1. Cash Flow

- **Current Ratio:** it passes from 0.81 in 2009 to 1.05 in 2010, the reason is that current asset increase in 15.98% and the current liability decrease the same amount. This means the times that the company can attend short term compromises with the current available. Even though in 2009 decrease comparing 2008, in 2010 it recovers and this indicates a good working capital management.

- **Acid Ratio:** this indicator went from 0.65% in 2009 to 0.87% in 2010, this was because the decrease on current liabilities on 10.88%, this indicator shows that the company does not have enough resources to long terms commitments.

- **Working Capital:** in 2009 the company had negative results; this shows the difficulty that the company had to maintain operations. In 2010 there was a big recovery due to the increase in sales.

- **Defensive Trial:** the results show that the company has not been able to complete their compromises in long term debts which show a big dependency on the sales.

Cash Flow				
Indicator	**2008**	**2009**	**2010**	**Units**
Current Ratio	1.02	0.81	1.08	Times
Acid Ratio	0.85	0.65	0.87	Times
Working Capital	3,510,408	-39,051,862	14,524,812	Pesos (thousands)
Defensive Trial	0.02	0.02	0.00	Times

Table 5: Cash flow

5.4.3.2. Liability Ratios

- **Debt Ratio:** year after year it shows that the company has less participation on the lenders on the finance of all the assets which means the shareholders are not earning money and are supporting the entire operation if the trend continues.

- **Current Debt:** in short term it decrease in 17.56% from 2009 to 2010, because current asset reduce of 12.84%, current liability to providers increase in 12.17%. This has become a constant in the company and the short term debt is charging on the providers.

- **Interest Coverage Rate:** 2008 and 2010 the financial obligations where covered by operational utility, in 2009 the indicator was 0. The result on this indicator generates trust on the banks and financial sector in case that loan is needed.

- **Pay Period:** during 2009 was 114 days and in 2010 reduce to 98 days, this shows that the company its financing the operation on providers and needs to be more strict on payment policy so it can maintain good relationship with the providers.

Liabilities Ratios				
Indicator	**2008**	**2009**	**2010**	**Units**
Debt Ratio	34.90%	40.96%	43.11%	Percentage
Current Debt	72.59%	78.73%	61.17%	Percentage
Interest Coverage Rate	5.91	0.69	8.42	Times
Pay Period		114	98	Days

Table 6: Liability ratios

5.4.3.3. Leverage Ratios

- **Total Leverage:** total leverage has grown 6.39% from 69.39% in 2009 to 75.78% in 2010. This obey mainly with an increase on total liabilities of 13.71%, meanwhile the equity reduces by 0.23%. this indicator has increase in each year and this means that the company money is passing to the lenders from the shareholders

- **Short Term Leverage:** the short term debts are covered by current assets as has being show in the whole analysis.

Leverage Ratios				
Indicator	**2008**	**2009**	**2010**	**Units**
Total Leverage	54%	69%	76%	Percentage
Short Term Leverage	39%	55%	46%	Percentage

Table 7: Leverage ratios

5.4.3.4. Activity Ratios

- **Turnover:** from 2009 to 2010 turnover was reduced in 4 days passing from 37 days to 33 days in 2010, this will help the company on cash flow so it can pay financial obligations.

- **Inventory Turnover:** it decrease 1 day from 2009 to 2010 passing from 6 days to 5 days, this will reduce the current asset and optimization of the inventory and sales.

- **Asset Rotation:** the company does not have the capacity on producing and sale through the asset invested, in other words, the company is not generating enough value to the assets through the sales.

Activity Ratios				
Indicator	**2008**	**2009**	**2010**	**Units**
Turnover		37	33	Days
Inventory Turnover	6	6	5	Times
Asset Rotation	0.30	0.32	0.37	Times

Table 8: Activity ratios

5.4.3.5. Equity Ratios

- **Gross Margin:** increase in 3.89% from 2009 to 2010, because the increase on cost of sales was lower than the increase on operational income.

- **Operating Margin:** it shows average equity; even that in 2009 diminish there was a turnover in 2010 achieving 9.77% due the benefits of the sales.

- **Net Margin:** this indicator shows the real equity of the company. And the results where good in all the periods meaning a good development of the company and the shareholders.

- **Return on Equity:** since the net profit and equity increase from 2009 to 2010 the ROE also increase 0.6% passing from 3.7% to 4.3%.

- **Return on Asset:** the ROA has being incremental each year of the period, meaning that the company resources are well handle and each year the asset are generating value to the company.

Equity Ratios				
Indicator	**2008**	**2009**	**2010**	**Units**
Gross Margin	17.67%	15.53%	19.89%	Percentage
Operating Margin	6.83%	3.20%	9.77%	Percentage
Net Margin	4.36%	6.75%	6.67%	Percentage
Return on Equity (ROE)	1.99%	3.60%	4.30%	Percentage
Return on Asset (ROA)	1.30%	2.18%	2.45%	Percentage

Table 9: Equity ratios

5.5. Financial Analysis Conclusion

Overall the mill has a great financial situation, over the last 3 years the ROE and ROA Ratios are growing, sales are also growing. However long terms debts are growing which means the company is delaying the pays to providers to pay short term debts. This means if the company doesn´t take this in consideration the shareholders will have to invest more money to pay the debts

With the defensive trial we can assume that the cost controlling on the mill is pretty low, this indicator shows that the company is too dependable on sales and again does not have any cost control.

One important point to take in consideration is the interest coverage rate, since the company's future on long term debts is getting darker, this Ratios will let them ask for loans to the bank, since the interest of the loan will be payable throw the operational margin.

CHAPTER 6 ACTUAL SITUATION

Sugar cane takes about 12 months to fully grow and be in the perfect maturity to be cut and processed to make sugar. The mill has 20.000 hectares destined to crop sugar cane, each hectare produces an average of 100 tons of sugar cane per year. The mill needs to ground 4000 tons daily to produce sugar and it's derivate to fulfill market requirements and sales. Production works at 100% of plant capability.

Production per day	4000 tons
Production per month	120.000 tons
Production yearly	1.460.000 tons
1 hectare	100 tons
20000 hectares	2.000.000 tons

Table 10: General information on production

The entire field is divided into 6 districts; each district has different distances from the plant and hectares.

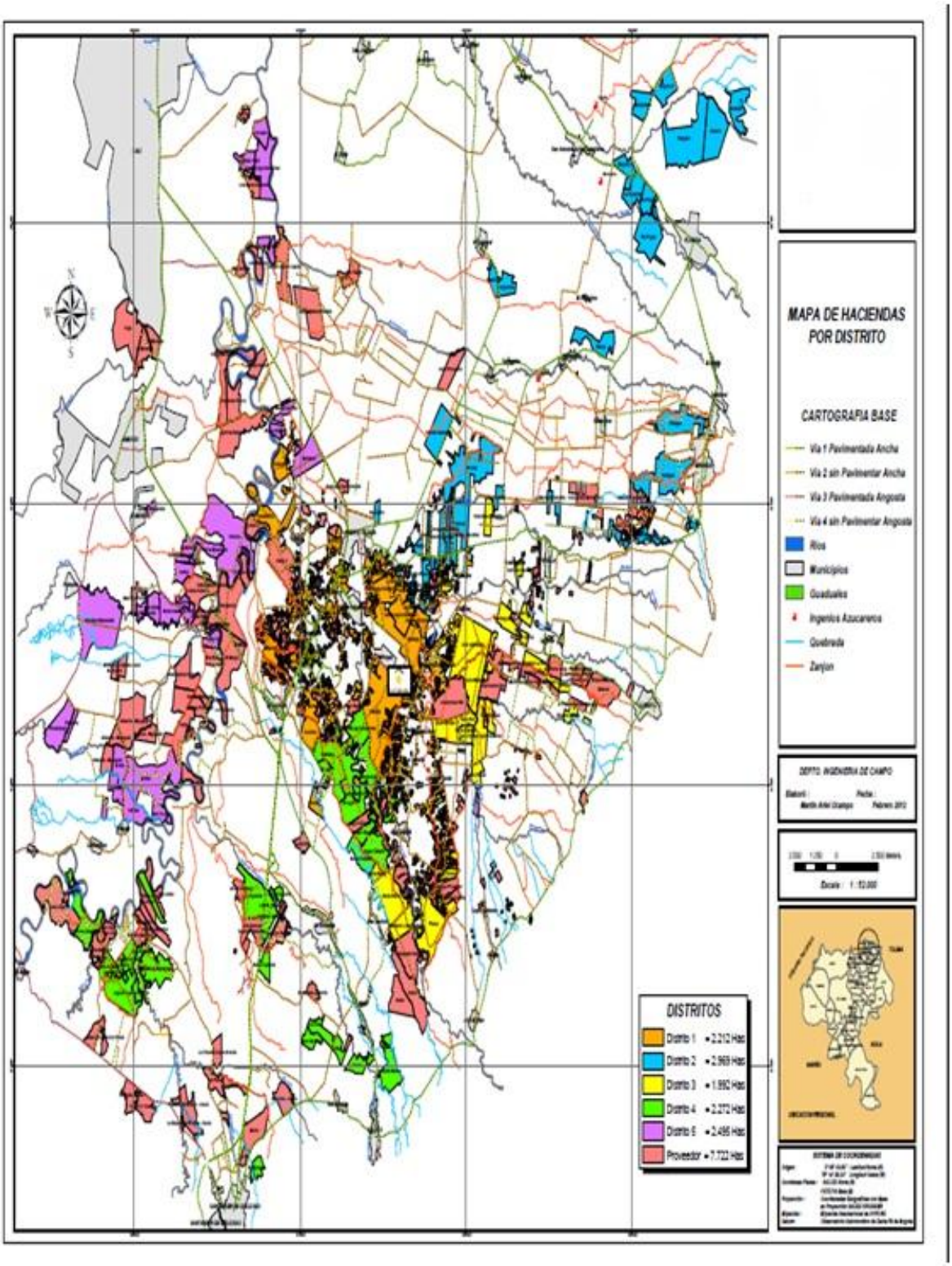


Figure 10: Map of the mill and field districts
Source: Mill

District	Hectares	Distance from the plant (Km)	Tons of sugar cane crop per year
1	2.212	8	212.100
2	2.969	28	296.900
3	1.992	28	199.299
4	2.272	32	227.200
5	2.495	32	249.500
6	7.722	15	772.200

Table 11: District distribution and distances from the plant
Source: Mill

District 6 is the only one that is not owned by the mill, however the mill crops in the district and has to cover all the expenses in transportation and harvesting

Cane cannot stay more than one day cut, because the cut cane will absorb minerals and water from the earth and decrease sacarose level. All of these factors affect productivity on the plant and the quality of the sugar. Quantity of cut cane per day is strictly observed and followed, since the plant needs 4000 tons daily, cane cutters only cut 4000 tons daily and no more. Cane cut in a day is used for the next day production

6.1. Distribution and Transportation

There are 3 different kinds of trolleys and 2 kinds of vehicles (tractors and trucks), all the vehicles can pull up to 5 trolleys of any type, the main difference is that the tractors are much slower than truck so the distance are taken in consideration depending on which district they need to go.

Trailer Type	Gross Weight (loaded) Kg	Net Weight (empty) Kg	Average Load Tons	Quantity own
1 – Volteo	10.000 – 13.000	4.800 – 5.500	6.35	40
2 – Milenio	17.000 – 23.000	8000 – 9000	11.5	40
3 – Transmilenio	24.000 - 35.000	10.000 – 12.000	18.5	64
TOTAL			**1898**	**144**

Table 12: Trolley types and quantities
Source: Mill

Vehicle	Quantity own	Average speed	District uses
Tractor	20	20 Km	1 and 6
Truck	15	40 Km	2, 3, 4, 5 and 6
Total	**35**		

Table 13: Vehicles types by quantity and average speed
Source: Mill

Figure 11: Volteo trolley

Figure 12: Milenio trolley

Figure 13: Transmilenio trolley

It takes 24 hours transit to bring the 4000 tons from the field to the plant and an average fuel of 74 gallons/day per vehicle.

6.2. Field Distribution

Production requires 4000 tons of sugar cane each day for production, the theoretical capacity of the 144 trolleys is 1898 tons per trip, this mean that the trolleys once they arrive to plant they have to go back again on the field to pick up the rest of the cane.

After an in-field visit, times of loading were taken according to the next table:

	Type of Trailer		
Sample	**Volteo**	**Milenio**	**Transmilenio**
1	3,26	6,00	9,00
2	2,24	6,40	9,00
3	3,00	6,26	9,55
4	3,00	6,82	8,20
5	3,76	5,72	9,44
6	3,00	5,81	8,99
7	3,00	5,85	9,54

8	2,27	5,07	9,14
9	3,53	6,87	8,39
10	3,00	6,13	8,89
11	3,90	6,17	8,17
12	3,00	6,00	9,00
13	2,16	6,00	9,83
14	3,79	6,00	9,00
15	3,15	6,00	8,30
16	2,54	5,11	9,71
17	3,94	6,00	8,08
18	3,00	5,32	9,85
19	3,32	6,00	8,57
20	2,29	5,38	9,08
21	3,32	6,00	8,48
22	3,05	5,65	9,00
23	2,84	6,00	8,58
24	3,00	6,76	9,00
25	3,57	6,00	8,97
26	3,00	6,00	9,00
27	3,00	6,00	9,93
28	2,47	6,00	8,81
29	3,00	6,00	9,00
30	3,82	6,00	9,96
Mean	**3,07**	**5,98**	**9,01**

Table 14: Loading times
Source; Mill

Trolleys get filled with a loader which can load a transmilenio in 9 min; milenio in 6 min and a volteo in 3 min. At the end of each day trolleys are left back on the field to be loaded each morning, cane cutters usually start working at 6:00 am; loader drivers start working at seven which start loading the trolleys and when the first trolley is filled up a truck comes from the plant, pick up the trolley and head back to plant, truck drivers start working at 8:00 a.m. which means loaders have 1 hour batch to load trolleys plus the transit time. This is how recollection of the cane works.

In most of the cases trucks go to different hectares in the same trip, however there is not scheduling on which hectares they must go first, works as first-call first-serve.

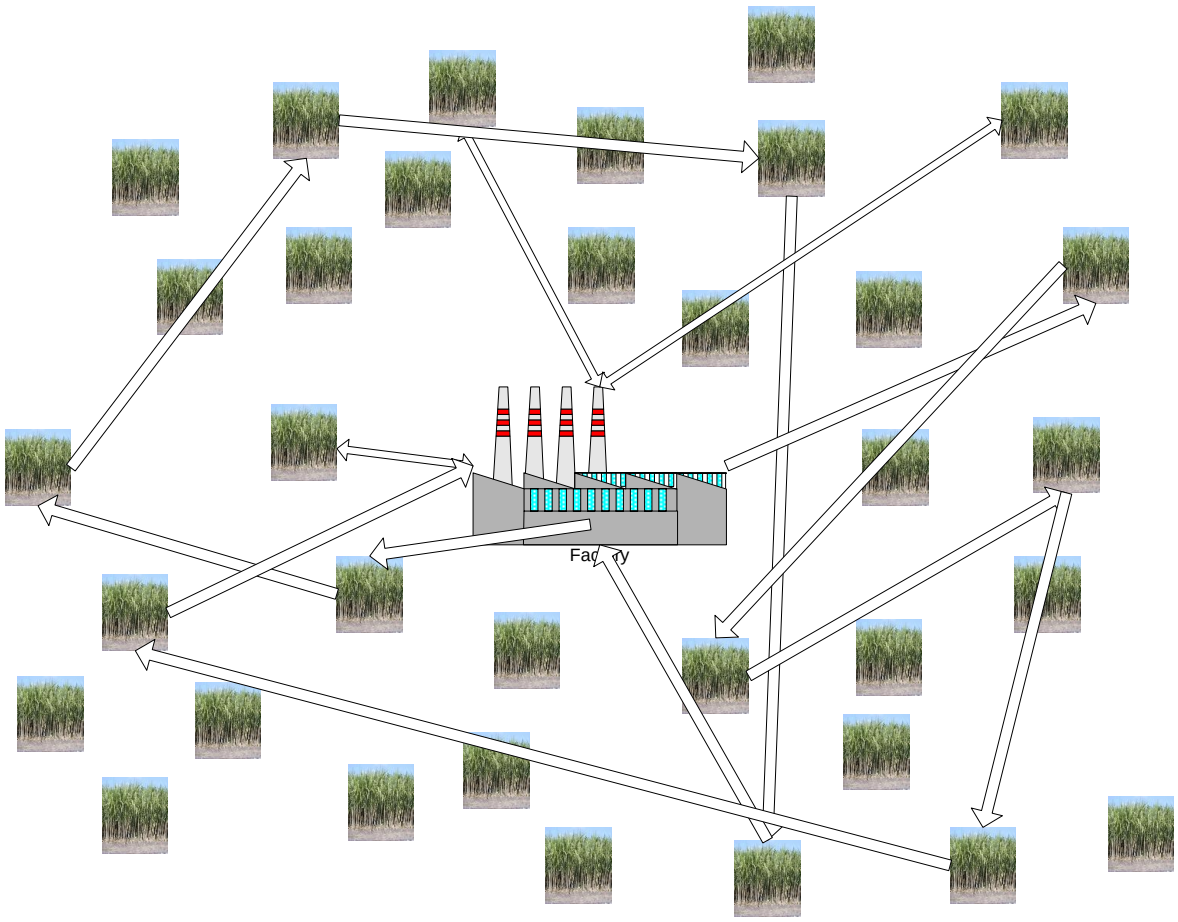


Figure 14: Actual cane recollection

6.3. Harvesting

The harvesting is programmed to ensure enough cane for the entire year production. Since the harvest of sugar cane requires 12 months, the field is also divided in zones. As shown in figure 2, there are different districts somehow equally distributed, however district 6 is spread out through the entire field because the mill does not own those lands. That is why it is necessary to have different zoning to ensure enough raw materials.

The districts are established according to the characteristics of the land to standardized consumption of fertilizers, distribution of irrigation of water. The zones are divided by cardinal direction and taking into account a radial distribution. The central point is the mill and according to the distance and the amount of hectares, the zone was divided to equal distance and the amount of cane to pick up:

Zones	Districts	Trimester
1 – SW	1, 3 and 6	First (January – March)
2 – NW	1, 2 , 5 and 6	Second (April – June)
3 – NE	1, 2, 3 and 6	Third (July – September)
4 – SE	1, 3 and 6	Forth (October – December)

Table 15: Harvesting zoning
Source: Mill

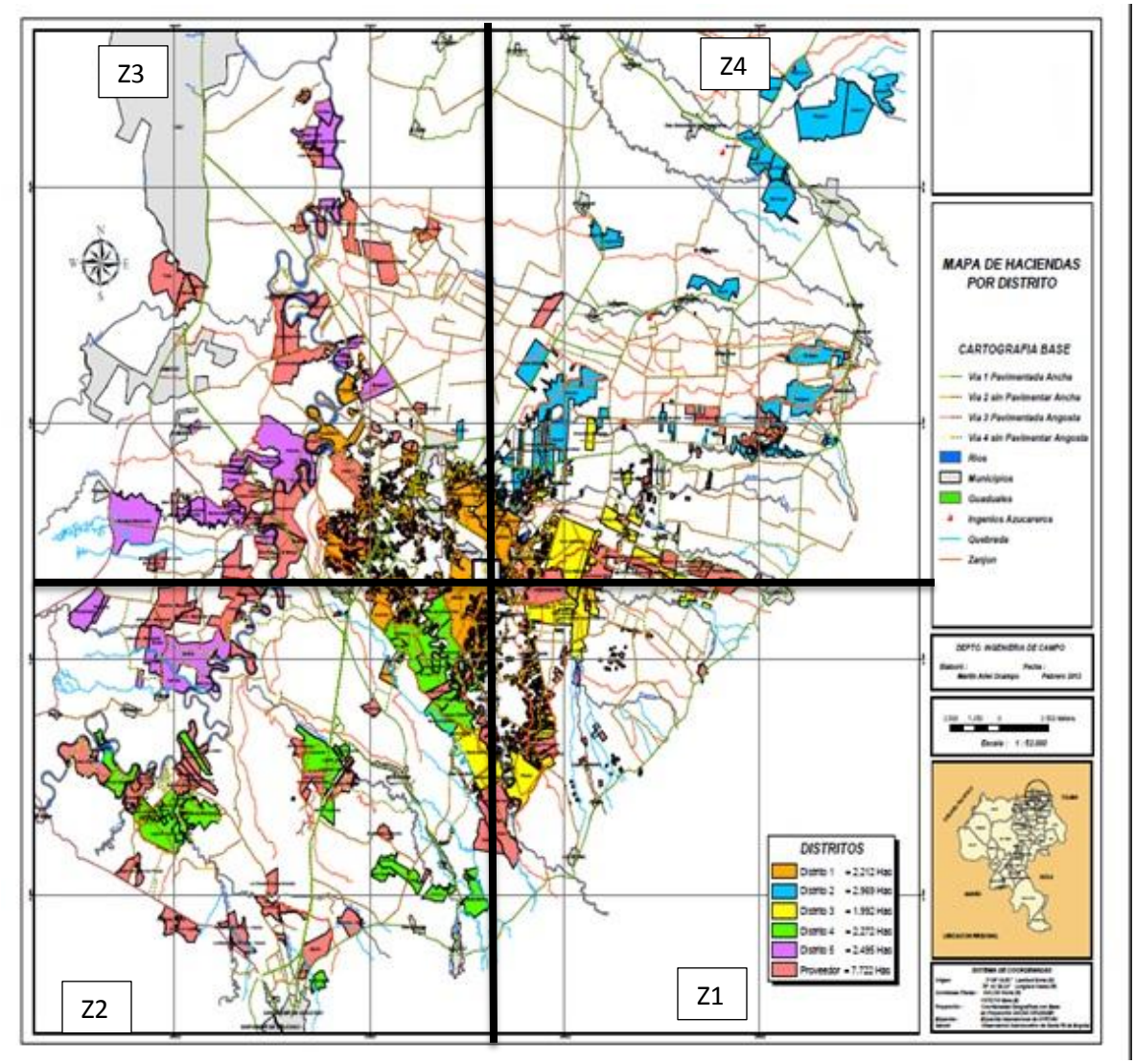


Figure 15: Harvesting distribution by zones
Source: Mill

There is no information on how many hectares there are by zone, so for further analysis it is assume that they are equally distributed.

CHAPTER 7 ADDRESSING THE PANORAMA

Following the methodology, a collaborative brainstorming with 20 employees of the mill from different areas: logistics, accounting, field engineering, plant engineering, operations and maintenance the employees took place, from different fields and different hierarchy. The main reason of the brainstorming was to find out different factors which led to a high transportation cost and have different points of view on the factors that led the high cost and which factors were already known.

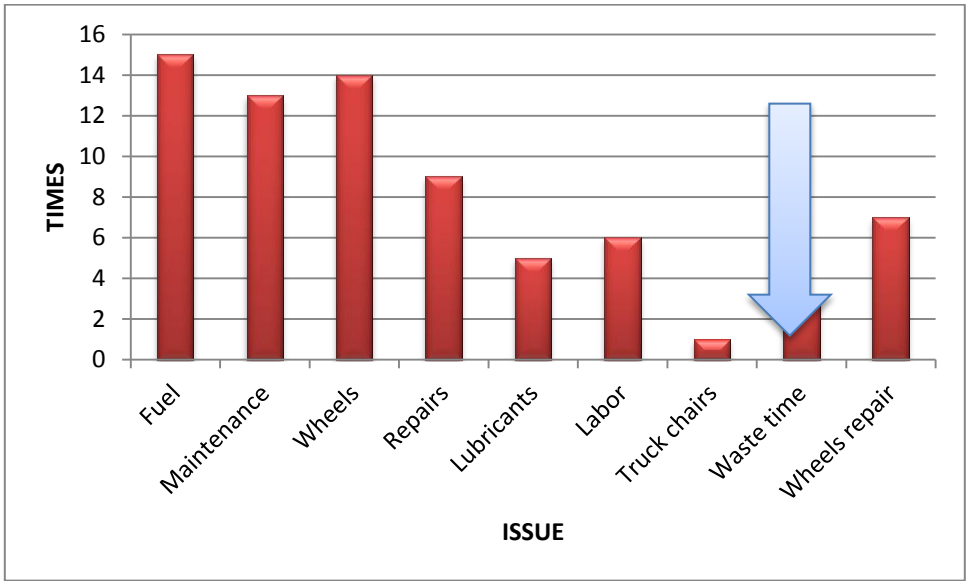


Figure 16: Brainstorming results

At the beginning of the brainstorming the results found where expected, however the field engineering department mention something about time waste and it was a major breakthrough to address the problem.

7.1. Waste of Time

This became a really interesting factor which had no direct consequence in transportation costing; however after going deeper in the subject the explanation was really important. The harvest process worked perfectly for the requirement of the plant, every day plant had enough raw materials to work and fulfill all of the production orders.

Field engineer explained that there is no scheduling on picking up the trolleys on the field. When a trolley got full a truck goes inside the field and picks up the trolley, two or three more found on the road to bring back to plant. It was common that when a truck leaves to

pick a trolley another trolley got full so they have to send another truck to pick up only one trolley and that becomes a waste of time.

Another time waste was because there was companionship between truck drivers and field workers; since the workers cannot leave the cut hectare until the truck comes and pick the trolley (company policies) sometimes the driver went to different destination that was sent, so the driver will go to his friend location so his friend can start working on another hectare, even though drivers sometimes receive money from the cane cutters, since the cane cutters salary is based on how much tons of cane they cut, but there is no proof.

CHAPTER 8 FINDINGS

With the brainstorming results the idea is to create a scheduling technique using routing elements to pick up the trolleys on the fields, the result will be less time on retrieving the trolleys to the plant and a cost reducing on overall transportation activities especially on fuel consumption and vehicles utilization.

8.1 Actual Situation Analysis

There are a total of 144 trolleys of different capacities; the sum of all capacities is 1898 tons. Since the plant needs 4000 tons a day all the trolley are needed at least twice every single day, there will be 204 tons that needed to pick up after the second recollection.

There are a total of 35 trucks (20 tractors and 15 trucks) the average speed of the tractor its 20 km/h and the truck is 40 km/h. Each truck can pull up to 5 trolleys at the same time no matter size to maintain the same average speed. The further location is 32 km from the plant, a truck will take 1.6 hours on picking up and coming back to plant, according to established times already measured by the mill.

In terms of capacity of trucks and trolleys the capacity is more than fulfill, adding all the trucks (35 in total) times 5, the number of trolleys a truck can pull, there is a grand total of carrying capacity of 175 trolleys versus 144 the mill has. In terms of time the further distance its 32 km, a round trip will be 64 km, and with average speed of 40 km/h a truck can do a round trip in 1.6 hours. Since the zones are mixes of districts not all the hectares needed in one day are that far away, the shortest distance is 8 km and with an average speed of 20 km/h can do the round trip in less than one hour.

In conclusion all the capacity of trucks and trolleys are enough to fulfill the requirements of production orders and there is no need to invest in more machinery and technology.

8.2. Adjusting Distances

As shown on figures 10 and 15 the districts are obviously further than the average distance, so for each zone it is necessary to take the distance of further district field as the closest to other districts and vice versa. The districts were divided into sub-districts to have more accurate distances to create the nodes and find the optimum route. This technique is based on radial mapping, which defines circle in map maintain the same scale creating circles on origin belonging to the distances.

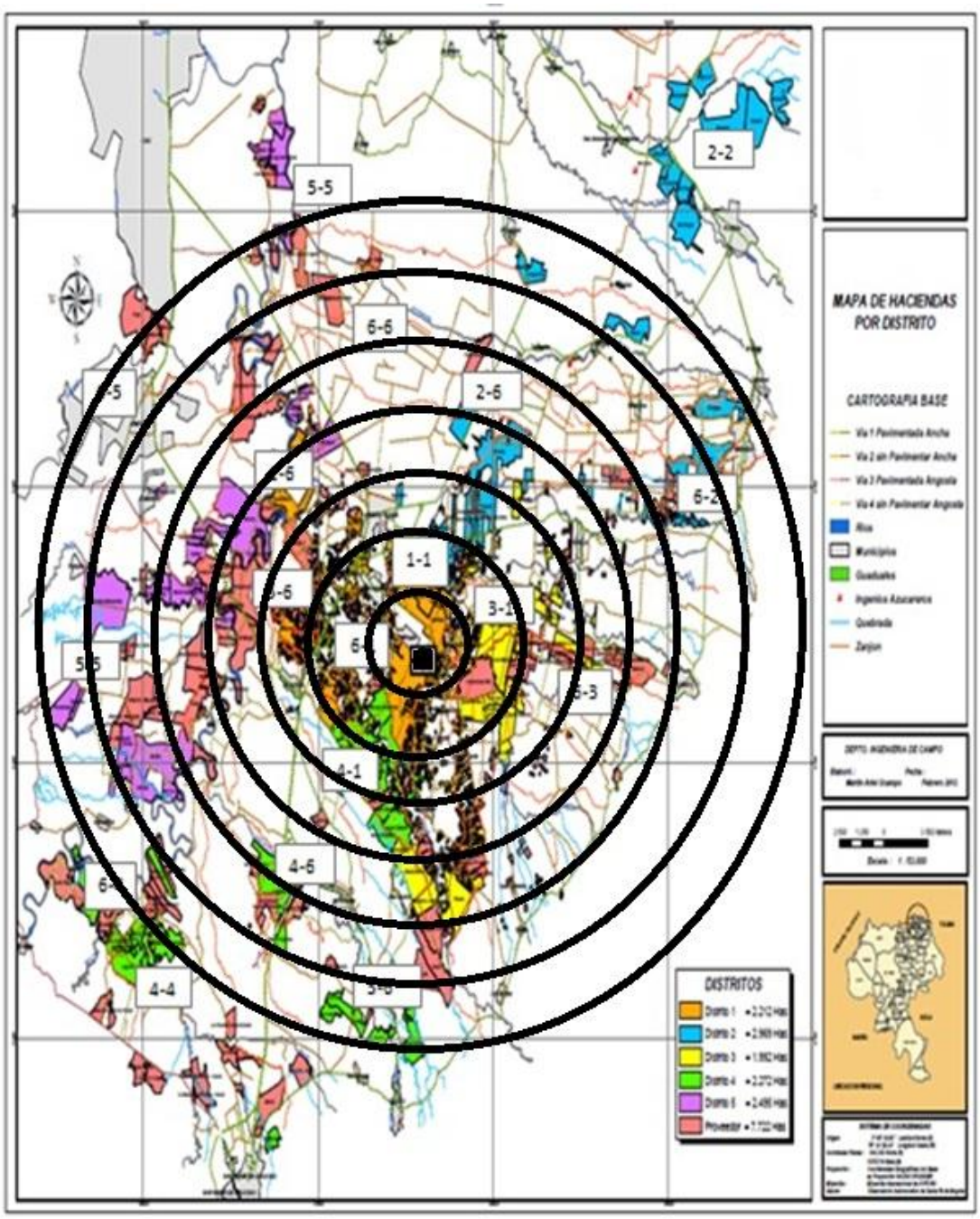


Figure 17: Radial mapping distribution

As the areas are so dispersed, it is necessary to combine the radial technique with land characteristics. According to the experience of the people of the mill, including lands that are linked, have different features, therefore it was necessary to make a combination of the radio technique with experience and yield hectare historical data. It was necessary to include the specifications of each area where the radio indicated to each analysis of each radio.

The nomenclature used, defines that the first number refers to the district address to and the second number to the district compare with:

	Distance (Km)
District 1	
Sub-District 1-1	8
Sub-District 1-6	15
District 2	
Sub-District 2-2	28
Sub-District 2-6	15
District 3	
Sub-District 3-1	8
Sub-District 2-2	28
Sub-District 3-6	15
District 4	
Sub-District 4-1	8
Sub-District 4-4	32
Sub-District 4-6	15
District 5	
Sub-District 5-5	32
Sub-District 5-6	15
District 6	
Sub-District 6-1	8
Sub-District 6-2	28

Sub-District 6-3	28
Sub-District 6-4	32
Sub-District 6-5	32
Sub-District 6-6	15

Table 16: District partition with sub districts

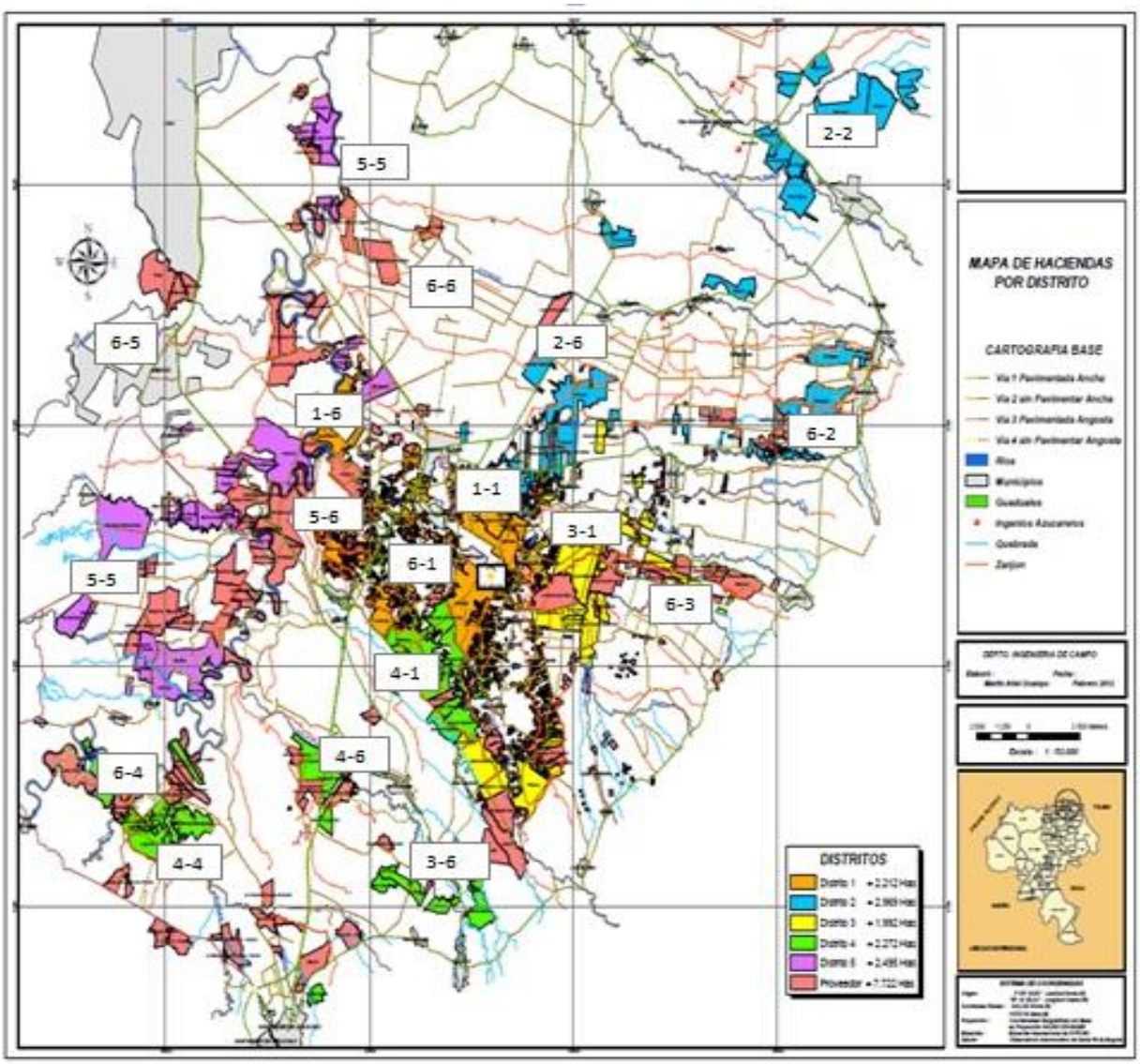


Figure 18: Sub districts partition

Each zone has different sub-district and will be useful when creating the routing model.

Zone	Sub-districts	Distances (Km)
1	1-1	8
	3-1	8
	3-3	28
	6-1	8
	6-3	28
	6-4	28
2	1-1	8
	3-6	15
	4-1	8
	4-4	32
	4-6	15
	5-5	32
	6-4	32
3	1-1	8
	1-6	15
	5-5	32
	5-6	15
	6-1	8
	6-5	32
4	1-1	8
	2-2	28
	2-6	15
	3-1	8
	6-1	8
	6-2	28
	6-3	28

Table 17: Zoning distribution by sub-district

8.3. Adjusting Capacity

The need is to collect 4000 tons of cane daily of to fulfill production requirements. There are 144 trolleys with different capacities with an overall theoretical capacity of 1898 tons.

This means that all the trolleys must be used twice to recollect 3796 tons with a balance of 204 tons to be collect in a third shift.

Each hectare produces 100 tons of cane, this mean that there is a necessity to recollect cane from at least 40 hectares every day. The overall capacity of the trolleys is 1898 which means that the trolleys can recollect from 19 hectares per shift.

Using lineal programming to determine the optimum trolley assignation maximizing cane recollection by hectare being the sum of trolleys type times its capacity with the following variable:

- X_{ij}: Type of trolley type i with capacity j

Parameters:

- C_i: Capacity of trolley type i
- N_i: Quantity of trolley type i

The mathematical model becomes:

$$\max \quad \sum X_{ij} * C_i \qquad (1)$$

$$\text{s.t} \quad X_{ij} * C_i \leq 100 \quad ; \qquad (2)$$

$$\sum X_{ij} \leq N_i \quad ; \qquad (3)$$

$$\sum X_{ij} \leq 5 \quad ; \qquad (4)$$

$$X_{ij} \in Integer \qquad (5)$$

For each i,j

The objective function (1) maximizes the total recollection of cane of each hectare adding the 19 hectares. Constraint (2) ensures that for each hectare the maximum amount of cane recollected is 100 tons. Constraint (3) makes sure the quantities of each trolley type will be met. Constraint (4) guarantees there will be only 5 trolleys of any type y hectare since a vehicle can pull only until 5 trolleys of any type. Constrain (5) limits variables to be integer numbers.

Hectares	Volteo	Milenio	Transmilenio	Total trolleys	Capacity (tons)
1	0	1	4	5	86
2	0	3	2	5	72
3	0	4	1	5	65
4	0	0	5	5	93
5	0	0	5	5	93
6	0	0	5	5	93
7	0	0	5	5	93
8	0	0	5	5	93
9	0	0	5	5	93
10	0	0	5	5	93
11	0	0	5	5	93
12	0	0	5	5	93
13	0	0	5	5	93
14	0	0	5	5	93
15	0	4	1	5	65
16	0	5	0	5	58
17	0	4	1	5	65
18	0	5	0	5	58
19	0	5	0	5	58
Totals	**0**	**31**	**64**	**95**	**1541**

Table 18: Assignment results from Solver

The results obtain in this run were not as expected, the maximum capacity of recollection was 1541 tons per shift with an overall use of 95 trolley mix where the trolley volteo was not used once and there where left in total 49 trolleys unused.

These results are not efficient since the purpose of the thesis is to reduce vehicle utilization, they will have to go over three shifts to recollect all the cane needed for production. Another factor will be that it is unequal the amount of cane recollected from each hectare which means there has to be another shift to recollect the rest of the cane left in the fields with 359 tons per shift left of cane. With the trolleys left it can be recollected with another shift, but still is not efficient enough since the vehicles must be distributed to go 4 times on the fields with this trolley assignment run.

Analyzing the results it appears to be obvious why the tool did not take in consideration volteo trolley since the objective function is to maximize capacity with a restriction of 5 trolleys per hectare, taking out constraint (4) to have a robust model the results are:

Hectares	Volteo	Milenio	Transmilenio	Total trolleys	Capacity (Tons)
1	2	2	3	7	**91.2**
2	2	2	3	7	**91.2**
3	2	2	3	7	**91.2**
4	2	2	3	7	**91.2**
5	2	2	3	7	**91.2**
6	2	2	3	7	**91.2**
7	2	2	3	7	**91.2**
8	2	2	3	7	**91.2**
9	2	2	3	7	**91.2**
10	2	2	3	7	**91.2**
11	2	2	3	7	**91.2**
12	2	2	3	7	**91.2**
13	2	2	3	7	**91.2**
14	2	2	3	7	**91.2**
15	2	2	3	7	**91.2**
16	2	2	3	7	**91.2**
17	2	2	3	7	**91.2**
18	2	2	3	7	**91.2**
19	2	2	3	7	**91.2**
Totals	**38**	**38**	**57**	**133**	**1732.8**

Table 19: Assignment results from Solver second run

This assignment results much more consistent with efficiency than the first one. The distribution of the trolleys is equal in each hectare. The results of the assignment for the trolleys per hectare finish with a total of 133 trolleys to use and a total capacity per shift of 1732.8 tons. There will be 11 trolleys unused in the fields; 2 Volteo, 2 milenio and 7 transmilenio these trolleys will be used to pick up the cane left in each hectare which is 168 tons. With the trolleys left there is a carrying capacity of 165.2 tons which needs 3 trucks pull the trolleys left and will be 2.8 tons left in the fields.

Since the tons per hectare is an average number, the 2.8 tons of cane left in the fields do not affect the model and I will not be taken in consideration.

	Tons recollect	Tons left	Trolleys use	Trolleys left	Truck use	Trucks on trolleys left	Shift need
Run 1	1541	359	95	49	19	10	5
Run 2	1732	168	133	11	27	3	3

Table 20: comparison of the two runs

The second run is more efficient than the first run, in the first run the vehicles must go on the field 5 times to recollect all the cane while in the second run they only need to go 3 times which reduces the time used by trucks and optimize vehicles and trolley utilization, the assignment selected to model a route will be the second run.

Assumptions of the model

1. Only 5 trolleys are used by train
2. It is possible to use any type of trolley for each train´s configuration
3 Truck, tractors and trolleys coupling times are negligible
4. Waiting time the discharge cane at the mill is not taken into account
5. The plant capacity is unlimited
6 Times used are given by the mill (except cane loading time into trolleys)
7. The cane is cut the day before it will be transported to the mill

8.4. Routing

Since the problem description is to reduce cost, and cost is measured by fuel consumption, the best routing technique to address the problem would be a traveling salesman problem, because the results of this technique is to reduce time by measuring the distance, it will finally reduce on fuel consumption. However since capacity is so tight and it is a major restriction, no routing technique per se will be used, instead the route to present will meet the capacity of the mill with the owned equipment and schedule a recollection itinerary maximizing capacity deliveries.

The idea on the routing proposal is to create one route per zone and that way will be replicate it each day. The routing will be by each hectare where a vehicle will go and pick up the trolleys assigned in each hectare, then going back to plant where will unload and with the same trolleys will do the same route on adjacent hectares to collect the rest of the cane. The same will happen to the 11 trolleys left on the hectare assignment; they will depart from plant and will do a single route where it is going to recollect the rest of the cane on the hectares.

It was explained before that since the distances are average, it was necessary to create sub-districts to have a better accuracy on the model. There will be 19 hectares per shift which will represent a node for each model. There will be 4 routing models in total; one for every zone, and 3 models per zone to optimize trolleys and vehicles utilization.

Since the model has to fit for everyday use, the distribution of the hectare for every single model will be equal; this means that the amount of hectare in each model will contemplate the further hectares and closest hectares in equal number so the model will fit for every day. In case the number is uneven the sub-district with more hectares will have an additional node.

The vehicle distribution will be according to average speed and distance. The tractors have an average speed of 20 km/h so the sub-districts covered by the tractors will be the ones that end with 1 and 6 since the distance are 8 km and 15 km respectively; the other sub-district, endings with 2, 3, 4 and 5, will be collect by trucks that have an average speed of 40 km/h. Vehicles and loading analysis will be made in the next section by each zone.

There will be a total of 3 routes per zone; the first route will collect the 19 nodes, the second route will be to collect the trolleys left in the initial 19 nodes. The third route is to collect cane left in the fields on the initial 19 nodes. This needs to be done twice a day using the same route to achieve the best efficiency.

Route 3 model will recollect the 8.8 tons left in each hectare with the 11 trolleys left unused (2 volteo, 2 milenio and 7 transmilenio). The assignation of the trolleys combination per truck will be explained depending on the zone, loading times and capacities.

Each route must be done twice or two shifts, doing it twice will ensure the recollection of 3800 tons from 38 hectares. Still there is the need to collect cane from another 2 hectares to complete production requirements; this recollection will take place as first-to-come first-serve. The routing for the last 2 hectares will fit depending on the zone and that will be the 3 shift

Route	**Number of trolleys to be collect**	**Number of trucks needed**
1	95	19
2	38	8
3	11	3
TOTAL	**144**	**30**

Table 21: Trolleys and truck utilization for each route

The proposed model will reduce on vehicle utilization; there are a total of 35 trucks, with the model proposed it is only needed to use 30 trucks. This will drastically reduce the overall cost on every single factor of truck cost.

8.4.1. Timing and Scheduling

Before modeling the network it is important to consider different times to schedule the recollection and measure the viability of the proposed model. Since cane cutters are paid according on how much cane they cut, cane will not be a problem since all the cane is already cut from the day before. However according to the proposed assignment it will take 45 min to load the 7 trolleys in each hectare and there are only 9 loaders which will be the bottle neck on the whole system especially for shift 2.

Trolley type	**Quantity**	**Loading time (min)**	**Total loading time (min)**
Volteo	2	3	6
Milenio	2	6	12
Transmilenio	3	9	27
TOTAL			**45**

Table 22: Trolleys loading times for each node

Trolley type	**Quantity**	**Loading time (min)**	**Total loading time (min)**
Volteo	40	3	114
Milenio	40	6	228
Transmilenio	64	9	513
TOTAL			**855**

Table 23: Total trolley loading times

Total time per hectare is 45 minutes to load the 7 trolleys in the first route. The total time to load all the trolleys is 855 minutes which takes 14.25 hours in total, time to take in consideration when modeling the route since the trucks may have idle times waiting on trolleys to be loaded.

Loaders are spread out around the field, there are 9 loaders in total and will be located on the nodes to be collected each day. The location will be according on how many sub-

districts are in each zone to maximize the load; loading time is taken in consideration as transit times since loaders have a 1 hour batch before trucks will start their route. Every single schedule will be explained in every route model for every zone.

Another consideration is that since there is enough capacity of vehicles and trolley availability the three routes will start at the same time. However since routes 1 and 2 recollect much more cane are priorities in terms of loading so trolleys assigned for route 3 will be the last to be loaded.

The time that a vehicle takes to attach a trolley is not going to be taken in consideration, this time is pretty small, between 30 seconds and 60 seconds so this time does not affect other idle times such as loading times.

Timing and scheduling is different from each shift although both of the shifts are going to follow the same routing models the loading and idle times are going to be different; since the first shift the trucks go into the fields with no trolleys the second shift they will go with the trolleys and as soon they arrive they start loading each one of them and that is an idle time to take in consideration when summarizing the times.

To measure the time of the whole routing there will be 3 times in consideration:

- Transit time: times that take each truck mobilizing from the plant to the fields by shift
- Idle time: time lost having the trucks waiting for any operation; these times are caused by machinery occupancy or others that make trucks wait for any reason.
- Loading time: this is the time that takes to load a trolley but only will affect a truck when the trolley is attached.

By the measure of these times will get a result of how much time is reduced in the whole operation with the propose touting models

Since there are 4 average distances each zone will be divided into area specifying the distance and which area correspond each node

8.4.2. Zone 1 routing

Zone 1 has 6 sub-districts, this means that the model for zone 1 will have for each sub-district 3 nodes with the exception of sub-district 6-3 which will have 4 nodes according to the trolley assignment.

Zone	Sub-districts	Distances (Km)	Number of nodes
1	1-1	8	3
	3-1	8	3
	3-3	28	3
	6-1	8	3
	6-3	28	4
	6-4	28	3

Table 24: Zone 1 sub-districts, distances and number of nodes.

There are 2 areas; area 1: 8 kilometers sub-districts, area 2; 28 kilometers sub-districts

Area	Truck	Distance (Km)	Round trip time
1	Tractor	8	0.4h – 24 min
2	Truck	28	1.4h – 84 min

Table 25: Round trip times per vehicle type and area

For route 1 there will be 9 tractors used for area 1 and 10 trucks for area 2 in the model, the round trip time for the tractors is 48 minutes and for the trucks is 84 minutes. Trolley configuration is 3 transmilenio trolleys and 2 milenio trolleys to maximize capacity per vehicle.

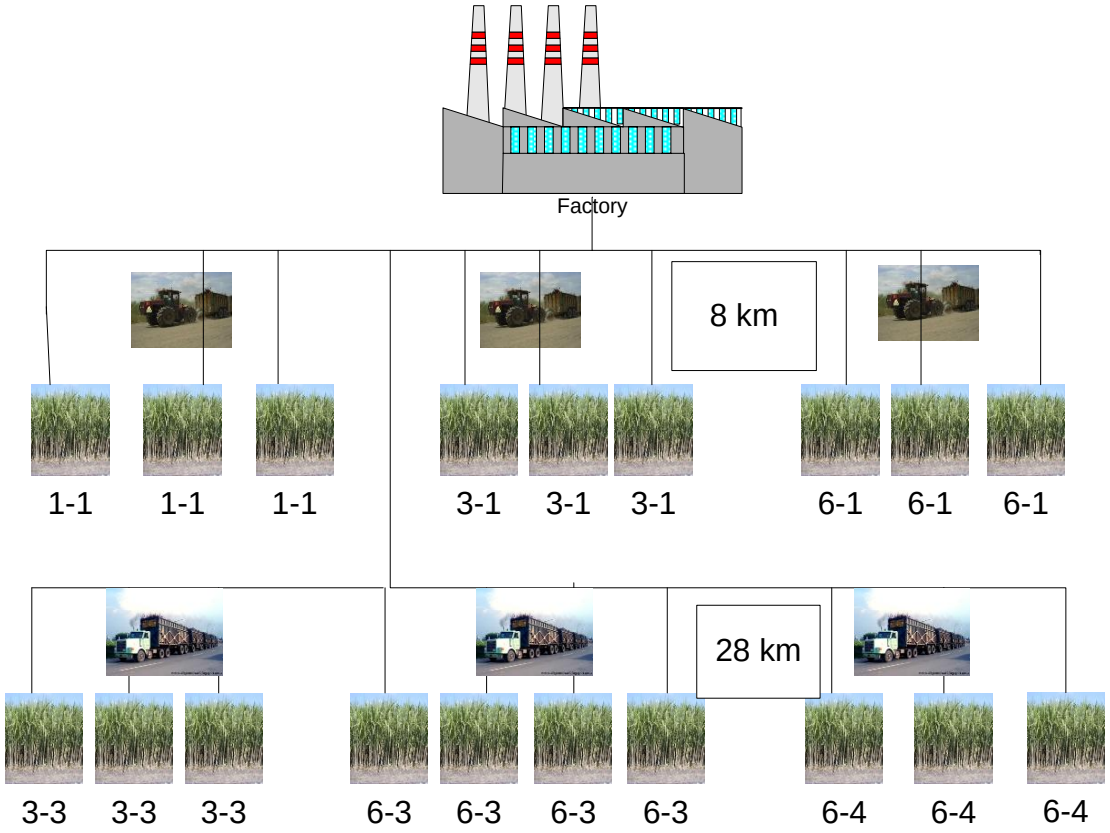


Figure 19: Route 1 configuration for zone 1

For route 2 there will be 4 tractors and 4 trucks and will attach 5 volteo trolleys each one.

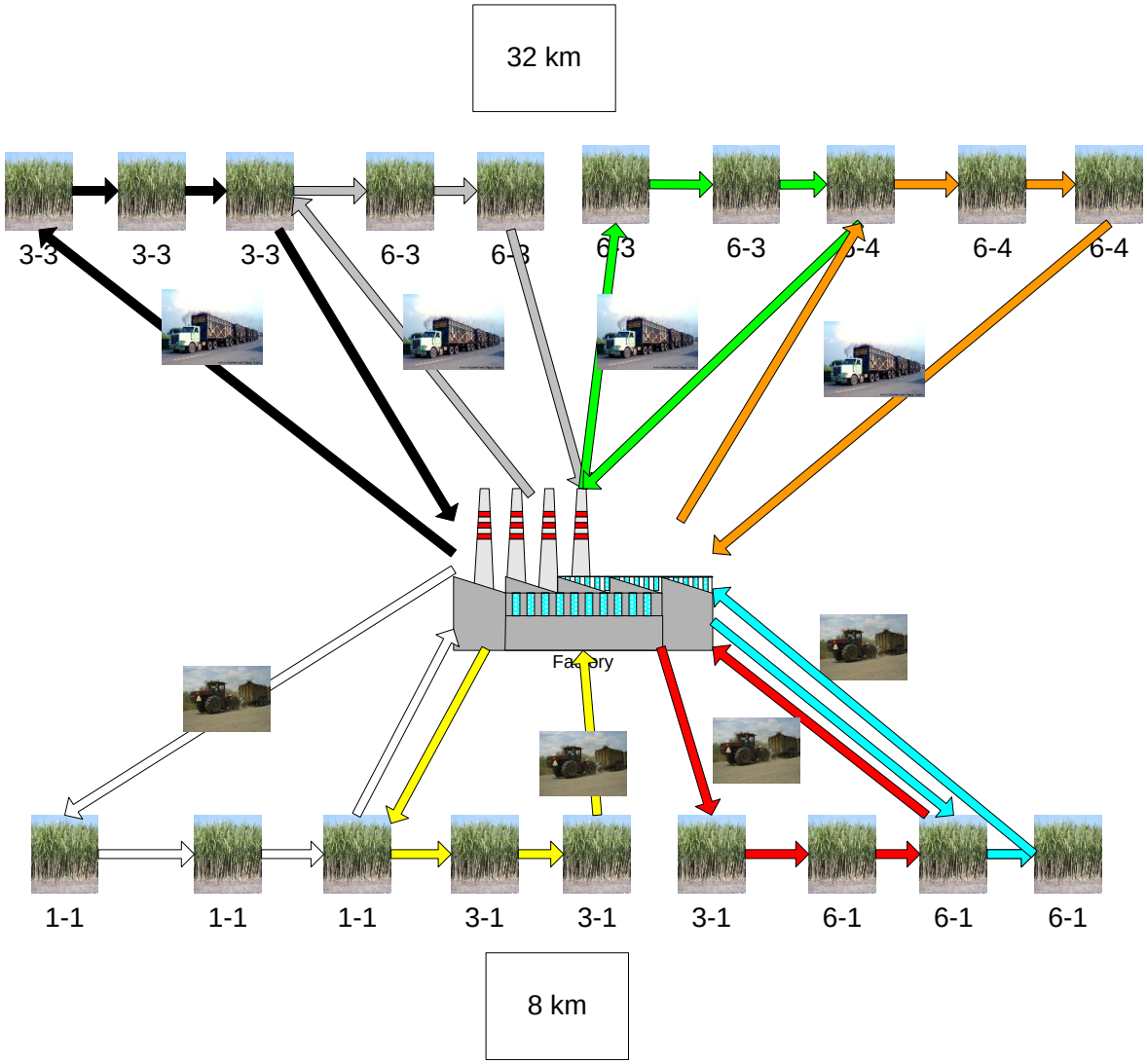


Figure 20: Route 2 configuration for zone 1

The utilization of trucks until now has been 14 trucks and 13 tractors which leave 1 truck and 7 tractors to be used in route model 3. Since there is only 1 truck left this truck will pull 4 transmilenio and one milenio to recollect cane from area 2 which are 10 fields with 88 tons. Area 1 will use one tractor with trolley configuration of 3 transmilenio, 1 milenio and 1 volteo with a total capacity of 73.4 tons which can recollect from 8 of the 9 left, and the last tractor will pull the last volteo to recollect the cane left from the last hectare on the area.

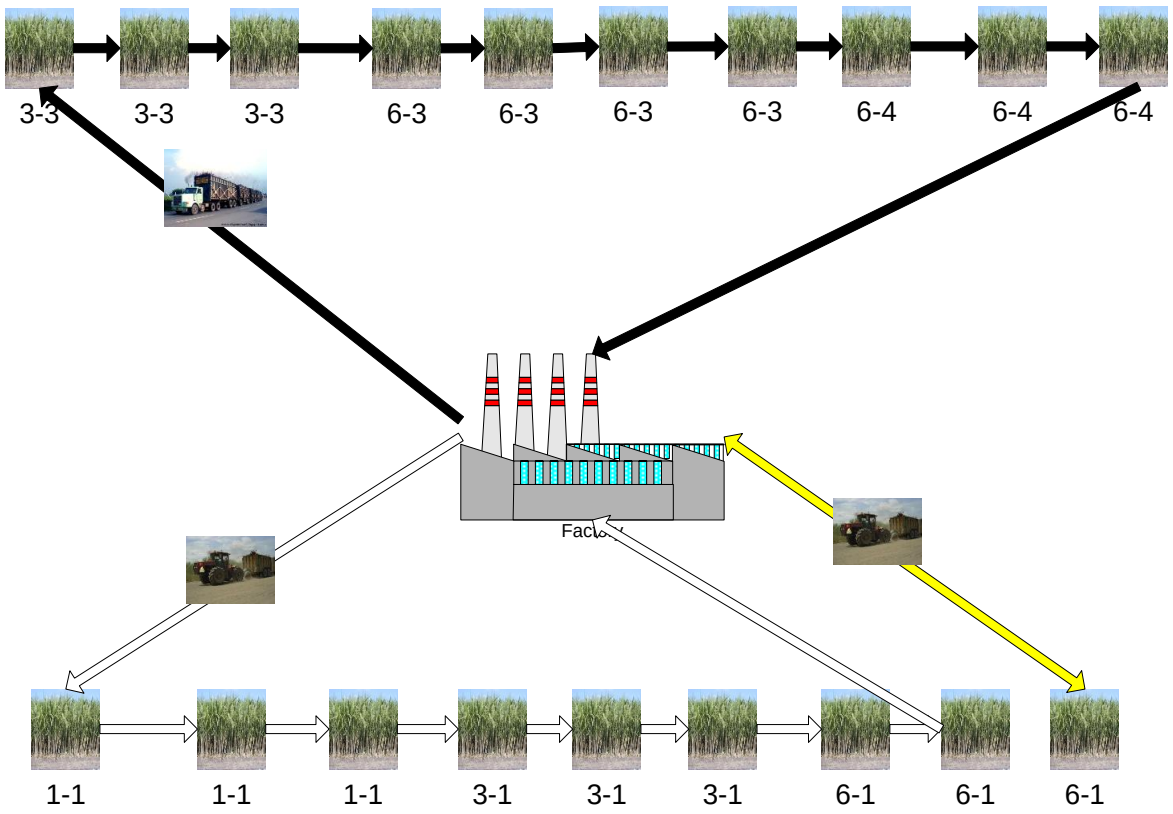


Figure 21: Route 3 configuration for zone 1

8.4.2.1 Timing, Loading and Scheduling for Zone 1

Here it considers transit times, distances from the plant to the field and average speed of the trucks. There is the need to analyze each shift separately since the procedures change for each shift. Loaders are distributed; 5 in area 1 and 4 in area 2.

8.4.2.1.1. First Shift

As the model proposes the first shift will start all the trucks departing at the same time from plant with no trolleys attached, there is a need to make a specific analysis on each route.

8..4.2.1.1.1 Routes Analysis

Loaders will start working at 7:00 a.m. they have 1 hour batch until the trucks arrive. It takes 45 minutes to complete all the trolleys in a node. In area 1 (8 km) the transit time for the tractor is 24 minutes; area 2(28 km) transit time is 42 minutes.

Area 1

There are 9 nodes and takes 2 shifts of loaders to finish the load for a complete node. In 45 minutes 5 nodes will be complete and 4 nodes to go. With 5 loaders the last 4 nodes will take 36 minutes to be completed with a total time for loading the 9 nodes of 81 minutes. Since the vehicle arrives at 86 minutes route 1 and 2 don´t have idle times and route 3 will start loading immediately. Loading time for one of the tractors is only three minutes with one loader; the other tractor total loading time is 36 minutes but with 4 loaders the time is reduced in 9 minutes total, since the first tractor takes only 3 minutes the other loader will help loading the last tractor reducing loading time to a final 4.2 minutes. For calculations route three loading time will be 4.2 minutes for both tractors.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time (min)**
1	42	0	0	**42**
2	42	0	0	**42**
3	42	4.2	0	**48.2**

Table 26: Area 1 times for shift 1

Area 2

For area 3 loaders have 102 minutes in total to finish the load the entire 10 nodes. With this time the 8 nodes will be loaded in 90 minutes and a batch time of 12 minutes to load 2 nodes left. The last 2 nodes will be loaded using the 2 loaders to each node and will take 22.5 minutes to complete the node. Since route 1 is priority the loaders will first load route 1 trolleys in 19.5 minutes and then finish the rest of the node 3 minutes later for route 2 and then load route 3. Route 3 loading time is 42 minutes but with 4 loaders the total loading time will be 10.5 minutes

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time (m)**
1	84	0	7.5	**91.5**
2	84	3	7.5	**94.5**
3	84	10.5	10.5	**105**

Table 26: Area 2 times for shift 1

8.4.2.1.1.2 Summarizing Times of Shift 1

In the first hour of operation area 1 is ready and 900 tons of cane ready to be processed completing 23% of production requirement. By the second hour area 2 will be done bringing another 1000 tons of cane ready for production completing 48% of production requirement

8.4.2.1.2 Second Shift

Shift 2 will begin as soon as the first trucks finish shift 1, the trolley configuration for all the truck will not change since the trolleys are already attached and need to loaded with cane to fulfill production requirement.

8.4.2.1.2.1 Route Analysis

Route 1 tractors will be the first on starting shift 2; they will start loading 24 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start right once they arrive, 5 loaders are available meaning only 5 vehicles at a time can be loaded. The other 4 tractors will have an idle time of 39 minutes. However the loading time for the last 4 tractors will be done using 5 loaders and reducing loading time by 31.2 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	5	48	39	0	**87**
2	4	48	31.2	39	**118.2**

Table 28: Time spent for route 1 in area 1, shift 2

Route 2 trucks will arrive at the same time route 1 and will have an idle time of 70.2 minutes. Route 3 will arrive 4.2 minutes later the idle time is route 1 and 2 loading times minus the loading time from shift 1. Since there are 5 loaders after route 1 is finish route 2 and 3 will start loading process at the same time with the exception of the second tractor of route 3. Route 2 loading time is 15 minutes and route 3 is 36 minutes. When route 2 is finished loading route 3 second tractor will begin loading with one loader, and when it finishes the 5 loaders will be available to route 3 first truck.

Route	**Number of trucks**	**Transit Time (min)**	**Loading Time (Min)**	**Idle Time (min)**	**Total Time**
2	4	48	15	70.2	**133.2**
3	1	48	24.6	66.3	**138.9**
3	1	48	3	81.3	**132.3**

Table 29: Time spent for route 2 and 3 in area 1

Area 2

Route 1 trucks will be the first on starting shift 2; they will start loading 42 minutes after unloading the cargo from the first shift. Loading time for these trucks is 39 minutes and will start right once they arrive, 4 loaders are available meaning only 4 at a time can be loaded. The other 6 trucks will have an idle time of 39 minutes. The last 2 trucks will start loading after the second wave of route 1 is done and the 4 loaders will both trucks reducing loading time by half with a loading time of 19.5 minutes

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	4	84	39	0	**123**
2	4	84	39	39	**162**
3	2	84	19.5	78	**181.5**

Table 30: Time spent for route 1 in area 2, shift 2

Route 2 arrive 10.5 minutes after route and will start loading after route 1 is finish total idle time for route 2 is 97.5 minutes and loading time is 15 minutes. Route 3 arrives 10.5 minutes after route 2 and will be loaded with 4 loaders with a total loading time of 10.5.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time**
2	84	15	87	**186**
3	84	10.5	76.5	**171**

Table 31: Time spent for route 2 and 3 in area 3

8.4.2.1.2.2 Summarizing times of Shift 2

By 5 hours of operation shift two have brought another 1900 tons of cane for a grand total of the day of 3800 tons and 95% of production requirement complete.

8.4.2.1.3 Third Shift

The third shift is to recollect cane from two hectares to complete production requirements. The fields to be recollected from will be the closest one to the factory (area 1) and will be collected by tractors since are the ones which are going to finish first. The recollection on these last two fields will be done using the same routing model and the same trolley assignment.

There will be after 2.15 hours of operations 4 tractors available which are from route 1 and have already finished route 2. For the recollection of the last two hectares there is a need for 2 tractors for route 1, 1 tractor to do route 2 and another to finish route 3. However since the 4 tractors available are from route 1 the configuration of these tractors is the highest and the capacity of these three tractors will be 235.5 tons and the need is to load 200 tons.

Each tractor will carry 66.7 tons of cane and will have an idle time of 6 minutes before loading because route 2 and 3 have not finished loading from shift 2. The configuration for loading the last 3 tractors is 3 transmilenio and 1 milenio trolleys which takes 33 minutes

Total time for shift 3 is 127 minutes which will end the shift with the total of cane recollected almost at the same time as route 3 from area 3 arrives to plant.

8.4.2.1.4 Forth Shift

This last shift is going to be only for trucks from routes 1 and 2, since this shift is only to leave the trolleys empty on the fields for the next day recollection. The last shit will start as soon as the trucks unload the cargo in the plant. Route 3 trucks will finish with the last shift.

The last truck to arrive is one from area 2 route 2 with a total time of 280.5 minutes to finish the routes. And will take an extra 84 minutes to leave the trolleys back into the fields.

8.4.2.2 Total Time and Recollection

The objective is to bring in a total of 4000 tons of cane in least amount of time possible. With the proposed model the total time is 4.675 hours in total

HOUR	TONS	AGGREGATED	PERECENTAGE	SHIFT
1	900	900	23%	1
2	1000	1900	48%	1
3	833.7	2733.7	68%	2
4	393.2	3126.9	78%	2
5	873.1	4000	100%	2 and 3

Table 32: Total time and percentage of accomplishment by shift.

With the propose model instead of 24 hours as the actual situation it will take only 4.675 hours to recollect 4000 tons of cane

8.4.3. Zone 2 Routing

In zone 2 are 7 sub-districts which mean that each sub district will have 3 nodes corresponding to each hectare in the sub-districts, with the exception of sub-districts 3-6 and 5-5 which will have 2 nodes each one. There are three areas; area 1: 8 kilometers sub-districts, area 2: 15 kilometers sub-districts and area 3: 32 kilometers sub-districts.

Zone	Sub-districts	Distances (Km)	Number of Nodes
2	1-1	8	3
	3-6	15	2
	4-1	8	3
	4-4	32	3
	4-6	15	3
	5-5	32	2
	6-4	32	3

Table 33: Zone 2 sub-districts, distances and number of nodes.

For route 1 there are 6 tractors for area 1, 5 tractors for area 2 and 8 trucks for area 3.

Area	Truck	Distance (Km)	Round trip time
1	Tractor	8	0.4h – 24 min
2	Tractor	15	1.5h – 90 min
3	Truck	32	1.6h - 96

Table 34: Round trip times per truck type

Route 1 trolley configuration will be 3 transmilenio and 2 milenio to maximize capacity.

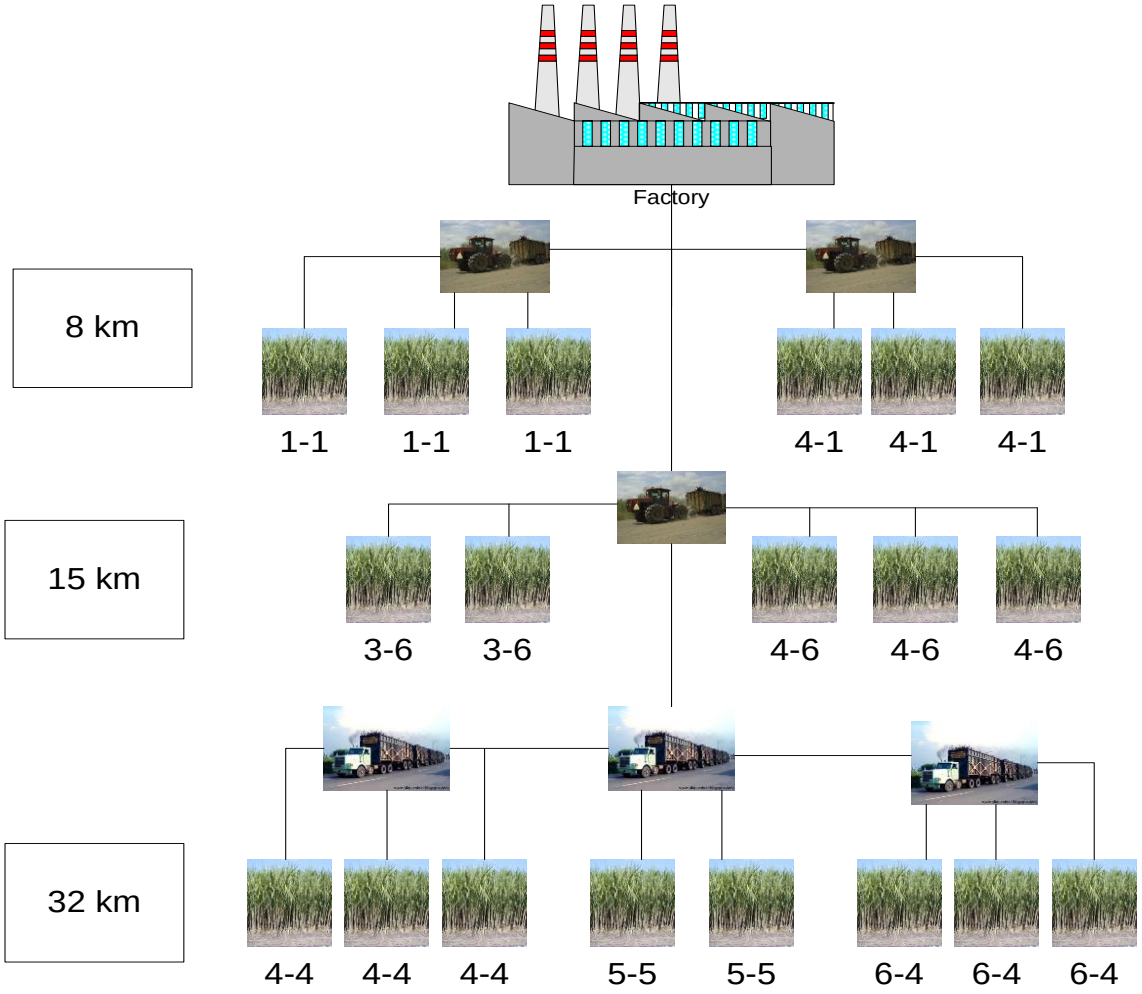


Figure 22: Route 1 configuration for zone 2

For route 2 the trolley configuration for trucks is be to recollect the volteo trolleys left from route 1. There are 3 tractors for area 1 and 1 for area 2, area 3 has 4 trucks. One of the trucks will recollect 1 trolley left on node 6-4 and go to node 4-6 which is 25 km away to recollect another 2 trolleys

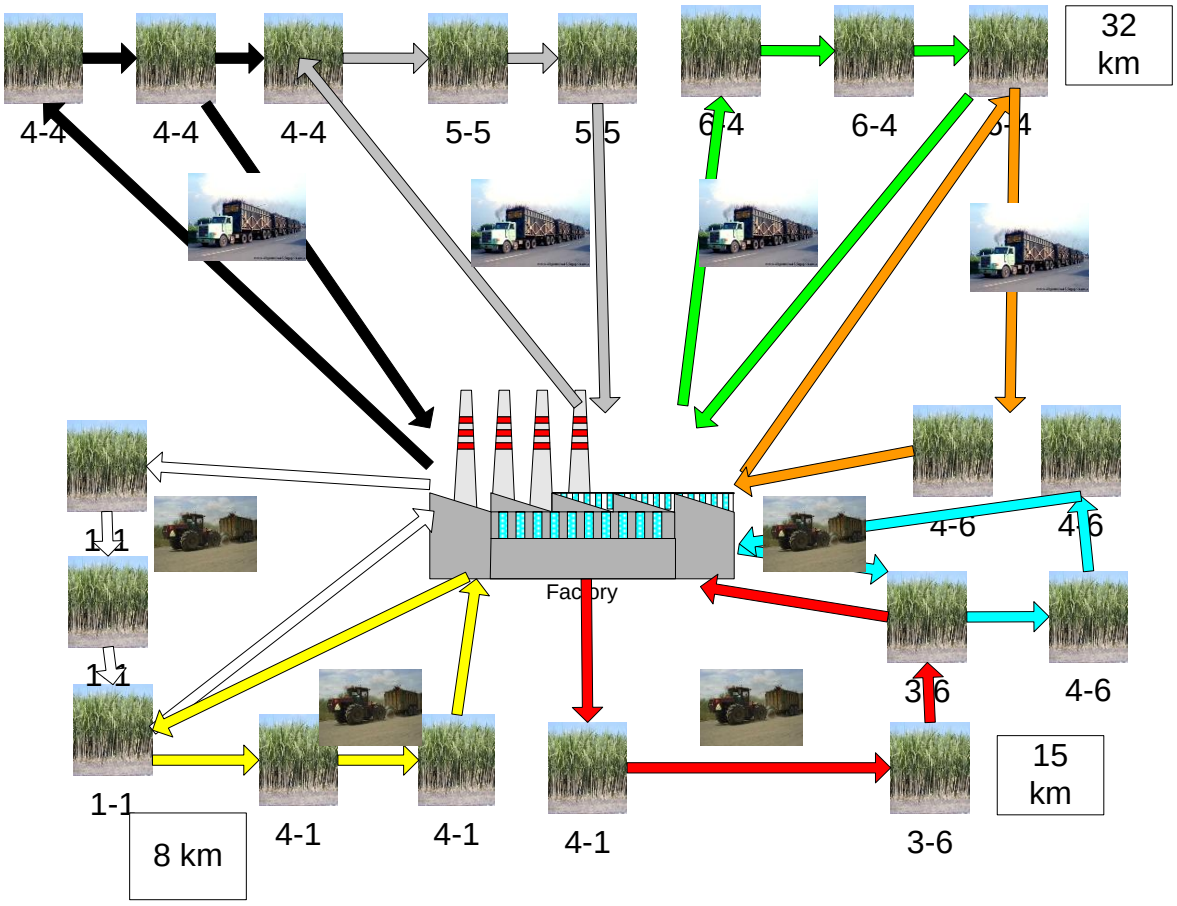


Figure 23: Route 2 configuration for zone 2

Total utilization of vehicles until now has been 15 tractors and 12 trucks, which, leave to be used 3 trucks and 5 tractors to be used in route 3. Area 1 and 2 tractor are going to pull 2 transmilenio and 1 milenio trolley with a loading time of 24 minutes each. For area three a truck will pull 3 transmilenio and 2 volteo with a loading time of 33 minutes.

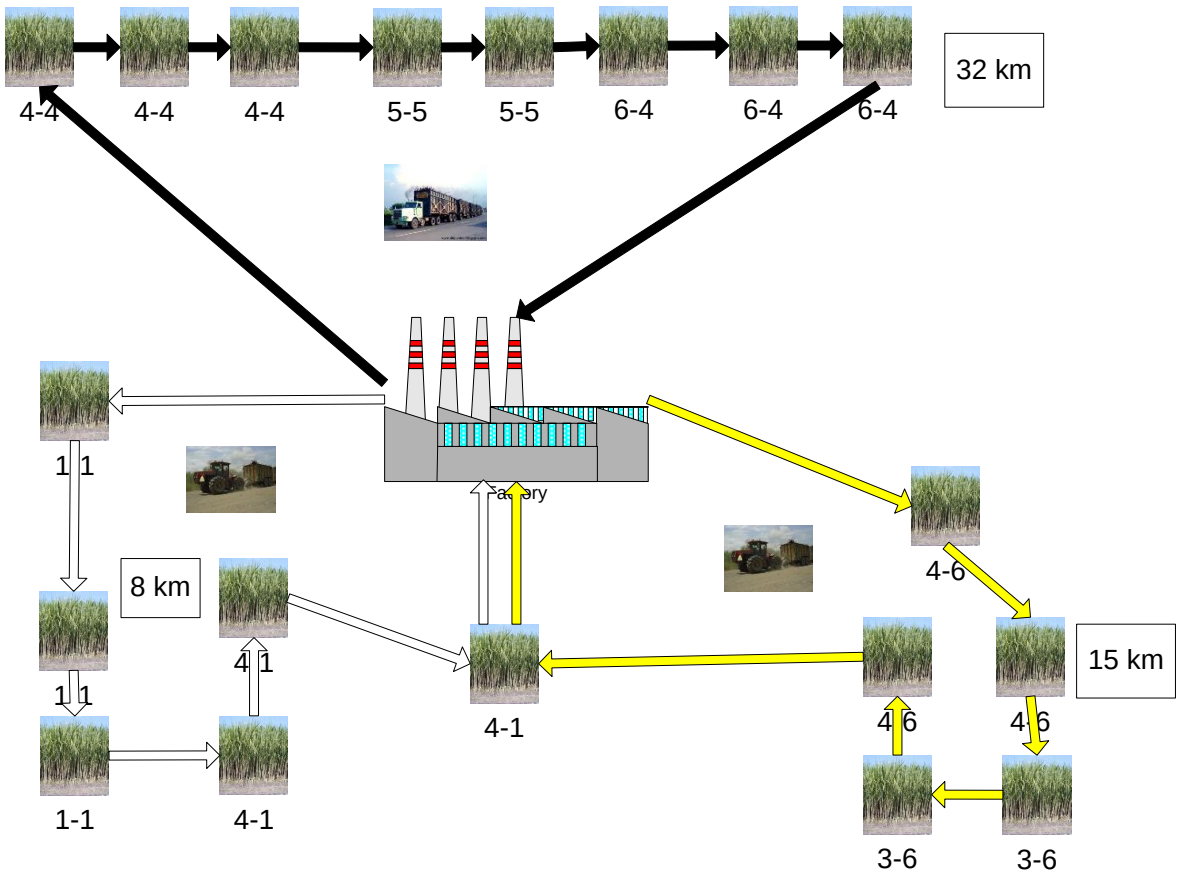


Figure 24: Route 3 configuration for zone 2

8.4.3.1. Timing, Loading and Scheduling

It considers transit times, distances from the plant to the field and average speed of the trucks. There is the need to analyze each shift separately since the procedures changes for each shift. For area 1 there are 3 loaders; for area 2 there are 2 loaders and for area 3 there are 4 loaders.

8.4.3.1.1 First Shift

As the model proposes the first shift will start all the trucks departing at the same time from plant with no trolleys attached, there is a need to make a specific analysis on each route.

8.4.3.1.1.1 Routes Analysis

Loaders will start working at 7:00 a.m. they have 1 hour batch until the trucks arrive. It takes 45 minutes to complete all the trolleys in a node with three loaders in each area. In area 1 (8 km) the transit time for the tractor is 24 minutes; area 2 (15 km) transit time is 45 minutes and area 3 (32 km) transit time is 48 minutes.

Area 1

For area 1 the loaders have a batch time to complete the other 3 nodes of 39 minutes the trucks will arrive and will have an idle time of 6 minutes before finishing the complete node. Route 1 tractors won't have idle time since they are priority but route 2 will have 6 minutes idle time. Route 3 will start loading after route 2 has finished and has an idle time of 6 minutes, loading time for this configuration is 24 minutes but with three loaders the time is 8 minutes.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time (min)**
1	42	0	0	**42**
2	42	6	0	**48**
3	42	8	6	**56**

Table 35: Area 1 times for shift 1

Area 2

For area 2 the loaders have 105 minutes in total to finish the load. With this time 4 nodes will be loaded in 90 minutes. The last node will be done in half (22.5 min) of the time since both loaders will help finishing the node and with the 15 minute batch until the trucks arrive there will be only 7.5 minutes idle time. Route 1 will only wait 1.5 minutes to complete the load, while route 2 tractors will have to wait a 1.5 minute idle time plus 6 minutes loading time.

Route 3 will start loading after route 2 is finished with a total idle time of 7.5, loading time for this route is 12 minutes with 2 loaders.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time**
1	90	1.5	0	**91.5**
2	90	6	1.5	**97.5**
3	90	12	7.5	**109.5**

Table 36: Area 2 times for shift 1

Area 3

4 loaders have a total time of 108 minutes to complete 8 nodes and with that amount of loaders in 90 minutes will finish loading the complete nodes with no loading or idle times for route 1 and 2. Route 3 loading time with 4 loaders is 8.3 minutes.

Route	Transit Time (min)	Loading Time (m)	Idle Time (m)	Total Time
1	96	0	0	**96**
2	96	0	0	**96**
3	96	8.3	0	**104.3**

Table 37: Area 3 times for shift 1

8.4.3.1.1.2 Summarizing Times of Shift 1 Zone 2

The first load of cane arriving to plant will be 48 minutes after departing with the trucks of route 1 area 1, 6 minutes later route 2 will arrive completing 91.2 tons per node recollected with a total of 547.2 tons in the first hour of operations.

After 2 hours of operation tractors from route 3 area 1 will arrive with 97 tons. Also the rest of the trucks in the other routes will arrive to plant and by the end of the second hour of operation the plant will have already 1900 tons of cane representing 48% of the cane needed for production in one day.

8.4.3.1.2 Second Shift

Shift 2 will begin as soon as the first trucks finish shift 1, the trolley configuration for all the truck won´t change since the trolleys are already attached and need to be loaded with cane to fulfill production requirement.

8.4.3.1.3.1 Routes analysis

Area 1

Route 1 tractors will be the first on starting shift 2; they will start loading 24 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start once they arrive, 3 loaders are available meaning only 3 at a time can be loaded. The other 3 trucks will have an idle time of 39 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	3	48	39	0	**87**
2	3	48	39	39	**126**

Table 38: Time spent for route 1 tractor

Route 2 tractors have 15 minutes loading time and can´t start until route 1 is finished this means they have 78 minutes idle time, however since they had 6 minutes idle time from shift 1 they will arrive 6 minutes later with an idle time of 72 minutes. Both tractors will begin loading at the same time and will have a total time of 135 minutes. For route 3 the tractor will arrive 14 minutes later than route 2 and have to wait also until route 1 is finish, it will start loading at the same time as route 2 tractor, loading time for this tractor is 24 minutes, total time for route 3 is 136 minutes.

Route	**Number of tractors**	**Transit Time (min)**	**Loading Time (Min)**	**Idle Time (min)**	**Total Time**
2	2	48	15	72	**135**
3	1	48	24	63.75	**135.75**

Table 39: Time spent for route 2 and 3 in area 1

Area 2

Route 1 tractors will be the first on starting shift 2; they will start loading 45 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start once they arrive, with two loaders available only two trucks at a time can be loaded. The 5 trucks of route 1 will be loaded using both loaders reducing loading time by half.

Route 2 tractors will arrive 7.5 minute later and will have route 1 idle time, both tractors will start loading at the same time loading time for this tractor is 15 minutes.

Route	**Number of tractors**	**Transit Time (min)**	**Loading Time (Min)**	**Idle Time (min)**	**Total Time**
1	2	45	39	0	**84**
1	2	45	39	39	**123**
1	1	45	19.5	78	**142.5**
2	2	45	15	136.5	**199.5**
3	1	45	12	151.5	**211.5**

Table 40: Time spent for routes in area 2

Area 3

Trucks will arrive 48 minutes after they finish the first shift. With 4 loaders takes 39 minutes the loading meaning that the other 4 trucks will have an idle time of 39 minutes. Route 2 will start loading after route 1 is finished and will load all at the same time. Route 3 will start loading after route 2 is finished, the load will be done with the 4 loaders at the same time to complete loading time of 8.3 minutes, also route 3 will arrive 8.3 minutes later than the other two routes and this will reduce idle time for the route.

Route	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	Total Time
1	4	96	39	0	**135**
1	4	96	39	39	**174**
2	4	96	15	78	**189**
3	1	96	8.3	84.7	**189**

Table 41: Time spent for area 3 trucks

8.4.3.1.2.2 Summarizing Times of Shift 2 Zone 2

The total cargo of shift 2 is another 1900 tons of cane, finishing the second shift the plant after 6 hours of operation already have for production 95% of the total raw material needed for the day.

8.4.3.1.3 Third Shift

The third shift is to recollect cane from two hectares to complete production requirements. The fields to be recollected from will be the closest ones to the factory (area 1) and will be collected by tractors since are the ones which are going to finish first. The recollection on these last two fields will be done using the same routing model and the same trolley assignment.

There will be 3 tractors available after three hours of operations which are from route 1 and have already finished route 2. For the recollection of the last two hectares there is a need for 2 tractors for route 1, 1 tractor to do route 2 and another to finish route 3. However since the 3 tractors available are from route 1 the configuration of these tractors is the highest and the capacity of this three tractors will be 235.5 tons and the need is to load 200 tons

Each tractor will carry 66.7 tons of cane and will have an idle time of 25 minutes before loading because routes 2 and 3 haven´t finished loading from shift 2. The configuration for loading the last 3 tractors is 3 transmilenio and 1 milenio trolleys which takes 33 minutes.

The third shift will end before routes 2 and 3 from area 3 arrive to plant.

8.4.3.1.4 Forth Shift

This last shift is going to be only for trucks from routes 1 and 2, since this shift is only to leave the empty trolleys on the fields for the next day´s recollection. The last shit will start as soon as the trucks unload the cargo in the plant. Route 3 trucks will finish with the last shift

The last truck to arrive is one from area 3 route 2 and it´s total time is 381 to finish the routes. And will take an extra 96 minutes to leave the trolleys back into the fields.

8.4.3.2 Total Time and Recollection

For this zone the proposed model recollects all the cane needed in 6.35 hours of operations and there is still time to prepare the field for the next day

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HOUR	TONS	AGGREGATED	PERECENTAGE	SHIFT
1	547.2	547.2	14%	1
2	1352.8	1900	48%	1
3	471	2371	59%	2
4	614.9	2985.9	75%	2
5	829.82	3815.72	95%	2 and 3
6	184.3	4000	100%	2

Table 42: Total time and percentage of accomplishment by shift for zone 2.

8.4.4. Zone 3 Routing

In zone 3 there are 6 sub districts, this means all of the nodes will have 3 sub-districts with the exception of 6-1 which will have 1 additional node, there will be three areas; area 1: 8 kilometers sub-districts, area 2: 15 kilometers sub-districts and area 3: 32 kilometers sub-districts

Zone	Sub-districts	Distances (Km)	Number of Nodes
3	1-1	8	3

	1-6	15	3
	5-5	32	3
	5-6	15	3
	6-1	8	4
	6-5	32	3

Table 43: Zone 3 sub-districts, distances and number of nodes.

Area	**Truck**	**Distance (Km)**	**Round trip time**
1	Tractor	8	0.4h – 24 min
2	Tractor	15	1.5h – 90 min
3	Truck	32	1.6h - 96

Table 44: Round trip times per truck type

Route 1 will have 13 tractors and 6 trucks, the trolley configuration will be 3 transmilenio and 2 milenio to maximize capacity

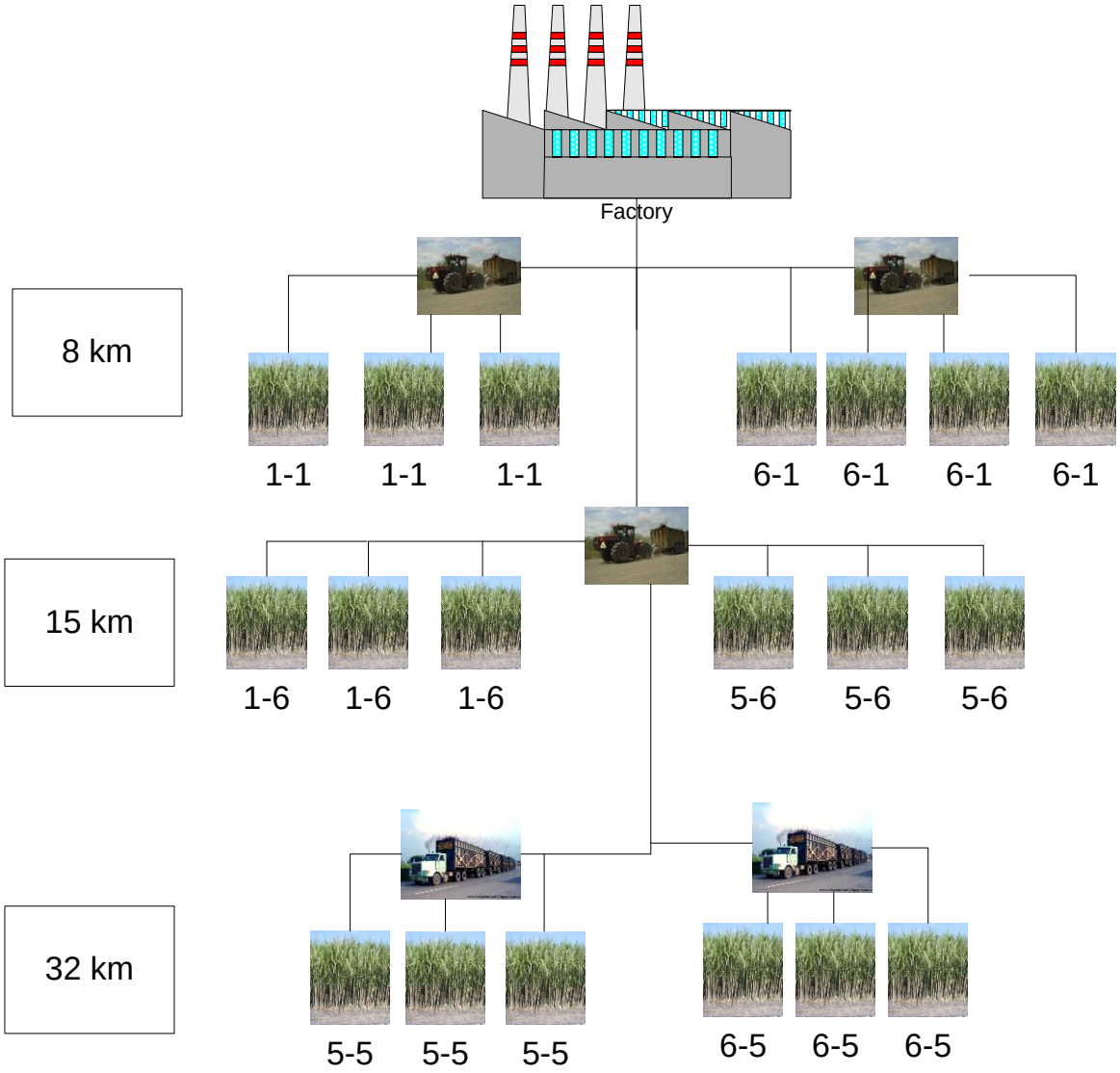

Figure 25: route 1 configuration zone 3

For route 2 the trucks must go in to each node and gather the two trolleys left from the first route, the configuration for this route will be with volteo trolleys. There will be 5 tractors to go to area 1 and 2; two tractors will bring 4 trolleys of each are.

There will be 3 trucks to go to area 3. One of the trucks will collect from one node and go to area 2 where is going to finish its capacity.

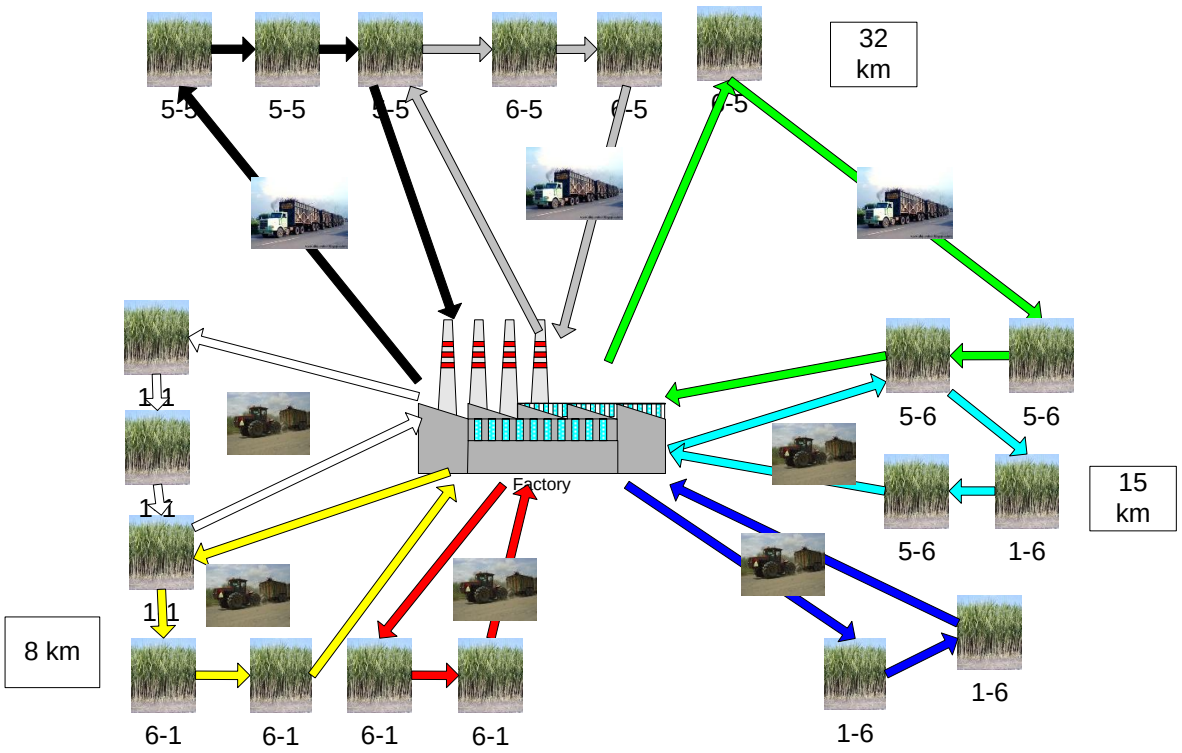

Figure 26: Route 2 configuration zone 3

The total truck utilization until now has being 18 tractors and 9 trucks for a total of 27 vehicles, this leaves 2 tractors and 6 trucks available for route 3.

The trolley configuration for route 3 will be:

- Area 1: 1 volteo and 3 transmilenio
- Area 2: 1 milenio and 2 transmilenio
- Area 3: 1 volteo, 1 milenio and 2 transmilenio

The loading time for each area is:

- Area 1: 30 minutes
- Area 2: 24 minutes
- Area 3: 27 minutes

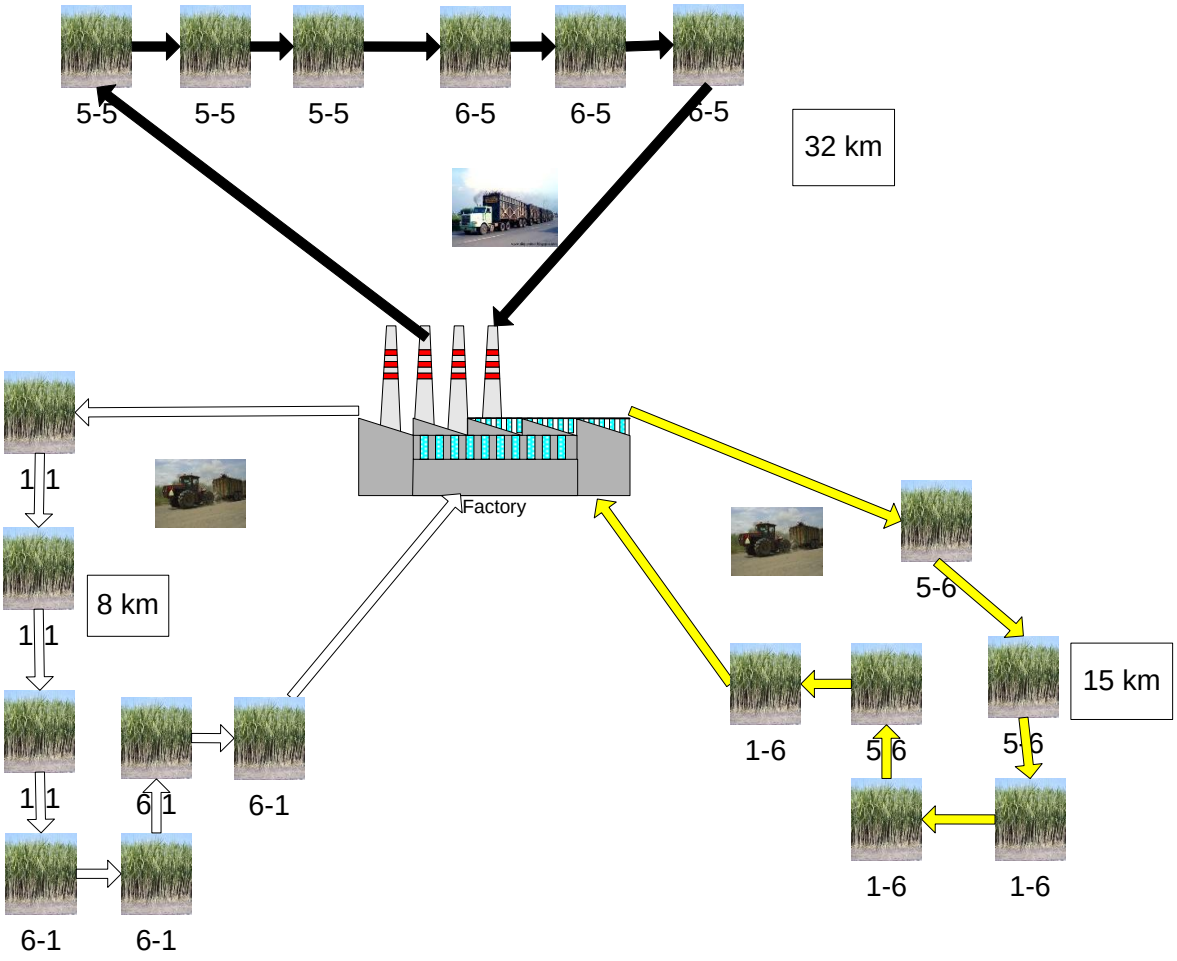

Figure 27: Route 3 configuration for zone 3

8.4.4.1 Timing, Loading and Scheduling

It considers transit times, distances from the plant to the field and average speed of the trucks. There is the need to analyze each shift separately since the procedures change for each shift. 3 Loaders will be distributed in each area.

8.4.4.1.1 First Shift

As the model proposes the first shift will start all the trucks departing at the same time from plant with no trolleys attached, there is a need to make a specific analysis on each route.

8.4.4.1.1.1 Routes Analysis

Loaders will start working at 7:00 a.m. they have 1 hour batch until the trucks arrive. It takes 45 minutes to complete all the trolleys in a node with three loaders in each area. In area 1 (8 km) the transit time for the tractor is 24 minutes; area 2 (15 km) transit time is 45 minutes and area 3 (32 km) transit time is 48 minutes.

Area 1

For area 1 the loaders have a batch time to complete the other 4 nodes of 39 minutes, since the objective is to maximize capacity and time, the loaders will first load route 1 configuration; by doing this in 78 minutes 6 out of 7 nodes will be loaded and a batch time of 6 minutes. The 3 loaders must together load the final node for route 1 and the time will be reduced by 13 minutes loading which route 1 tractors will have a 7 minute idle time.

Route 2 tractors will have and idle time of 7 minutes and a loading time of 15 minutes. Route 3 will have 7 minutes idle time from route 1 plus the loading time of 15 minutes for route 2 for a total idle time of 22 minutes. The loading time for route 3 will be done with the three loaders and will take 10 minutes.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time (min)**
1	42	0	7	**55**
2	42	15	7	**70**
3	42	10	22	**80**

Table 45: Area 1 times for shift 1

Area 2

For area 2 the loaders have 105 minutes in total to finish the load. With this time the 6 nodes will be loaded in 90 minutes. When routes 1 and 2 arrive the trolleys can be attached and depart to plant.

Route 3 must be loaded immediately and will be loaded with three loaders at the same time. Trolley configuration for this route gives a loading time of 24 minutes, but with the three loaders it will finish by 8 minutes total.

Route	Transit Time (min)	Loading Time (m)	Idle Time (m)	Total Time
1	90	0	0	**90**
2	90	0	0	**90**
3	90	8	0	**98**

Table 46: Area 2 times for shift 1

Area 3

For area 3 the loaders have 108 minutes in total to finish the load. With this time the 6 nodes will be loaded in 90 minutes. When routes 1 and 2 arrive the trolleys can be attached and depart to plant.

Route 3 must be loaded immediately and will be loaded with three loaders at the same time. Trolley configuration for this trolley gives a loading time of 27 minutes, but with three loaders it will finish by 9 minutes total

Route	Transit Time (min)	Loading Time (m)	Idle Time (m)	Total Time
1	96	0	0	**96**
2	96	0	0	**96**
3	96	9	0	**105**

Table 47: Area 3 times for shift 1

8.4.4.1.1.2 Summarizing Time of Shift 1 Zone 3

The first arrival will be route 1 from area 1 in 55 minutes with a total load of 549.5 tons. By the next hour the rest of shift will arrive ending with route 3 in area 3 that will arrive 105 minutes bringing an extra 1350.5 completing in less than 2 hours 1900 tons of cane which represent 48% of the total cane needed for the day.

8.4.4.1.2 Second Shift

Shift 2 will begin as soon as the first trucks finish shift 1, the trolley configuration for all the truck won´t change since the trolleys are already attached and need to loaded with cane to fulfill production requirement.

8.4.4.1.2.1 Routes Analysis

Area 1

Route 1 tractors will be the first on starting shift 2; they will start loading 24 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start once they arrive, 3 loaders are available meaning only 3 at a time can be loaded. The other 4 trucks will have an idle time of 39 minutes. There is going to be one truck that will have another 39 minutes idle time but it will get loaded with 3 loaders at the same time with a loading time of 13 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	3	48	39	0	**87**
2	3	48	39	39	**126**
3	1	48	13	78	**139**

Table 48: Time spent for route 1 in area 1

Route 2 tractors will arrive 22 minutes later than route 1 and their idle time is going to the loading time of the three waves of route 1, 76 minutes. There will be loading of each one with one loader and loading time takes 15 minutes per truck.

ROUTE 2					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	3	48	15	69	**132**

Table 49: Time spent for route 2 in area 1

Route 3 tractor will arrive 32 minutes after route 1 and will have to wait until route 2 is done. Total idle time for route 3 is 74 minutes. Load will be done with three loaders at the same time reducing loading time

ROUTE 3					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	1	48	10	74	**132**

Table 50: Time spent for route 3 in area 1

Area 2

Route 1 tractors will be the first on starting shift 2; they will start loading 45 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start once they arrive, 3 loaders are available meaning only 3 at a time can be loaded. The other 3 trucks will have an idle time of 39 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	3	90	39	0	**129**
2	3	90	39	39	**168**

Table 51: Time spent for route 1 in area 2

Route 2 two tractors will start loading after route 1 is finish the same as route 3. The difference for route 3 is that since it had loading time in shift 1 idle time is lower, also since route 2 takes only 15 minutes to load 3 loaders will finish loading route 3 with a total loading time of 20 minutes.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time**
2	90	15	78	**183**
3	90	20	70	**200**

Table 52: Time spent for route 2 and 3 in area 2

Area 3

Route 1 trucks will be the first on starting shift 2; they will start loading 48 minutes after unloading the cargo from the first shift. Loading time for these trucks is 39 minutes and will start right once they arrive, 3 loaders are available meaning only 3 at a time can be loaded. The other 3 trucks will have an idle time of 39 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	3	96	39	0	**135**
2	3	96	39	39	**174**

Table 53: Time spent for route 1 in area 3

Route 2 two trucks will start loading after route 1 is finish the same as route 3. The difference for route 3 is that since it had loading time in shift 1 idle time is lower, also since route 2 takes only 15 minutes to load 3 loaders will finish loading route 3 with a total loading time of 16 minutes.

Route	Transit Time (min)	Loading Time (m)	Idle Time (m)	Total Time
2	96	15	78	**189**
3	96	16	69	**181**

Table 54: Time spent for route 2 and 3 in area 3

8.4.4.1.2.2. Summarizing Time of Shift 2 Zone 3

By the end of shift 2 there will be 3800 tons of cane in plant ready for production in over 5 hour of operations. The last truck to arrive will be route 3 from area 3 in 286 minutes or 4.8 hours of operations.

The cane represents 95% of the total production order.

8.4.4.1.3 Third Shift

The third shift is to recollect cane from two hectares to complete production requirements. The fields to be recollected from will be the closest ones to the factory (area 1) and will be collected by tractors since they are the ones which are going to finish first. The recollection on these last two fields will be done using the same routing model and the same trolley assignment.

There will be 3 tractors available after 2.8 hours of operations which are from route 1 and have already finished route 2. For the recollection of the last two hectares there is a need for 2 tractors for route 1, 1 tractor to do route 2 and another to finish route 3. However since the 3 tractors available are from route 1 the configuration of these tractors is the highest and the capacity of this three tractors will be 235.5 tons and the need is to load 200 tons.

Each tractor will carry 66.7 tons of cane and will have an idle time of 46 minutes before loading because route 2 and 3 haven´t finished loading from shift 2. The configuration for loading the last 3 tractors is 3 transmilenio and 1 milenio trolleys which takes 33 minutes.

Total time for shift 3 is 127 minutes which will end the shift with the total of cane recollected almost at the same time as route 3 from area 3 arrives to plant.

8.4.4.1.4 Forth Shift

This last shift is going to be only for trucks from routes 1 and 2, since this shift is only to leave the empty trolleys on the fields for the next day recollection. The last shift will start as soon as the trucks unload the cargo in the plant. Route 3 trucks will finish with the last shift

The last truck to arrive is one from area 3 route 3 with a total time of 286 minutes to finish the routes. And will take an extra 96 minutes to leave the trolleys back into the fields.

8.4.4.2 Total Time and Recollection

For this zone the proposed model recollects all the cane needed in 4.8 hours of operations and there is still time to prepare the field for the next day.

HOUR	TONS	AGGREGATED	PERECENTAGE	SHIFT
1	549.5	549.5	14%	1
2	1350.5	1900	48%	1
3	235.5	2135.5	53%	2
4	942.3	3077.8	77%	2 and 3
5	922.2	4000	100%	2

Table 55: Total time and percentage of accomplishment by shift for zone 3

8.4.5. Zone 4 Routing

Zone 4 has 7 sub-districts, this means that all of the sub-districts will have 3 nodes with the exception of sub-districts 1-1 and 2-6. There are three areas; area 1: 8 kilometers sub-districts, area 2: 15 kilometers sub-districts and area 3: 28 kilometers sub-districts

Zone	Sub-districts	Distances (Km)	Number of Nodes
4	1-1	8	2
	2-2	28	3
	2-6	15	2
	3-1	8	3
	6-1	8	3
	6-2	28	3
	6-3	28	3

Table 56: Zone 4 sub-districts, distances and number of nodes

Area	Truck	Distance (Km)	Round trip time
1	Tractor	8	0.4h – 24 min
2	Tractor	15	1.5h – 90 min
3	Truck	28	1.4h – 84 min

Table 57: Round trip times per vehicle type and area

Route 1 will have 10 tractors and 9 trucks. The trolley configurations is 3 transmilenio and 2 milenio trolleys to maximize capacity per vehicle

For route 2 the trucks must go in to each node and gather the two trolleys left from the first route, the configuration for this route will be with volteo trolleys. There will be 3 tractors for area 1 and one for area 2, the last trolley to collect from the tractor of area 2 is on area 1 so after the tractor finishes it will go to area 1 and gather the last trolley.

There will be 4 trucks in total to collect the trolleys from area 3; the last truck will only pull 3 trolleys since there are no more left.

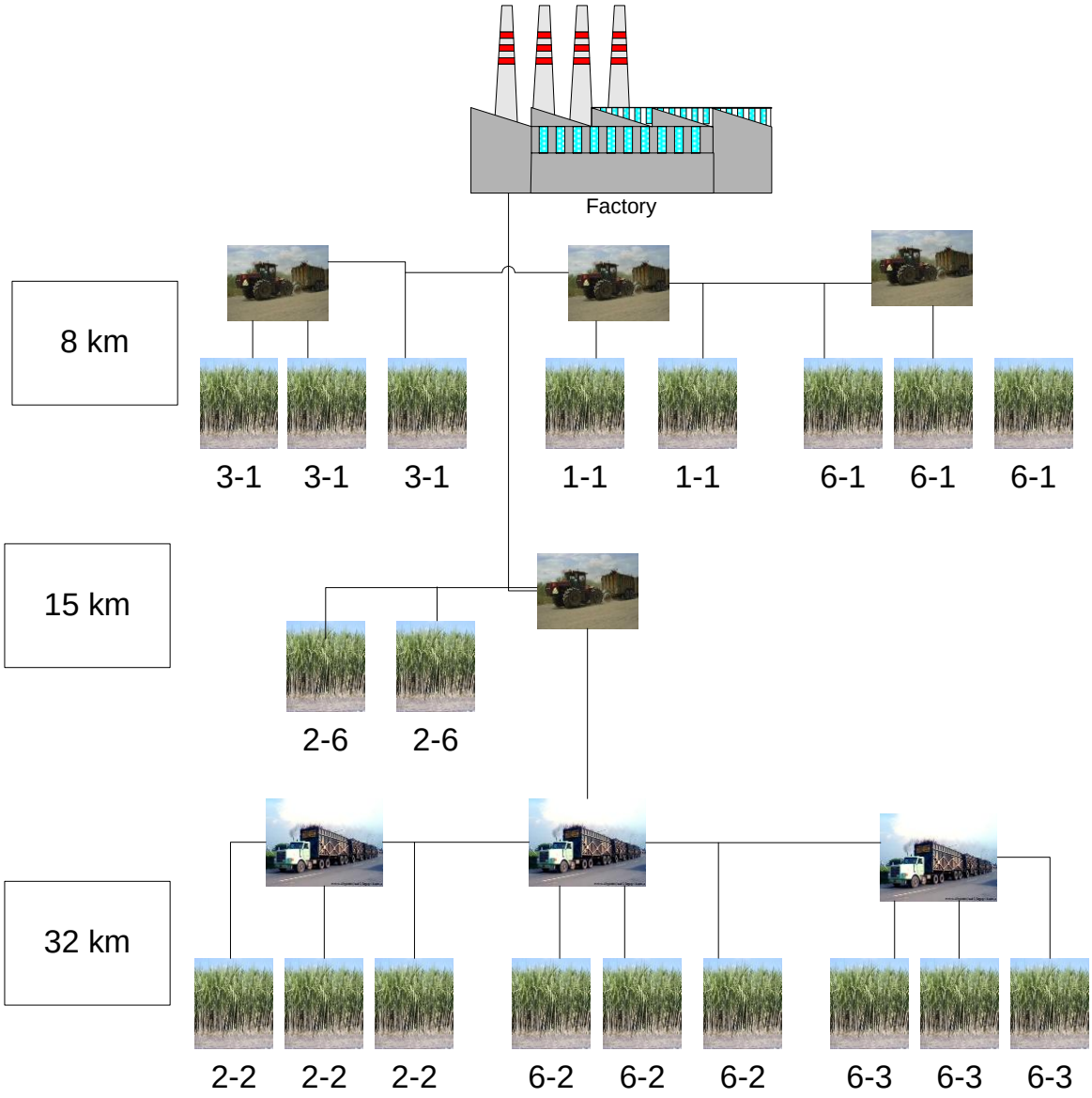

Figure 28: Route 1 for zone 4

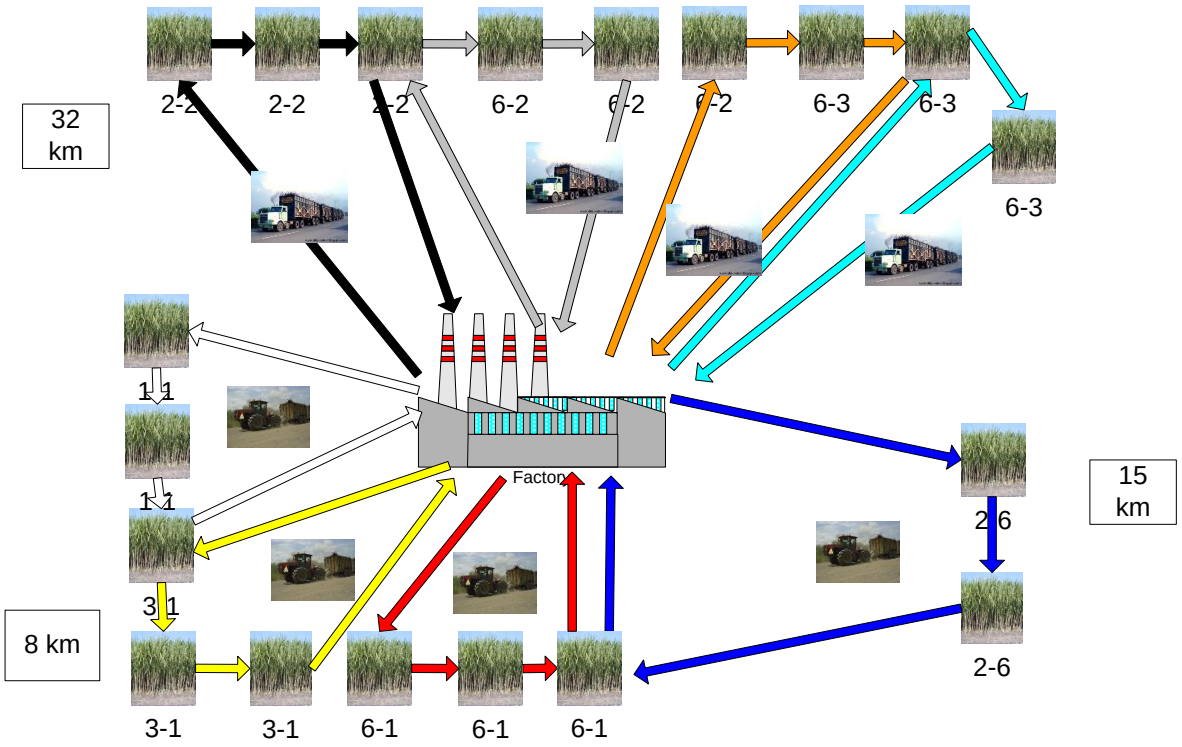

Figure 29: Route 2 for zone 4

Total truck utilization until now has being 14 tractors and 13 trucks for a total of 27 vehicles, this leaves 6 tractors and 2 trucks available for route 3 configuration.

The trolley configuration for route 3 will be:

- Area 1: 1 milenio and 3 transmilenio
- Area 2: 1 milenio and 1 volteo
- Area 3: 1 volteo and 4 transmilenio

The loading time for each area is:

- Area 1: 33 minutes
- Area 2: 9 minutes
- Area 3: 39 minutes

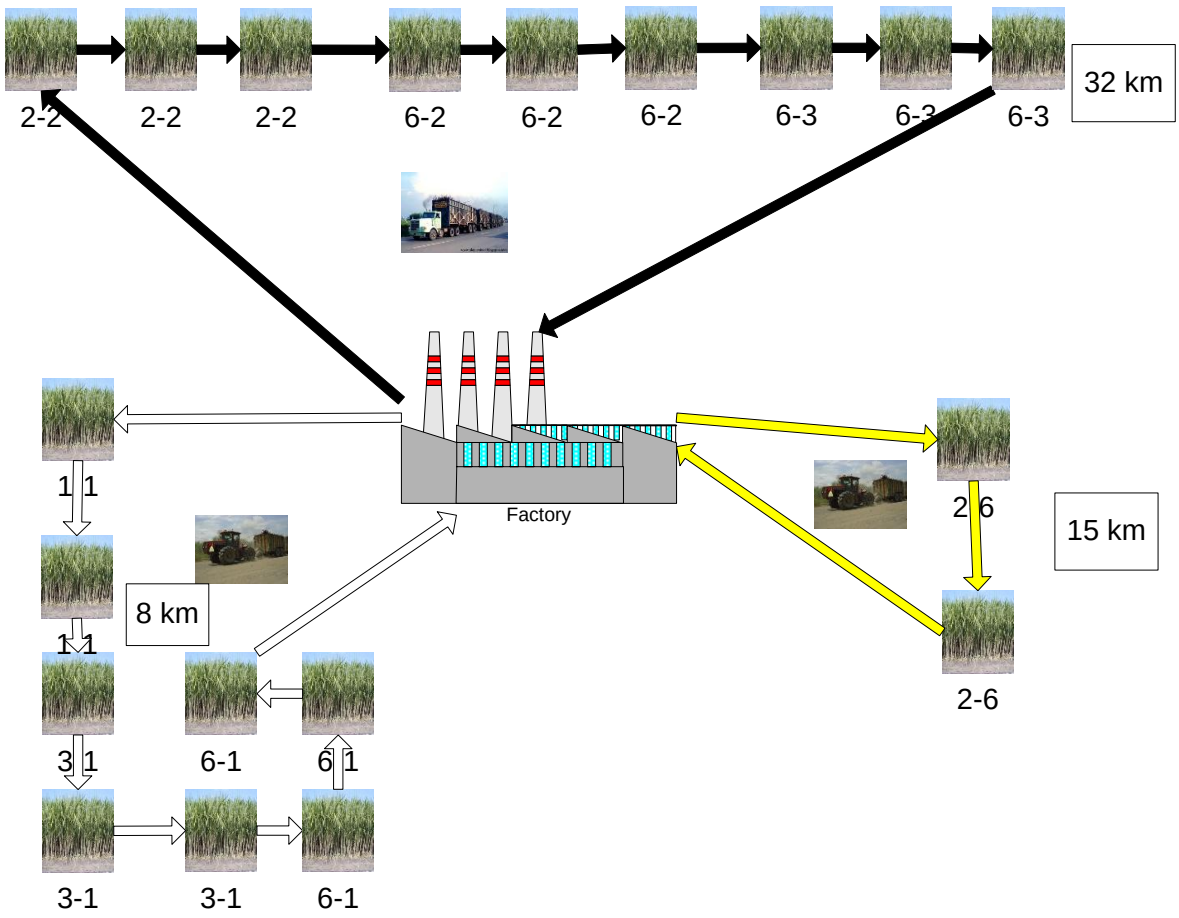

Figure 30: Route 3 for zone 4

8.4.5.1 Timing, Loading and Scheduling

It considers transit times, distances from the plant to the field and average speed of the trucks. There is the need to analyze each shift separately since the procedures change for each shift. Loaders will be distributed 4 for area 1 and 3 and 1 loader for area 2.

8.4.5.1.1 First Shift

As the model proposes the first shift will start with all the trucks departing at the same time from plant with no trolleys attached, there is a need to make a specific analysis on each route.

8.4.5.1.2.1 Routes Analysis

Loaders will start working at 7:00 a.m. they have 1 hour batch until the trucks arrive. It takes 45 minutes to complete all the trolleys in a node with three loaders in each area. In area 1 (8 km) the transit time for the tractor is 24 minutes; area 2 (15 km) transit time is 45 minutes and area 3 (28 km) transit time is 42 minutes.

Area 1

To complete the load for the 8 nodes the 4 loaders need 90 minutes, the tractors will arrive 84 minutes after the loaders start operations, this will give an idle time of 6 minutes. Since 6 minutes is the time that takes to load a milenio route 1 will be completed in 84 minutes and route 2 will have 6 minutes idle time.

Route 3 will have 6 minutes idle time and loading time of 33 minutes. Since all of the loaders are available the loading time for route 3 is going to be only 8.25 minutes.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time (min)**
1	42	0	0	**42**
2	42	0	6	**48**
3	42	8.25	6	**56.25**

Table 58: Area 1 times for shift 1

Area 2

For this area the loader has 105 minutes to load 2 nodes before tractors arrive. Each node takes 45 minutes so for the two nodes it will be 90 minutes. Route 1 and 2 will be complete by the time the tractors arrive.

Route 3 must be loaded immediately; the trolley configuration for this route gives a loading time of 9 minutes

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time**
1	90	0	0	**90**
2	90	0	0	**90**
3	90	9	0	**99**

Table 59: Area 2 times for shift 1

Area 3

For area 3 loaders have 102 minutes in total to finish the load for the entire nodes. With this time the 8 nodes will be loaded in 90 minutes and a batch time of 12 minutes to load the third node. The last node will be loaded using the 4 loaders and takes 11.25 minutes to complete the node which is enough time until the trucks arrive.

Route 3 must be loaded immediately and will be loaded with 4 loaders at the same time. Trolley configuration for this trolley gives a loading time of 39 minutes, but with 4 loaders it will be finished in 9.75 minutes total.

Route	Transit Time (min)	Loading Time (m)	Idle Time (m)	Total Time
1	84	0	0	**84**
2	84	0	0	**84**
3	84	9.75	0	**93.75**

Table 60: Area 3 times for shift 1

8.4.5.1.1.2 Summarizing Time of Shift 1 Zone 4

By the first hour of operation area 1 will be ready in plant with tons of cane ready to be process. In the second hour area 2 and 3 will be ready to process bringing another 1000 tons of cane. This amount of cane represents 45% of the total production order.

8.4.5.1.2 Second Shift

Shift 2 will begin as soon as the first trucks finish shift 1, the trolley configuration for all the trucks won´t change since the trolleys are already attached and need to loaded with cane to fulfill production requirements.

8.4.5.1.2.1 Routes Analysis

Area 1

Route 1 tractors will be the first on starting shift 2; they will start loading 24 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start once they arrive, 4 loaders are available meaning only 4 at a time can be loaded. The other 4 trucks will have an idle time of 39 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	4	48	39	0	**87**
2	4	48	39	39	**126**

Table 61: Time spent for route 1 in area 1, shift 2

Route 2 trucks will arrive 6 minutes later than route 1 since they had 6 minute idle time before. Route 3 will arrive 14.25 minutes later and will also have the same idle time as route 2 but starting at the arriving time. Since there are 4 loaders after route 1 is finished route 2 and 3 will start loading process at the same time. Route 2 loading time is 15 minutes so after route 2 is finished the loaders will load route 3 altogether reducing the total loading time from 33 minutes to 19.5 minutes in total.

Route	Number of tractors	Transit Time (min)	Loading Time (Min)	Idle Time (min)	Total Time
2	3	48	15	72	**135**
3	1	48	19.5	63.75	**131.25**

Table 62: Time spent for route 2 and 3 in area 1

Area 2

Route 1 tractors will be the first on starting shift 2; they will start loading 45 minutes after unloading the cargo from the first shift. Loading time for these tractors is 39 minutes and will start once they arrive, with one loader available for each one of the route drag the idle times. The only route with a deduction on the idle time will be route 3 because it arrives 9 minutes after route one.

Route	Number of tractors	Transit Time (min)	Loading Time (Min)	Idle Time (min)	Total Time
1	1	45	39	0	**84**
1	1	45	39	39	**123**
2	1	45	15	78	**138**
2	1	45	15	93	**153**
3	1	45	9	108	**162**

Table 63: Time spent for routes in area 2

Area 3

Route 1 trucks will be the first on starting shift 2; they will start loading 42 minutes after unloading the cargo from the first shift. Loading time for these trucks is 39 minutes and will start once they arrive, 4 loaders are available meaning only 4 at a time can be loaded. The other 5 trucks will have an idle time of 39 minutes. The last truck will start loading after the second wave of route 1 is done and the 4 loaders will load it with a loading time of 9.75 minutes.

ROUTE 1					
Wave	Number of trucks	Transit Time (min)	Loading Time (Min)	Idle Time (min)	**Total Time**
1	4	84	39	0	**123**
2	4	84	39	39	**162**
3	1	84	9.75	78	**171.75**

Table 64: Time spent for route 1 in area 3

For routes 2 and 3 it will start after route 1 finishes, route 2 has 4 trucks that can start immediately and route 3 will have to wait, however when loading route 3 the 4 loaders will be available and will reduce loading time drastically.

Route	**Transit Time (min)**	**Loading Time (m)**	**Idle Time (m)**	**Total Time**
2	84	15	87.75	**186.75**
3	84	9.8	69	**196.55**

Table 65: Time spent for route 2 and 3 in area 3

8.4.5.1.2.2. Summarizing Time of Shift 1 Zone 3

By the end of shift 2 there will be 95% of the cane in plant ready for production at almost 5 hours of operation that gives a total of 3800 tons of cane ready to process.

8.4.5.1.3 Third Shift

The third shift is to recollect cane from two hectares to complete production requirements. The fields to be recollected from will be the closest ones to the factory (area 1) and will be collected by tractors since they are the ones which are going to finish first. The recollection on these last two fields will be done using the same routing model and the same trolley assignment.

There will be 4 tractors available after 2.15 hours of operations which are from route 1 and have already finished route 2. For the recollection of the last two hectares there is a need for 2 tractors for route 1, 1 tractor to do route 2 and another one to finish route 3. However since the 4 tractors available are from route 1 the configuration of these tractors is the highest and the capacity of this three tractors will be 235.5 tons and the need is to load 200 tons.

Each tractor will carry 66.7 tons of cane and will have an idle time of 6 minutes before loading because routes 2 and 3 haven´t finish loading from shift 2. The configuration for loading the last 3 tractors is 3 transmilenio and 1 milenio trolleys which takes 33 minutes.

Total time for shift 3 is 127 minutes which will end the shift with the total of cane recollected almost at the same time as route 3 from area 3 arrives to plant.

8.4.5.1.4 Forth Shift

This last shift is going to be only for trucks from routes 1 and 2, since this shift is only to leave the empty trolleys on the fields for the next day recollection. The last shift will start as soon as the trucks unload the cargo in the plant. Route 3 trucks will finish with the last shift.

The last truck to arrive is one from area 3 route 3 with a total time of 290.3 minutes to finish the routes. And will take an extra 84 minutes to leave the trolleys back into the fields.

8.4.5.2 Total Time and Recollection

The propose model recollect

For this zone the proposed model recollects all the cane needed in 4.8 hours of operations and there is still time to prepare the field for the next day.

HOUR	TONS	AGGREGATED	PERECENTAGE	SHIFT
1	800	800	20%	1
2	1000	1800	45%	1
3	628	2428	61%	2
4	654	3082	77%	2
5	918	4000	100%	2

Table 66: Total time and percentage of accomplishment by shift for zone 3

CHAPTER 9 CONCLUSIONS

The proposed model uses only 30 out of 35 trucks the mill owns. Each truck spends 74 gallons of fuel /day, using 30 trucks the fuel spent will be 2220 gallons/day, 2590 gallons/day that the 35 trucks use. According to the data provided by UPME (Colombian Ministry of mines and energy), average fuel cost in 2011 in Colombia was $8414.46 Colombian pesos, the mill spends $21.793.451 Colombian pesos with the 35 trucks daily, with the proposed model the mill will spend $18.680.109 Colombian pesos and will save $3.113.342 Colombian pesos daily and annually $1.136.373.273 on fuel.

	Actual Situation	**Proposed Model**	**Savings**
Daily	$ 21,793,460	$ 18,680,109	$ 3,113,351
Monthly	$ 653,803,801	$ 560,403,258	$ 93,400,543
Annually	$7,954,612,912	$ 6,818,239,639	$ 1,136,373,273

Table 67: Fuel saving analysis

According to truck expenses each vehicle cost $1.092.404 Colombian pesos daily, the mill will save $5.462.020 daily with the proposed model because 5 vehicles will not be used for recollection.

	Actual Situation	**Proposed Model**	**Savings**
Daily	$ 38,234,140	$ 32,772,120	$ 5,462,020
Monthly	$ 1,147,024,212	$ 983,163,611	$ 163,860,602
Annually	$13,955,461,249	$ 11,961,823,928	$ 1,993,637,321

Table 68: Total Saving analysis

Each factor of the components of transportation cost would be affected as follows:

Factor	% Transportation cost	Actual Situation COP	Proposed Model COP	Savings COP
Fuel	57%	7.954.612.912,00	6.818.239.639	1.136.373.273
Labor	13%	1.814.209.962,39	1.555.037.111	259.172.852
Wheels	14%	1.953.764.574,88	1.674.655.350	279.109.225
Wheels repair	4%	558.218.449,96	478.472.957	79.745.493
Lubricants	2%	279.109.224,98	239.236.479	39.872.746
Filters	1%	139.554.612,49	119.618.239	19.936.373
Maintenance and repairs	6%	837.327.674,95	717.709.436	119.618.239
Others	3%	418.663.837,47	358.854.718	59.809.120
TOTAL	**100%**	**13.955.461.249,12**	**11.961.823.928**	**1.993.637.321**

Table 69: Total Saving analysis

The total saving for the mill will be $1.993.637.321 Colombian pesos annually which are US$ 1.107.576.

CHAPTER 10 DISCUSSIONS AND FURTHER INVESTIGATIONS

A discussion open to the public will be the accuracy of the model since all the distances were average. However the savings found were not only the results from the routing model, one of the most important things were the trolley assignments which maximize trolley capacity in the field, that is why the model can fit to any mill and the key to success is not only the routing but trolley assignment and configuration.

With more accurate measures besides distances, such as fuel expense by vehicle type (truck and tractor) and depending on the route the savings will be actually higher that the propose.
Another saving that is not being quantified is the time for the entire process and the quality of the cane for production. Current situation takes around 24 hours to bring the cane to plant, this means more labor more shifts which result in more expenses. Since the quality of the cane varies with the time the cane waits on the ground to be collected, with the proposed model the cane will get to plant more pure and better for production, this will result on a better quality sugar and longer life for the equipment.

The bottle necks of the entire process are the loaders, the mill should consider on investing in more loaders to optimize time and resources. A further analysis of how many loaders will be needed must be done, taking into consideration that 5 trucks are unused and could sell them to earn extra resources for the project.

It is necessary to establish in this type of companies, programs or analysis areas where constantly look for the status of logistics operations. The thesis shows a huge opportunity for continuous improvement, establishing study centers where indicators can be frequently revised, updated and modified to fit the measurements to the operations of the company.
It is also important to work on changing people´s minds; normally these companies are old-fashioned in terms of giving the necessary importance to logistics and operations. Normally these matters are not taken seriously sometimes because of the complexity of the analysis of some situations where technical basis are necessary.

Discussion on Capture Methodology

The methodology used is experimental and created under common sense, the reason is that there is a big constraint in terms of capacity. The model needs to fit with own capacity of trolleys and technology. There is still a lot of work to be done in terms of infield routing, especially in Colombia, the reason is that there is a lot to be done in terms of technology and organization since lots of the things done are merely based on employees experience and knowledge, for example infield transit routes; there are not in any organization or specifications, where the vehicles must pass through the transit

routes, that are created by time where the vehicles have transited before and the street, as a matter of speaking, were defined by the pass of years.

However even with lots of information missed, this thesis is proof that with analysis and common sense an infield logistic can be consolidated without using a based methodology on routing and scheduling.

This thesis can be considered as phase 1 of whole logistic acculturation on any company, work is needed, and profitable changes can be met applying logistics and supply chain management techniques. The hardest step for any company is to take into consideration that sales are not always the most important area of the company and major breakthroughs can be achieved reducing costing on operation areas, which will end on increasing overall profit.

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