NEMAK: A LOOK IN TO THE FUTURE USING A DYNAMIC BALANCED SCORECARD

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ABSTRACT

Nemak, a Mexican enterprise devoted to the production of engine cylinder heads and blocks a market leader on the industry, tries to identify critical external factors to gain competitive advantage as well as to understand their influence on its overall performance in order to face the challenges of the global economy.
This paper presents the use of Balanced Scorecard based on a System Dynamics model that intends to be a decision-making tool for the company. The model is able to generate behavior trends on several different scenarios.

Keywords
System Dynamics, Systems Thinking, Dynamic Balanced Scorecards, Automotive Industry

CASE OF STUDY|: NEMAK'S SITUATION ANALYSIS

NEMAK is a global group of enterprises devoted to the production of engine cylinder heads and blocks, which are high-tech components for the motor industry. After acquiring with Rautenbach, Nemak also participates as a supplier of several European and Asian companies (NEMAK, 2007).
Their operations are totally focused on the automotive industry, specifically to the production of aluminum-alloy-based heads and blocks. Given this, changes in production and sales of this industry in the US, Canada and Western Europe could adversely affect the financial situation and results of the company. Entering new markets is a strategy used by the company to face this situation. NEMAK's management has developed a detailed process to achieve its objectives, some of its main aspects are:

- Maintain its technological leadership on the making of high tech components for motor vehicles, based on R&D;
- Reduce costs improving productivity, optimizing production processes and operations, as well as implementing best practices on the production facilities; and
- Maintain its high production quality and service standards, focusing on the quality and quantity needs of its clients.

NEMAK’s strategy includes a long-run business plan, which deals with the following factors:

- Penetrate rapidly on the European market, and penetrate the Asian market on the medium-run;
- Turn NEMAK into a supplier of high tech aluminum components for the global market; and
- Continue research of new technologies and applications of materials for the production of motor vehicle components.

The acquisition with Rautenbach represents an important step on the business strategy, since it allows NEMAK to diversify geographically on the European market, while it continues to grow in North America.
On the other hand, the company diversifies its clients importantly, since they currently include Audi, Volkswagen, Porsche, BMW, DaimlerChrysler, Skoda, Smart, PSA Peugeot Citröen and SsangYong. Also, it incorporates new technologies for the production of aluminum heads for diesel engines and other aluminum components, like chassis and suspension components. Now we present the analysis of some Key factors to understand Nemak’s situation.

Products

The heads distribute air and gas to the combustion chamber and allow gases to go out of the engine. The block transforms the energy generated on the chamber into mechanical energy, which allows the vehicle to move. Each engine requires a block and can have one or two heads, depending on the size of the engine. Examples of these products are shown on figure 1.

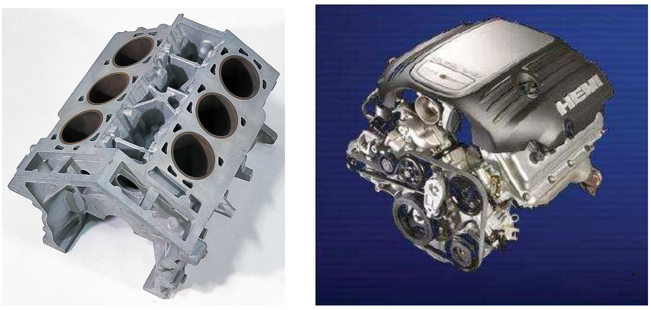


Figure 1 Main Nemak Products

Competitors

The head and block industry has a limited number of competitors. Besides the Original Equipment Manufacturers (OEM), there are only tour large producers of heads and blocks: NEMAK, *Teksid, Hydro Aluminum & Montupet*.
The limited amount of competitors is due to the strong entry barriers that exist for the potential competitors. The heads and blocks segment is growing in the motor vehicle industry due to the substitution of iron parts by aluminum ones. NEMAK is the main producer on North America. On the last seven years, the company has been the choice of three out of each four potential clients for blocks and heads.

Power Rates

From year 2000, the Federal Commission of Electricity (CFE) has ceased to be the only independent producer of electric power, but it is still the largest one by far. Nevertheless, independent production of electric power has increased 15 times if compared to 2000 and 5 times if compared to 2001. Besides, the possibility of changes in the constitution that would allow private enterprises to invest in power generation is still alive. (INE, 2007)

Power rates have slightly decreased on the last months. On past years they had been increasing and reached their peak value on December, 2005. (INEGI, 2007)

Macroeconomic conditions

Currently, there are some efforts to integrate universities, government and the Mexican Association of Automotive Industry (AMIA) to achieve better levels of productivity and attractiveness in Mexico. The International Congress of Automotive Industry in Mexico (CIIAM) is in charge of the coordination of the efforts for the next 10 years. The strategic topics are interaction with universities, infrastructure and technology. (EL UNIVERSAL, 2007)

Value Chain

A value chain is one that refers to the value added of each of the different activities of an organization. This concept can be extended to a group of organizations that collaborate (only looking for their individual interests though) to deliver a finished product or service to the consumer. NEMAK could be considered as a part of a value chain that ends on the cars that consumers buy. Nevertheless, we will focus only on NEMAK, and we will consider auto parts as the final product.

The whole value chain consists on primary activities, which can be categorized in: Receival logistics, operations, delivery logistics, marketing/sales and client service.

The main raw materials that NEMAK uses are aluminum, resins and sand. NEMAK has around 200 suppliers of raw materials, none of which represents more than 10% of the total purchases.

The manufacturing processes of the company are divided into four main phases: melting, making of the sand mold, molding and finishing. NEMAK has highly flexible equipment, which allows a higher degree of machine investment optimization, as well as to react rapidly to its customers' needs.

Heads and block made in Mexico destined to North America are transported via ground transport, with an average delivery time of 18 hours in Mexico and 3 days on the US and Canada. NEMAK sends a product to 46 facilities in 17 countries, which are located in North America, several European countries, China, Korea, Australia and Brazil. The company does not have specialized distribution networks.

NEMAK has a reputation as a leader in costs, quality, service and development of new processes. This is the reason it continues to get new contracts. Due to the nature of the contracts with its clients, the company does not need to incur any marketing or advertisement costs, with the exception of some technical publications or the assistance to some industry-related events. NEMAK has commercial offices that provide any special attention to its customers in the US and Germany.

NEMAK is also greatly supported by its R&D activities. It counts with some patents already, and it continues to work on this field. This has translated in competitive advantages in cost, quality and service. In consistence with its objectives and policies, the company has three centers for technological development, located in García, Mexico, Windsor, Canada and Wernigerode, Germany.

Also, the constant revision of processes has been a main factor to maintain the good reputation NEMAK has among its clients, which include Ford, Daimler-Chrysler, GM, and after acquiring Rautenbach, Volkswagen, Audi, Porsche, BMW, Smart, etc.
Considering the main activities of the company, as well as the supporting ones, the NEMAK value chain can be viewed in Figure 2.

FORMULATING NEMAK'S STRATEGY USING BALANCED SCORECARD

We will now use the Kaplan and Norton's Balanced Scorecard methodology (Kaplan and Norton, 1992). BSC helps organizations to clarify their strategies and to implement them. It also provides feedback among internal business processes and results, in order to improve performance continuously. BSC focuses on four perspectives: learning and growth, business processes, customer, finance. Measurement criteria are established for each of these perspectives and goals are set.
The LodeStar institute proposes the following questions to cover all the four perspectives:

- Financial: What financial objectives must be accomplished to ensure the success of our project?
- Customer: By working on this project, what customer objectives will be met?
- Processes: To achieve our customer objectives, which process will have to be worked on?
- Learning and growth: To achieve our project goals, how must our team learn and innovate?

The financial perspective refers to the tangible results that the company desires to have. To achieve that, NEMAK needs to keep costs as low as possible and maintain a sustained growth, which will allow it to remain a leader in its industry.
The customer perspective defines the value the clients are expecting to get. NEMAK emphasizes a close communication with its clients, being always responsive to their requirements and offering the best quality at a low price, with very short delivery times.
The internal processes perspective identifies the critical processes necessary to achieve results. NEMAK has worked searched for strategic locations that allow fast delivery to its customers. The use of aggressive programs to reduce costs and the development of state-of-

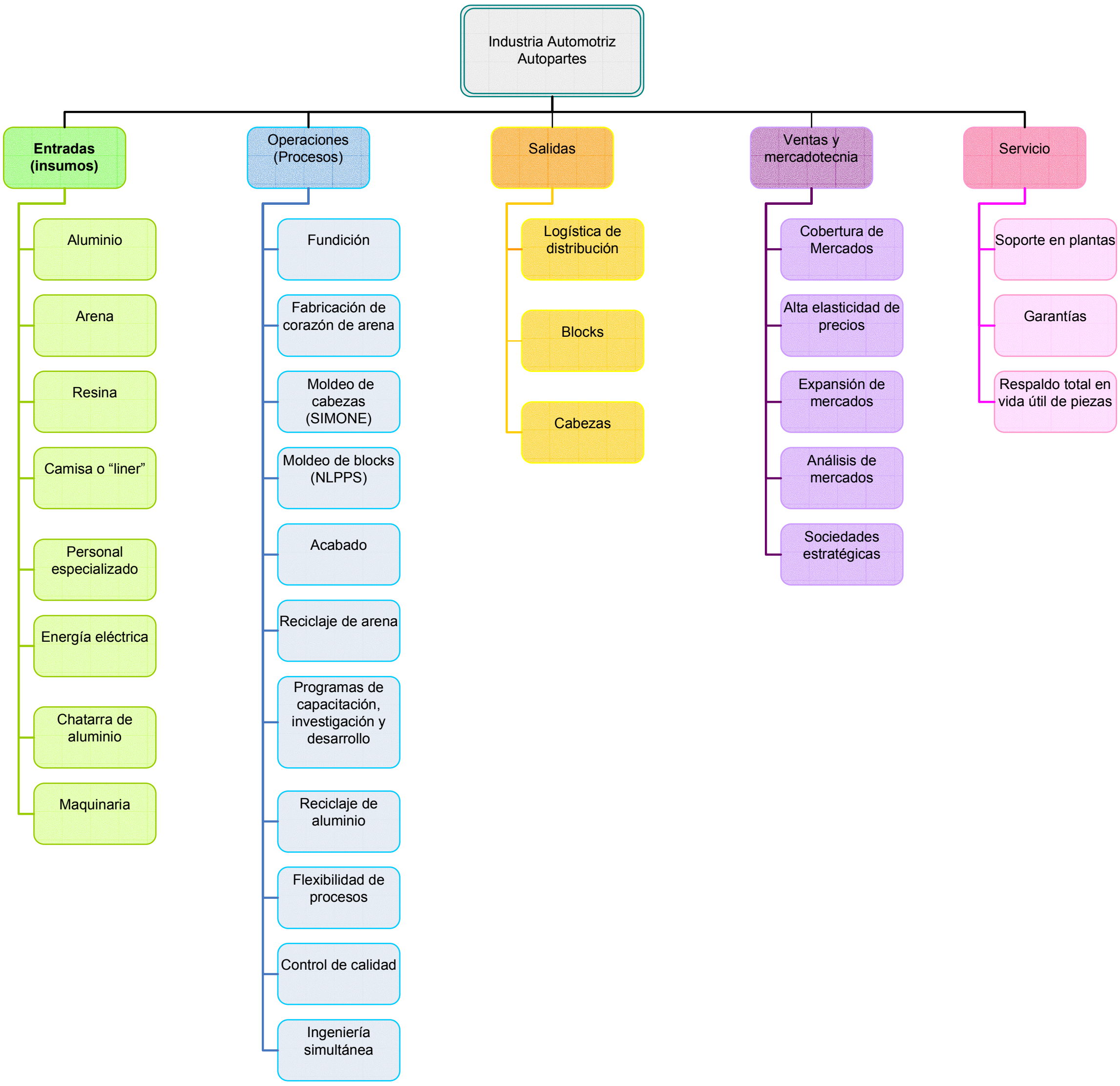


Figure 2 NEMAK's Value Chain

the-art technology have been the key aspect to maintain NEMAK's current leadership. A point that NEMAK has to reinforce is its speed to respond to sudden demand changes.
The learning and innovation perspective identifies the intangible goods that are important for strategy. For NEMAK, to have highly trained employees (some of them highly specialized in several fields of metallurgy) has always been fundamental to be able to innovate and gain competitive advantage. NEMAK's R&D department has a close relationship with various universities and has funded several graduate theses. These works helped NEMAK to cut costs in some of its processes and to provide better training to its workforce. The BSC Chart is showed in Figure 3 and the Figure 4 shows the lead and lag indicators.

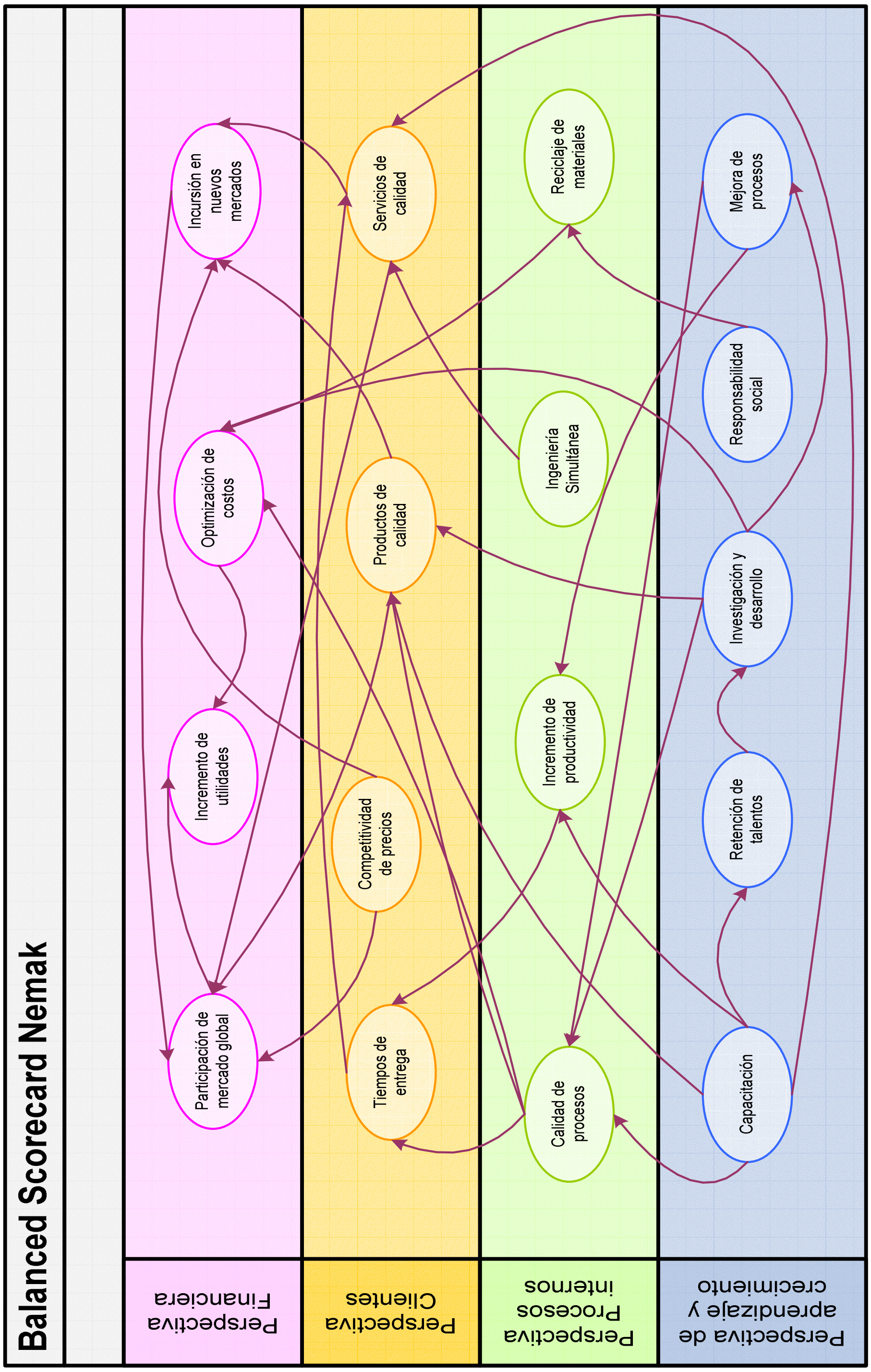


Figure 3 Nemak's Balanced Scorecard.

Perspective	Strategic Objective	Measurement
Learning and Growth	Training	Programs per year
	Talent retention	Number of specialized employees that leave the company
	R&D	Programs per year
	Social responsibility	Number of practices to support the community
	Process improvement	Number of optimized processes
Processes	Process Quality	Number of certifications achieved and maintained
	Productivity Increase	Produced items
	Concurrent Engineering	Number of products developed under this scheme.
	Materials Recycling	Percent of recycled raw materials
Clients	Delivery Times	Delivery periods in days
	Price competitiveness	Price of the product
	Quality of product	Number of defectives
	Quality services	Complaints received
Financial	Maintain leadership	Market Share
	Increment of profit	Profit
	Cost optimization	Cost per unit
	Penetration in new markets	Market share in new market

Figure 4 BSC Measurement criteria

DESIGNING A 'DYNAMIC' BALANCED SCORECARD

As Bianchi and Montemaggiore mentioned (2006), different scholars have remarked that BSC is a static approach. The links among the parameters inside the four perspectives do not express their dynamic relationships. As a result, in the analysis of the strategy, delays between actions and their effects on the system are ignored.

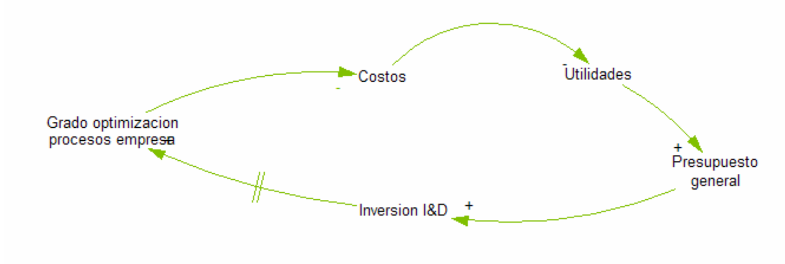
Also Kaplan and Norton warn managers that BSC, through correctly implemented, does not point out whether the vision is wrong, the model is not a valid description of the strategy, nor the performance indicator are correct. In this point is where System Dynamics (SD) models comes to enhance BSC methodology, since Sterman mentioned (2000) that SD models offer managers a virtual world where they can test their hypotheses and evaluate the possible effects of their strategies without bearing the costs and risks of experimenting with them in the real word. Thus, if an organization design their strategy using BSC and SD models, people could learn about the processes and the impact of external factors using scenarios as fly simulators.

The next sections will show the design of a SD model based on Balanced Scorecard methodology: a causal loop diagram is presented, followed by the SD model.

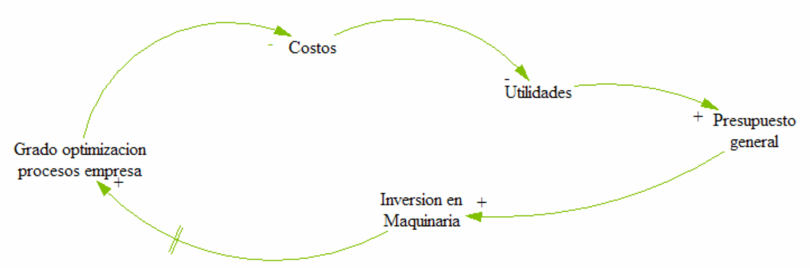
Causal loop diagram

Using each one of the BSC dimensions, we designed a Causal loop diagram. The whole diagram is presented at the Appendix 1, but the analysis of each loop is present below. Diagrams for each loop are presented below its analysis.

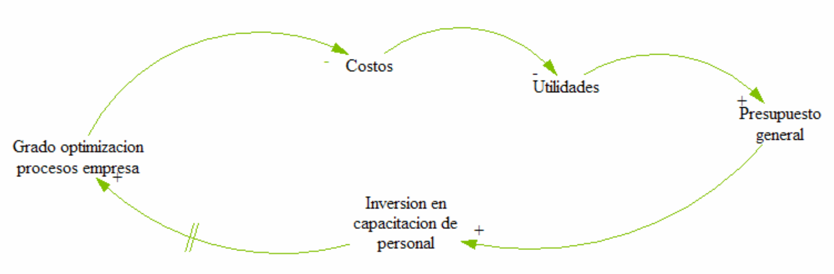
Loop 1: If process optimization increases, costs diminish, profit grows, which allows general budget to be larger, which translates into more R&D investment. With time, this investment will allow a higher degree of process optimization.



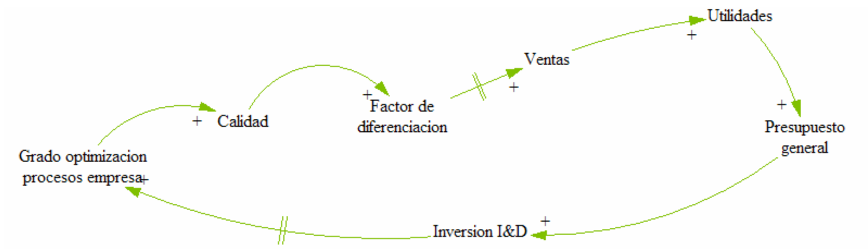
Loop 2: A high degree of process optimization is a result of a cost reduction. This leads to larger profits, which make the budget grow larger. Larger budget leads to more investment in machinery, which in time will translate into a higher degree of process optimization.



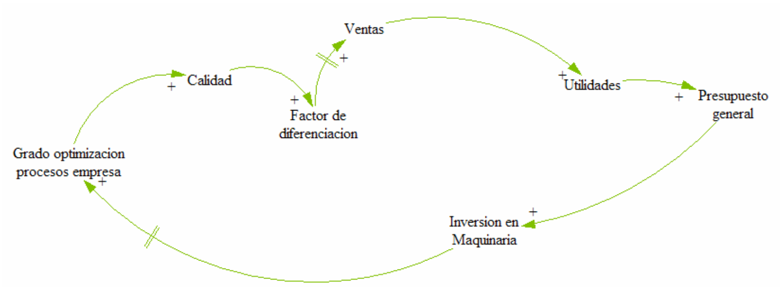
Loop 3: A high degree of process optimization leads to cost reductions. When costs are reduced, profits are larger and general budget grows larger. This increase in budget can be used to invest in employee training, which will lead to achieve a higher degree of process optimization.



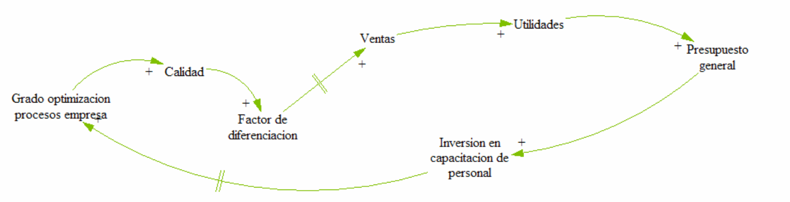
Loop 4: A higher degree of optimization leads to better quality, which increases the differentiation factor of the company. With time, this will lead to more sales, which in turn will lead to more profits, a larger general budget and more R&D investment which will lead to a higher degree of process optimization.



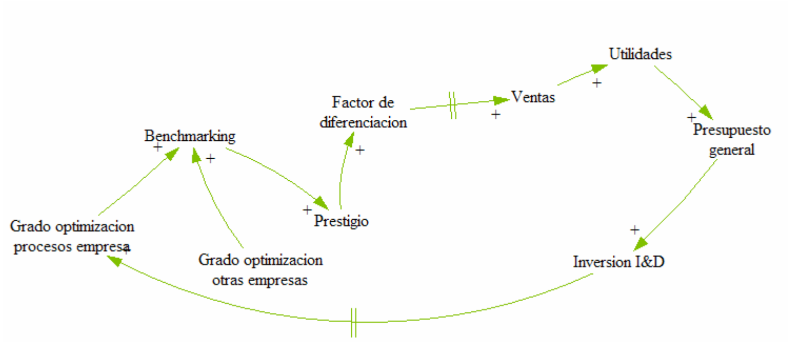
Loop 5: A higher degree of optimization leads to better quality, which increases the differentiation factor of the company. With time, this will lead to more sales, which in turn will lead to more profits, a larger general budget and more machinery investment which will lead to a higher degree of process optimization.



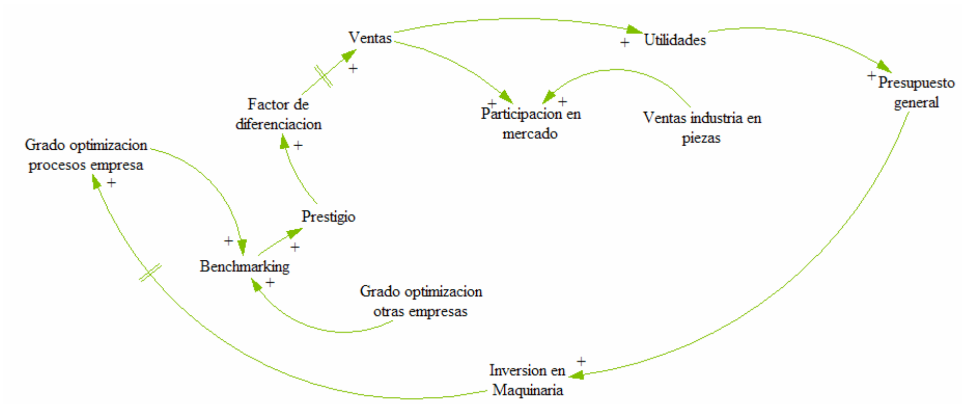
Loop 6: A higher degree of optimization leads to better quality, which increases the differentiation factor of the company. With time, this will lead to more sales, which in turn will lead to more profits, a larger general budget and more workforce training investment which will lead to a higher degree of process optimization.



Loop 7: A higher degree of process optimization allows more positive benchmarking results. This will lead to a better reputation and will increase the differentiation factor. With time, this will lead to more sales, then more profit, a larger budget, more R&D investment, and a higher degree of process optimization.



Loop 8: A higher degree of process optimization allows more positive benchmarking results. This will lead to a better reputation and will increase the differentiation factor. With time, this will lead to more sales, then more profit, a larger budget, more machinery investment, and a higher degree of process optimization.



Loop 9: A higher degree of process optimization allows more positive benchmarking results. This will lead to a better reputation and will increase the differentiation factor. With time, this will lead to more sales, then more profit, a larger budget, more workforce training investment, and a higher degree of process optimization.

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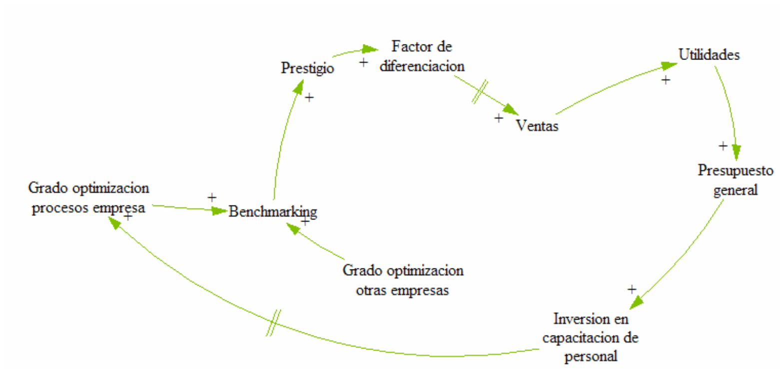
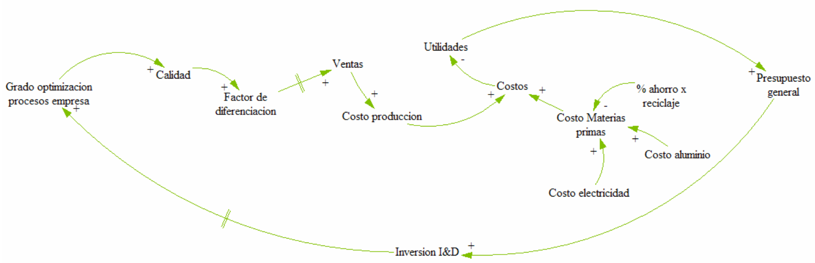
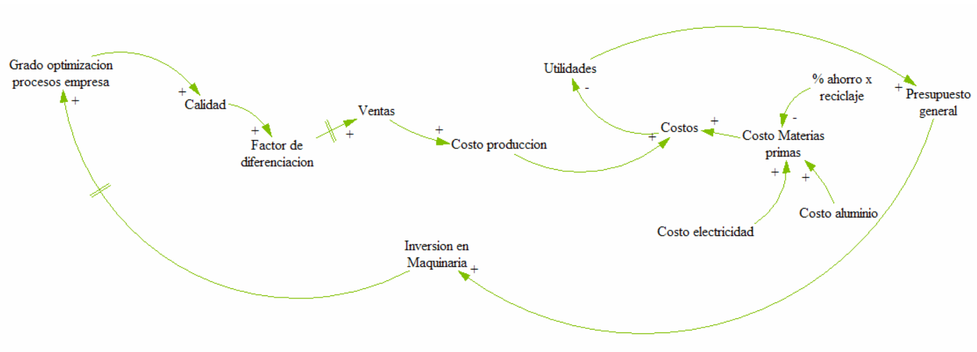


Loop 10: A higher degree of process optimization leads to higher quality, which in turn increases the factor of differentiation and later on, sales. Since more has to be sold, production costs will increase.

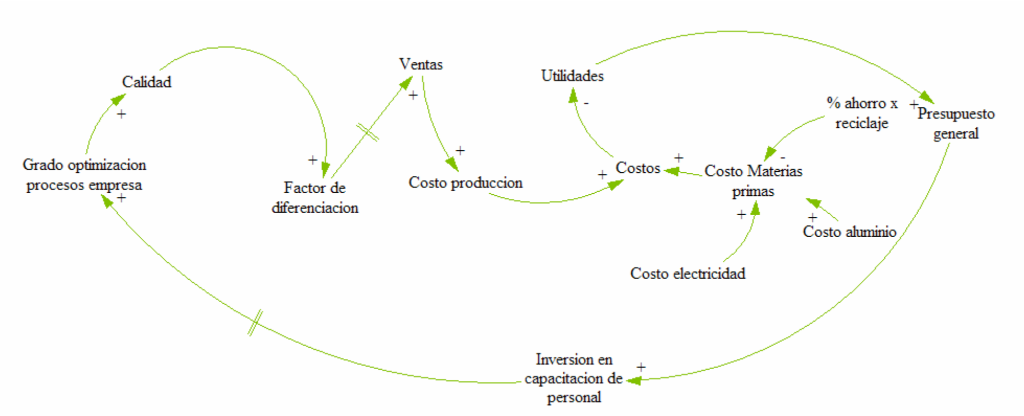
These, combined with other costs such as power and ray materials will lead to higher overall costs for the company. Increasing costs will make profits and general budget smaller. This will translate into less R&D investment, which in time will lead to a lower degree of process optimization.



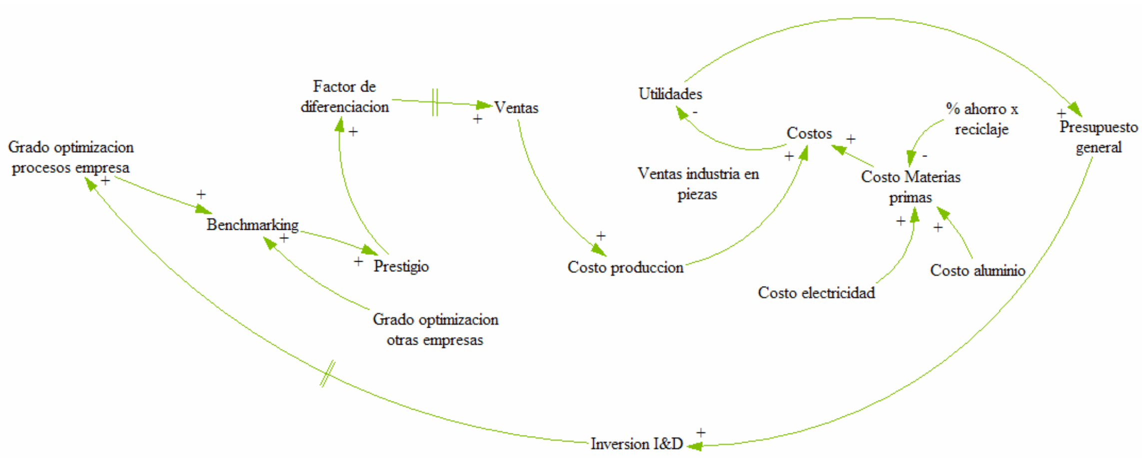
Loop 11: A higher degree of process optimization leads to higher quality, which in turn increases the factor of differentiation and later on, sales. Since more has to be sold, production costs will increase. These, combined with other costs such as power and ray materials will lead to higher overall costs for the company. Increasing costs will make profits and general budget smaller. This will translate into less machinery investment, which in time will lead to a lower degree of process optimization.



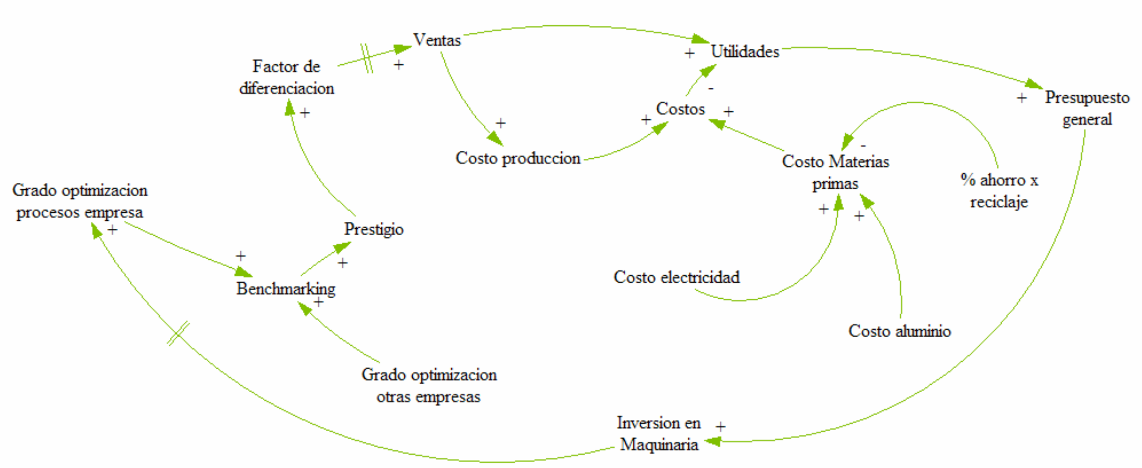
Loop 12: A higher degree of process optimization leads to higher quality, which in turn increases the factor of differentiation and later on, sales. Since more has to be sold, production costs will increase. These, combined with other costs such as power and ray materials will lead to higher overall costs for the company. Increasing costs will make profits and general budget smaller. This will translate into less workforce training investment, which in time will lead to a lower degree of process optimization.



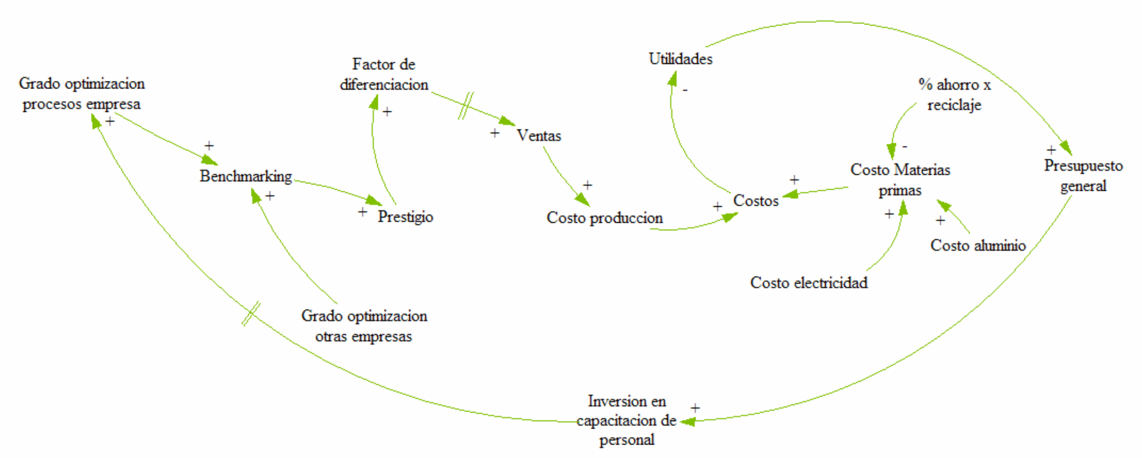
Loop 13: A higher degree of process optimization leads to positive benchmarking results, which lead to a better reputation, which in turn increases the factor of differentiation and later on, sales. Since more has to be sold, production costs will increase. These, combined with other costs such as power and ray materials will lead to higher overall costs for the company. Increasing costs will make profits and general budget smaller. This will translate into less R&D investment, which in time will lead to a lower degree of process optimization.



Loop 14: A higher degree of process optimization leads to positive benchmarking results, which lead to a better reputation, which in turn increases the factor of differentiation and later on, sales. Since more has to be sold, production costs will increase. These, combined with other costs such as power and ray materials will lead to higher overall costs for the company. Increasing costs will make profits and general budget smaller. This will translate into less machinery investment, which in time will lead to a lower degree of process optimization.



Loop 15: A higher degree of process optimization leads to positive benchmarking results, which lead to a better reputation, which in turn increases the factor of differentiation and later on, sales. Since more has to be sold, production costs will increase. These, combined with other costs such as power and ray materials will lead to higher overall costs for the company. Increasing costs will make profits and general budget smaller. This will translate into less workforce training investment, which in time will lead to a lower degree of process optimization.



Stocks and Flows Model

Following the structure of the Causal Loop diagram and the BSC Chart the modeling was designed considering each dimension. The equations are presented in the Appendix 2 and the Stock-and Flow diagram is shown on figure 5.

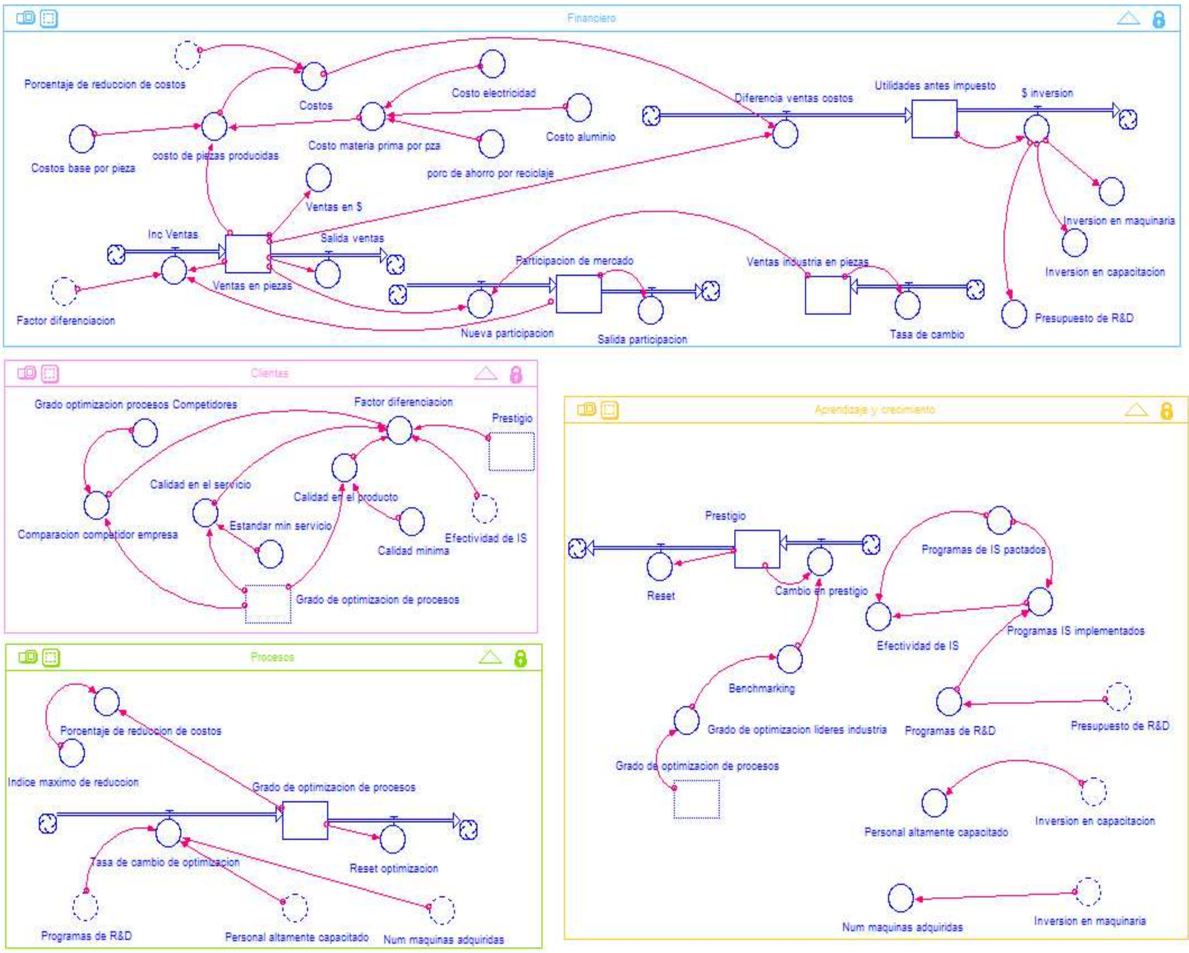


Figure 5 BSC-based Stocks and Flows diagram of NEMAK

Base run

On this run, we analyzed the financial perspective as well as market share. Market share has a steep growth in market share (from 48% to 91%), which comes from a very strong investment in R&D, machinery and training. Profit increases fourfold in 15 years. After that period of time, market share reaches steady state.

As mentioned before, the whole cylinder head industry (aluminum and non-aluminum) is assumed to have an annual growth rate of 5%. Given that this study does not cover all the areas of the company, there could be factors, like poor managerial practices or sudden changes in the market that inhibit this growth.

Another important aspect is that despite cost growth, costs are always under control since they depend on the amount of units produced. This model does not cover all the factors that are involved in calculating costs (e.g. costs of locating a new facility, negotiations with suppliers, etc.). If these factors are not controlled, results can be disastrous.

In general, as it can be seen on figure 6, the scenario looks very good. Profit grows fourfold on the next 15 years and costs have a smaller growth rate than the sales. The main factor responsible of this growth was investment in machinery, R&D and training.

Market share reaches a peak of 95% and then stabilizes at 91%. Consequently, profits and investment also grow.

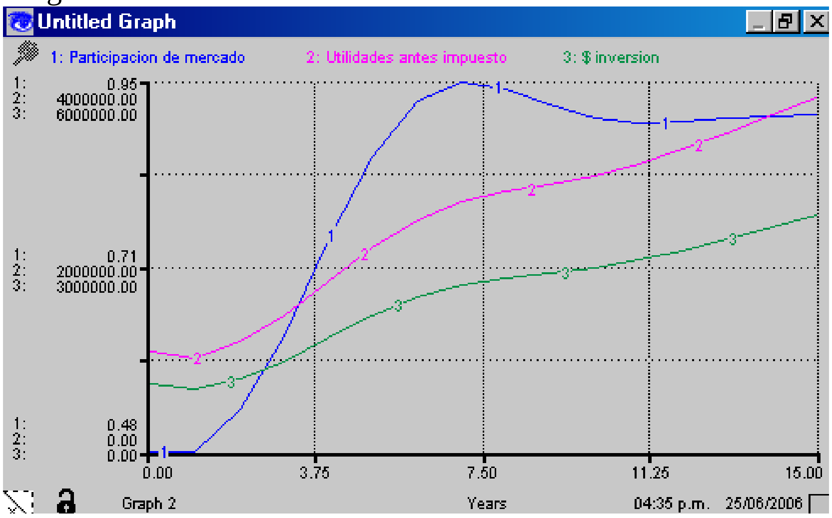


Figure 6 Graph of base run behavior.
Profit (pink), $ invested (green), market share (blue)

Growth is also related with a very strong reputation. As mentioned before, reputation is a function of benchmarking. Reputation reaches the maximum reputation level (10) in a very short time. These behaviors can be seen on figure 7.

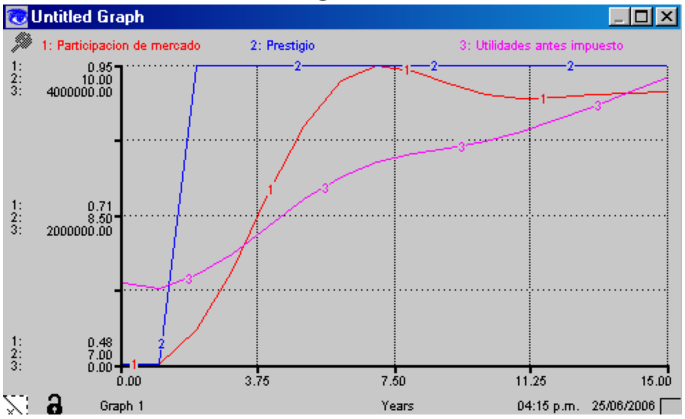


Figure 7 Graph of reputation (blue), profit (pink) and market share (red).

Good benchmarking results are the product of good service and product quality. Reputation does not grow immediately since initial investments have delays. Nevertheless, its slope is tremendously steep. Numerical results achieved via simulation are given in table 1.

Years	Prestigio	Calidad en el producto	Calidad en el servicio	Participacion de mercado
Initial	7.00	6.60	7.80	0.48
0	7.00	7.00	9.00	0.48
1	10.00	7.00	9.00	0.53
2	10.00	7.00	9.00	0.63
3	10.00	7.00	9.00	0.75
4	10.00	7.00	9.00	0.85
5	10.00	7.00	9.00	0.92
6	10.00	7.00	9.00	0.95
7	10.00	7.00	9.00	0.94
8	10.00	7.00	9.00	0.92
9	10.00	7.00	9.00	0.90
10	10.00	7.00	9.00	0.90
11	10.00	7.00	9.00	0.90
12	10.00	7.00	9.00	0.90
13	10.00	7.00	9.00	0.91
14	10.00	7.00	9.00	0.91
15	10.00	7.00	9.00	0.91

Table 1 Behavior of reputation, product quality, quality in service and market share.

To conclude, we can see a very strong reinforcing cycle that begins with NEMAK current leadership in the industry. This allows NEMAK to invest and to keep increasing its market share.
Some factors that were mentioned above are out of the scope of this model and can have a positive or negative effect –mainly negative- on the real behavior of the variables.

SCENARIO ANALYSIS

We developed several tests as Sterman suggests (2000) to get enough confidence in the model. A sensitivity analysis is presented in the Appendix 4, their results help to focused the Scenarios were designed presented below.
Scenario 1: “Collapse”. Not investing on R&D and lowering product and service quality.
For this scenario, we adjusted R&D investment to be zero, without modifying the other two investment components (machinery and training). Also, the values of minimum service standards and service quality are set to a smaller value (4) than the original one (6). Next, we proceeded to observe the impact on sales.
We could observe that quality in service and product quality changed. At the beginning, quality in service had a value of 5.8 and product quality had 4.6. Before ending the first year, these variables had values of 4.45 and 5.35 respectively, remaining stable for the following 15 years. Even if this change was small, we could see its (negative) impact on sales.
On the second graph, we can see that the degree of process optimization reduces to 4.5 as al result of a lack of investment in R&D. As the degree of optimization is reduced, reputation decreases, negatively impacting sales and profit. Market share is dramatically affected by this change, having a value of 1% by year 15.
On the first year of the model run, NEMAK had sales of 11397000 thousands of pesos, with 1096000 thousands of pesos in profits. At the end of year 5, sales had decreased to 6232302.03 thousands of pesos, with 684243.12 thousands of pesos in profits. This is, a

45% decrease. By year 10, sales would be 1484150.14 and profit 182951.52, which is 76% less than what we had on year 5. The trend continues until the model stops running.
Now, we present in tables 2 and 3 the comparative tables for this scenario for a 15 year simulation:

Untitled Table

03:12 p.m. 20/06/2006 Escenario 1a

Years	Utilidades antes i	Calidad en el pro	Calidad en el ser	Costos	Ventas en $
Initial	1,096,034.00	4.60	5.80	10,375,200.00	11,397,000.00
0	1,021,800.00	4.45	5.35	10,164,790.94	11,165,868.84
1	1,001,077.90	4.45	5.35	9,716,041.49	10,672,924.36
2	956,882.87	4.45	5.35	9,019,154.72	9,907,404.81
3	888,250.09	4.45	5.35	8,084,790.18	8,881,019.52
4	796,229.34	4.45	5.35	6,947,699.42	7,631,942.55
5	684,243.12	4.45	5.35	5,673,543.91	6,232,302.03
6	558,758.11	4.45	5.35	4,421,768.04	4,857,245.19
7	435,477.16	4.45	5.35	3,373,207.36	3,705,417.17
8	332,209.82	4.45	5.35	2,523,098.13	2,771,585.06
9	248,486.94	4.45	5.35	1,857,661.63	2,040,613.16
10	182,951.52	4.45	5.35	1,351,088.40	1,484,150.14
11	133,061.74	4.45	5.35	973,700.15	1,069,594.86
12	95,894.71	4.45	5.35	697,070.35	765,721.22
13	68,650.87	4.45	5.35	496,676.16	545,591.23
14	48,915.08	4.45	5.35	352,722.80	387,460.66

Table 2 Profit, Product quality, Quality in service, costs, sales in $

Untitled Table

04:51 a.m. 25/06/2006 Escenario 1b

Years	Grado de opti	Prestigio	Utilidades ant	Participacion
Initial	6.00	7.00	1,096,034.00	0.48
0	4.50	7.00	1,021,800.00	0.48
1	4.50	5.50	1,001,077.90	0.45
2	4.50	4.00	956,882.87	0.41
3	4.50	2.50	888,250.09	0.36
4	4.50	1.00	796,229.34	0.31
5	4.50	0.00	684,243.12	0.25
6	4.50	0.00	558,758.11	0.20
7	4.50	0.00	435,477.16	0.15
8	4.50	0.00	332,209.82	0.11
9	4.50	0.00	248,486.94	0.08
10	4.50	0.00	182,951.52	0.05
11	4.50	0.00	133,061.74	0.04
12	4.50	0.00	95,894.71	0.03
13	4.50	0.00	68,650.87	0.02
14	4.50	0.00	48,915.08	0.01

Table 3 Degree of optimization, reputation, profit, market share

After observing these results, we are aware of the importance of R&D in NEMAK. If R&D investment is reduced, it will cause a significant decrease on quality and reputation. This would affect sales and profit. Our hypothesis is proved after observing the behavior of this scenario.
Scenario 2: “Comfortable ignorance”. Stop investing in training and reducing product and service quality.
On this scenario, the percent of investment destined to training becomes zero and the components for R&D and machinery keep the original values. Also, the variables ‘minimum service standard’ and ‘service quality’ are adjusted to have a value of four. We monitored sales and profit.

Product and service quality remain constant with values of 4.60 and 5.80 respectively. Considering that the scale to measure them runs from 0 to 10, these are relatively low quality values. These values remain constant for the whole simulation time of 15 years.
Sales rise 15, 16 and 14% for 5, 10 and 15-year periods, respectively. Even if they increase, market share decreases to 39% due to the low quality levels and the low degree of process optimization. Costs also rise, but the rate of increase is reduced over time. Costs rise 18, 16 and 14% on for 5, 10 and 15-year periods, respectively. This is mainly because of the low level of process optimization.
Profit rises by 9, 16 and 14% by years 5, 10 and 15, respectively. This is actually nothing to celebrate, since market share is decreasing. Concluding, if we do not invest in training, the company will be able to survive in 15, but with lackluster results and a continuous loss of market share.
Scenario 3: “The minimum effort” Reducing all kinds of investment. Maintain minimum quality standards.
This is an interesting scenario, since NEMAK bases its success on the quality of its processes and products; and to maintain and develop this quality a certain degree of investment is needed. Besides the absence of investment, quality standards are assumed to remain constant at their lowest allowable value, an unrealistic assumption given NEMAK’s background.
It is natural to think that a strong decrease in investment will have a serious decrease of profit as a consequence. If we divide by 100 the investment percentage used for the base run (50%), we can notice that the company still grows at an acceptable pace (although much slower than the base run).
We can observe that, thanks to the positive inertia NEMAK has, product and service quality can still be maintained as long as the environment is not very competitive. This is the case of the block and head industry, since there are strong barriers to the entrance of new suppliers.
On figure 8, we can observe the profit, sales and costs, which grow only 10% less than on the base run.

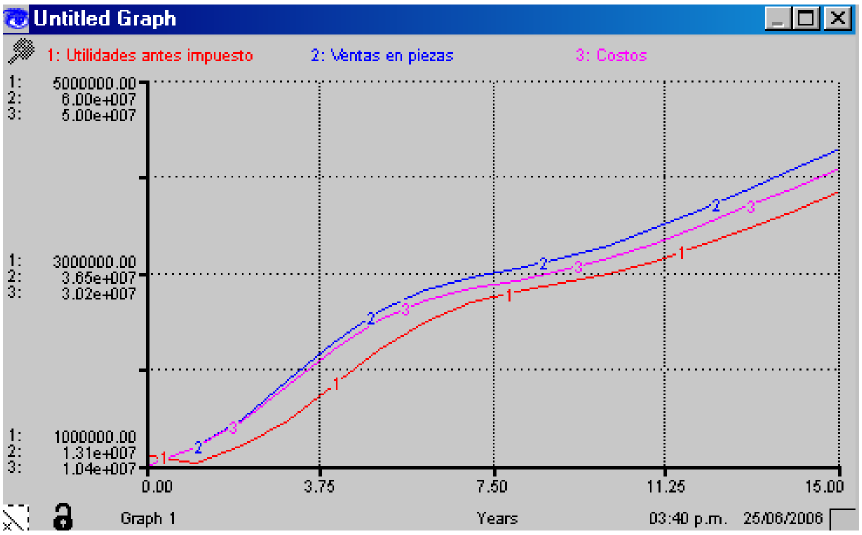


Figure 8 Profit (red), sales (blue), costs (pink)

It is important to remind that we only changed investment, and assumed that all the other aspects on the company would work perfectly. Also, we considered that the strong barriers to entrance would remain in this industry. In this scenario, NEMAK grows, but is less protected of the innovations that their competitors might introduce to the industry.

Comparative table of scenarios

5 years

	Scenario 1	Scenario 2	Scenario 3
Profit	796,229.34	1,159,482.00	2,103,344.56
Costs	6,947,699.42	12,164,273.02	25,311,511,27
Product Quality	4.45	4.60	6.98

10 years

	Scenario 1	Scenario 2	Scenario 3
Profits	248,486.94	1,371,068.80	2,992,885.56
Costs	1,857,661.63	14,413,241.34	31,678,580.74
Product Quality	4.45	4.60	7.00

15 years

	Scenario 1	Scenario 2	Scenario 3
Profits	48,915.08	1,636,458.05	3,830,286.64
Costs	352,722.80	17,231,468.78	40,843,026.17
Product Quality	4.45	4.60	7.00

Of the three scenarios, the one that has the worst consequences is Scenario 1, where R&D investment becomes zero. As we can observe on the tables, profits and costs show an extremely quick decay. On Scenario 2, where investment in training is reduced to zero, growth is achieved, though slowly. Scenario 3 has good results, but it puts NEMAK on a more unstable position on the market than the base run.

STRATEGIES

The scenarios analyses help us to suggest the next strategies:

1. Designate a significant percentage of profit to the R&D department: Investing more each year will allow a continuous improvement on the company's processes. This

will lead to an improvement in product and service quality and therefore more sales and profits.

2. Designate a percentage of profit to training: having a highly competitive workforce will be a main factor to generate products and services of the highest quality. The optimal approach is to complement R&D investment with training investment and vice versa. Both need each other and one alone can not replace the other one.

3. Constantly monitor process improvement: It is important to check that investments are translating into process improvements. If it is not the case, the factors that interfere with the optimal behavior of the system should be pointed and solved.

4. Continue benchmarking: If we are constantly comparing with the best practices there are, we can tell where we stand in industry. In this way, we know if we can continue following our current trends, or if we have to start changing.

5. Communication with clients: Constant communication with clients is necessary to verify that their needs are being satisfied by the products or services that the company offers.

CONCLUSIONS

We consider that the process of doing this model was a very enriching experience, because we had the chance to observe a company in a complete, holistic way. To achieve this, it was necessary to identify the elements that interact inside the system –the company-, their interrelationships, and the way they affect each other.

With the goal of identifying these elements, we relied on the Balanced Scorecard (BSC) methodology. BSC proposes four basic perspectives to represent a company: Financial, clients, learning and processes. In each one of these perspectives, we identified elements and relationships between them. After finishing the BSC process, we had a more complete view of the company.

Nevertheless, with BSC we only got a ‘picture’ of the company, a complete view, but a static one. System Dynamics made possible for us, with the use of a mathematical model of the elements and interrelationships of the system, to represent a behavior of the system in time. This model tried to reproduce as closely as possible the behavior the company would present.

We shall remember that the results of the model are not to be represented as predictions, but as trends or tendencies. The point of System Dynamics models are to reach understanding of the structure that originates the behavior of a system. This understanding should create a better frame to determine the actions that are oriented to improve the system or to solve its problems. System Dynamics allows to simulate these actions with a very low cost, without implementing them on the real system.

With a finished model it is possible to estimate the future behavior of the company and try several scenarios. This approach allows choosing the actions that will have milder collateral effects.

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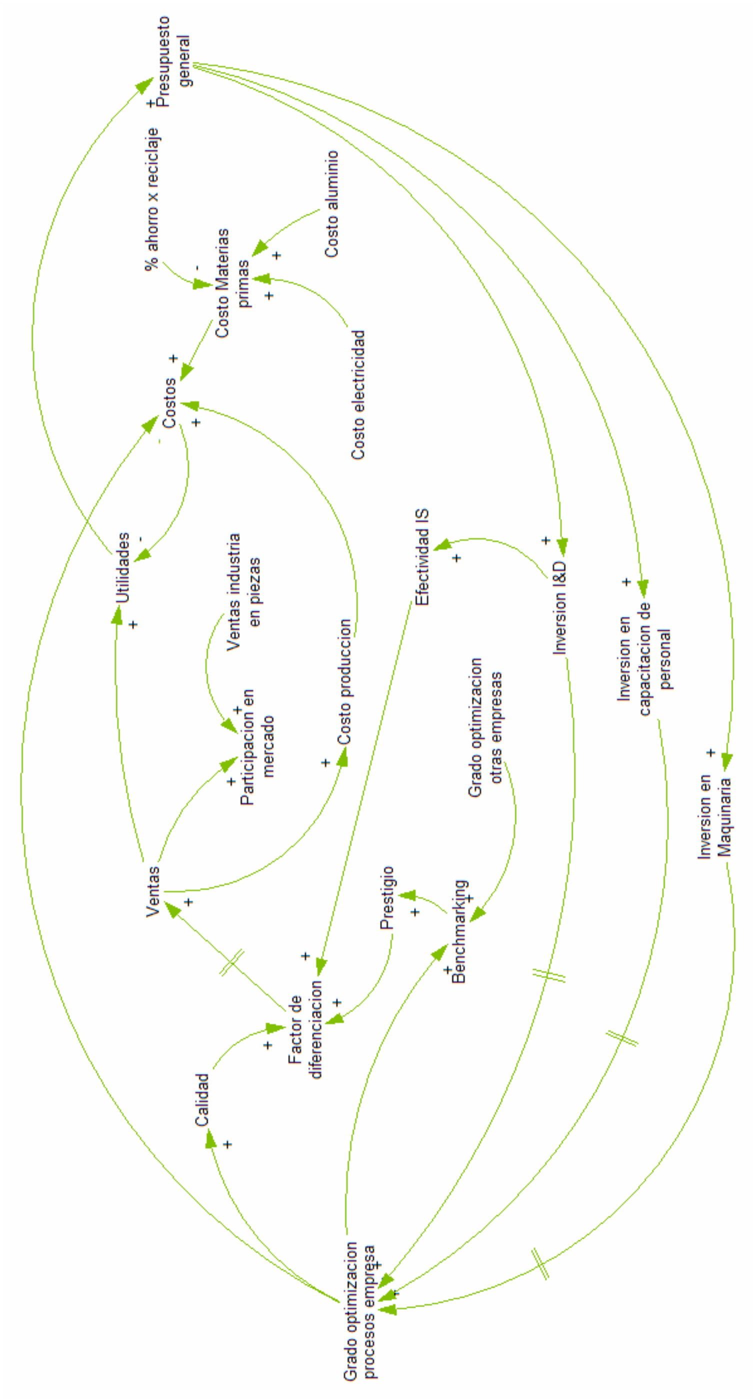
Appendix 1 Causal Loop Diagram



Appendix 2 Variables dictionary

Variable	Description	Exogenous	Endogenous	Controlable	Non-Controlable
Degree of optimization of other companies	How optimized are competitors' processes	X			X
Degree of optimization	How optimized are our processes		X	X	
Quality	Process and product quality, as a result of process improvement.		X	X	
Investment in machinery	Amount of money destined to buy new machinery.		X	X	
Sales	NEMAK's sales		X		X
R&D investment	Fraction of budget destined to R&D		X	X	
Investment in training	Money destined to training activities		X	X	
General Budget	Percent of profit destined to reinvestment		X	X	
Power costs	Power cost	X			X
Raw material cost	Raw material cost		X		
Aluminum cost	Aluminum cost	X			X
Percent of savings due to recy cling	Percent of costs that is saved due to recycling.	X		X	
Costs	Total production costs		X	X	
Industry sales in units	Total sales in the whole industry.	X			X
Production costs	Costs incurred to produce the units that will be sold.		X	X	
Profit	Profit from sales		X	X	
Effectiveness of concurrent engineering	Effectiveness obtained from concurrent engineering programs		X	X	
Market Share	Market Share		X	X	
Benchmarking	Benchmarking results		X		X
Reputation	Reputation on the market		X		X
Differentiation factor	Degree of differentiation compared with competitors		X		X
Raw material cost	Raw material cost	X			X

Appendix 3 Equations

Equation	Description
Profit_before_taxes(t) = Profit_before_taxes(t - dt) + (Sales_costs_difference - $_invested) * dt INIT Profit_before_taxes = 1096034	Company's profit. 2004 is taken as year zero. (given in thousands of pesos)
Sales_costs_difference = (Sales_in_units*.87)-Costs	Sales are multiplied times 0.87 thousands of pesos (870 pesos), which is the average price given to each unit. Costs are subtracted. This variable is a flow that accumulates in the profit.
$_invested = Profit_before_taxes	Is a way to reset the profit stock, it allows us to register yearly profit. Is the budget we are able to invest each year, without accumulating? It can be invested depending on 'Training', 'Machinery_investment' and ´R&D_budget'. (Thousands of pesos)
Sales_in_units(t) = Sales_in_units(t - dt) + (Inc_sales - output_sales) * dt INIT sales_in_units = 13100000	Stock that shows every year's sales. Its initial value is the one of year 2004. (units)
Inc_sales = (sales_in_units)*(1+(Differentiation_factor *(1-market_share)))	Yearly sales in thousands of pesos. They are directly connected to yearly sales in units. Depending on the differentiation factor, they can rise or drop with respect to the last year. As market share grows is harder to keep increasing sales. We modeled this level of difficulty as '1-market_share'.
output_sales = sales_in_units	Resets yearly the variable 'Sales_in_units'.
Degree_of_process_optimization(t) = Degree_of_process_optimization(t - dt) + (optimization_rate_of_change – optimization_reset) * dt INIT Degree_of_process_optimization = 6	The conventional equation for a stock. This variable shows how optimized are processes (10 is the maximum value of this scale)
optimization_rate_of_change = (MIN(DELAY((num_of_acquired_machines*.02*.05),1),.05)+MIN(DELAY((Highly_skilled_personnel*.1*.40),1),.40)+MIN(DELAY((R&D_programs*.25*.55),1),.55))*10	Process optimization is a function of machinery, training and R&D. They have weights of %%, 40% and 55%, respectively. Delays (time between investments and results) are given in years. In the end, we multiply times 10 to get a 0 to 10 scale.
optimization_reset = degree_of_process_optimization	To empty the Degree of process optimization variable.

Equation	Description
Market_share(t) = Market_share(t - dt) + (New_Share – output_share) * dt INIT Participacion_de_mercado = .48	Another stock. Initial value is 48%. Scale goes from 0 to 1.
New_share = Sales_in_units/industry_sales_in_units	Market share. It actualizes from year to year. Goes from 0 to 1.
Share_output = Market_share	To reset the Market share stock.
Reputation(t) = Reputation (t - dt) + (Change in reputation - Reset) * dt INIT Prestigio = 7	Indicates the company's reputation on the market. Scale from 0 to 10. Initial value of 7.
change_in_reputation = MIN((Reputation+(Benchmarking-6)),10)	It grows or decreases depending on the results of benchmarking. Six is the average industry value. Scale from 0 to 10.
Reset = Reputation	To reset the Reputation stock
industry_sales_in_units(t) = industry_sales_in_units (t - dt) + (rate_of_change) * dt INIT industry_sales_in_units = 27300000	2004 taken as initial value. In thousands of pesos.
rate_of_change = industry_sales_in_units*.05	A 5% yearly growth is estimated in this industry. Thousands of pesos.
Benchmarking = (degree_of_process_optimization/degree_of_optimization_of_other_leaders)*10	Benchmarking. Gives values from zero to 10. Other industries are expected to have a value of 10, which is very demanding to NEMAK.
Product_quality = minimum_quality+(degree_of_process_optimization*.1)	With totally optimized processes, product quality could be improved in 10%. The minimum quality variable refers to the quality obtained with very little investment. (0 to 10 scale)
Quality_in_service = minimum_service_standards+(degree_of_process_optimization*.3)	Analogous to the previous one. Minimum standard is fixed at 6. (0 to 10 scale)
minimum_quality = 6	Minimum quality NEMAK expects to have on its products.
Training= $_invested*.2	Percent of budget destined to training programs. In the model it is fixed to a value of 20%. (Thousands of pesos).
comparisson_with_competitor = degree_of_process_optimization/degree_of_customer_process_optimization	Works like the Benchmarking variable. Customer is fixed at 9.
Costs = cost_of_produced_units*(1-	The costs of the total production. The cost

Equation	Description
cost_reduction_percent)	reduction percent depends on the degree of optimization of the processes.
base_costs_per_unit = .6	Production costs of a unit, not counting raw materials (600 pesos).
aluminum_cost = .08	Production costs of the aluminum needed to make one unit.(80 pesos)
cost_of_produced_units = sales_in_units*(raw_material_costs_per_unit+base_costs_per_unit) power_rate = .12	Total production cost. (Thousands of pesos) Power costs in thousands of pesos
raw_material_costs_per_unit = power_rate+(aluminum_cost*(1-recycling_savings))	Cost of raw materials per unit
minimum_standard_of_service = 6	Minimum standard of service without additional investment in processes. (0 to 10 scale)
differentiation_factor = ((quality_in_service-5)*.2*.35)+((product_quality-6)*.25*.25)+((comparisson_with_competitor-5)*.2*.15)+((reputation-5)*.2*.15)+(Effectiveness_of_CE*.1)	Differentiation factor is composed of product quality, comparison with competitors, reputation and effectiveness of CE programs. Each of the factors has an assigned weight. The maximum value is one.
degree_of_optimization_of_competitor_processes = 10	Used to compute benchmarking. Fixed value of 10.
degree_of_optimization_of_competitor_processes = 9	Used to compute the comparison with competitors. Fixed value of 9.
maximum_index_of_reduction = 0	Fixed at zero, since we did not observe much chance to reduce costs any further.
investment_in_machinery = $_invested*.1	Percent of total investment that was destined to machinery. Currently 10%. (Thousands of pesos)
effectiveness_of_CE = implemented_CE_programs/total_CE_programs	To measure the effectiveness of CE programs.
Num_of_acquired_machines = investment_in_machinery/50	Divides money over the cost of each machine. (50 thousand pesos).
Highly_trained_workforce = (Training/30)*2	Two employees are estimated to cost 30 thousand pesos in training.
recycling_savings = .1	10% of the raw material costs are expected to be saved after recycling.

Equation	Description
Cost_reduction_percent= (degree_of_process_optimization*maximum_index_of_reduction)/10	Since Maximum index of reduction=0, it is always equal to zero.
R&D_budget = $_invested*.2	20% of the invested money goes to R&D. (Thousands of pesos)
Total_CE_programs = 4	Average number of yearly CE programs.
R&D_programs = R&D_budget/100	The estimated cost of a program is 100 thousand pesos. The output is the number of R&D programs in a year.
implemented_CE_programs= MIN(R&D_programs*.5,total_CE_programs)	Estimates that half of the R&D programs are CE related.
Sales_in_$ = sales_in_units*.87	Estimated price of a unit in the market of 870 pesos.

Appendix 4 Sensitivity analysis

The variables that were suitable for a sensitivity analysis were:

- Degree of process optimization
- Market share
- Reputation
- Profit
- Sales in units
- Industry sales in units
- Minimum Quality
- Base cost per unit
- Aluminum costs
- Power rates
- Minimum service standard
- Degree of optimization of competitors' processes
- Degree of optimization of industry leaders
- Maximum index of reduction
- Percent of savings due to recycling
- Total CE (Concurrent engineering) programs

Some of these variables are dynamic and only need a constant value to define their initial condition, but as the model runs, their value is determined by their outflows and inflows. Also, among this group, there are some other variables that remain constant as the model runs. If they are modified the behavior of the model is very likely to change. These variables are:

- Minimum Quality
- Base cost per unit
- Aluminum costs
- Power rates
- Minimum service standard
- Degree of optimization of competitors' processes
- Degree of optimization of industry leaders
- Maximum index of reduction
- Percent of savings due to recycling
- Total CE (Concurrent engineering) programs

The most representative variables for our model are: Power rates, minimum quality, minimum service standard, maximum index of reduction, base cost per unit and percent of savings due to recycling.

We could observe that reducing minimum product or service quality does not affect sales severely. Since quality is always improving, we will always be far away from the minimum, as long as it is a reasonable number.

The maximum reduction index, as its name suggests, is a factor that tells us how optimized are the processes. It reflects on cost reduction. In short words it means "How much can I pretend to reduce costs as I optimize processes?

To analyze this variable we established values of 0, 0.2 and 0.4. This last one is a little exaggerated (it implies that if processes are fully optimized, a 40% cost reduction can be achieved). Given that processes are optimal and that this index is a function of those processes, we can see that costs are really sensitive to this index.

We defined base cost per unit as the money required to produce a unit, not taking into account the cost of raw materials. Its units are thousands of pesos. To analyze this variable, we used values of 0.45, 0.5, 0.55 and 0.6 (from 450 to 600 pesos), which means we considered a maximum variation of 25% from the original value (600).

When we graphed this variable against the total costs (the production costs of the whole year), we could see that there was a significant difference among the best case (400 pesos per unit) and the worst one (600 pesos per unit). On the best case, costs are 20% smaller.

Our next analysis dealt with recycling. The original savings value was set to be 10%, but it only applies to raw materials. This is, a little less than 20 pesos. If we vary this value to 5, 10 and 15%, we can save a few pesos per unit; but they practically remain constant.

Power costs were not very significant in the sensitivity analysis, even if they affect profit more than 'savings due to recycling' do. The current price is 120 pesos per unit. We tried values of .06, .12 and .18 and we observed a difference of little more than 15% between the lowest and the highest value. We conclude that the value with the greatest leverage is 'base cost per unit'.