LEAN ENTERPRISE MODEL PROPOSAL FOR THE
EMERGING MEXICAN AEROSPACE INDUSTRY

TESIS

PRESENTADA COMO REQUISITO PARCIAL PARA OBTENER
EL GRADO ACADÉMICO DE:

MAESTRO EN CIENCIAS CON ESPECIALIDAD EN
SISTEMAS DE MANUFACTURA

POR:

CARLOS ALBERTO CALLEROS MARTINEZ

MONTERREY, N.L. DICIEMBRE 2005
Los miembros del comité de Tesis recomendamos que el presente proyecto presentado por el ING. CARLOS ALBERTO CALLEROS MARTINEZ sea aceptado como requisito parcial para obtener el grado académico de:

**Maestro en Ciencias con Especialidad en Sistemas de Manufactura**

Comité de Tesis:

---

Ing. Luis Vicente Cabeza Aspiazu
Asesor

Dr. Neale Ricardo Smith Cornejo
Sinodal

Dr. Jorge Limón Robles
Sinodal

Dr. Federico Viramontes Brown
Director del Programa de Graduados en Ingeniería
Diciembre 2005
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ABSTRACT

The aerospace industry is one of the most important markets in the United States. With sales reaching $161 billion in 2004, it contributes to around 9% of its Gross Domestic Product.

Mexico has a very small share of the aerospace market, with around 0.5% of the total; it is located in 19th place (according to statistics from 2004). At the moment, Mexico and Brazil (which is in 4th place) are the only Latin American countries involved in this market.

The major problems in Mexico are that: a) Most of the people and companies do not have a real insight and significance of this industry; and b) those already involved, face the challenge of becoming more competitive to maintain and increase their share.

Therefore, this thesis has 2 main purposes:

1.- To present a general introduction to the aerospace industry by describing its components and structure; presenting facts, figures, statistics, charts and information in order to understand its economic and strategic importance.

2.- To define and explain some of the models that are used to increase competitiveness in the companies. And propose a lean enterprise model, based in lean thinking concepts (manufacturing and logistics), suitable for its application as a tool and option to the organizations.

A 5-phase model is being proposed for implementation, which includes:

1.- Lean infrastructure deployment
2.- Organization’s flow redesign
3.- Operations management development
4.- Process improvements
5.- Continuous improvements

Some of the results that can be found (based in case studies) by applying the lean thinking concepts are:

<table>
<thead>
<tr>
<th>METRIC</th>
<th>RANGE OF RELATIVE IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
<td>11% to 50%</td>
</tr>
<tr>
<td>Productivity</td>
<td>27% to 100%</td>
</tr>
<tr>
<td>Cycle time</td>
<td>20% to 97%</td>
</tr>
<tr>
<td>Inventory</td>
<td>31% to 98%</td>
</tr>
<tr>
<td>Lead time</td>
<td>16% to 50%</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

I would like to thank the following persons for helping me finish this personal project:

God, for giving me health, strength, patience, intelligence and spiritual support.

My parents, Alberto Calleros and Clementina Martinez, my older brother Alberto. All the members of the Calleros and Martinez family for their wishes and help. To all of my friends, for being there when I needed it.

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From Arizona State University, I would like to thank Dr. Rene Villalobos and Dr. John Fowler for the lessons taught, and all the effort placed in the dual Master’s Program to make it a success.

Everybody at Yazaki Service Co, Inc., Yazaki North America and Arncem S.A. for allowing me to develop my first professional skills, and giving me the opportunity to grow as an engineer and as a person.

Cemex’s Technology Vicepresidency executive team in Mexico, for the professional opportunity.
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1.- INTRODUCTION

This chapter is intended to provide a brief introduction to the existence purpose of this work. Through its different sections, the reasons considered to develop it will be presented and described. It will also explain the approach that will be followed to lead this project to its successful completion.

1.1.- Background

In today’s competitive world, companies are always searching for opportunities to reduce costs, but at the same time increase key advantages giving added value to their products. This is not different for the aerospace industry manufacturing sector, greatly dominated by a few countries, including Mexico’s commercial partners U.S and Canada.

Such requirements, open a big door in this manufacturing area regarding commercial and business development opportunities, because among the advantages that can be considered are:

a) Lower labor costs compared to both countries (U.S. and Canada).
b) Lower supply chain costs compared to other countries due to geographical location.
c) Young, well educated workforce.
d) Local, high-experienced, english-speaking management.
e) Plenty of successful business experiences in other areas, like the automotive and electronics industry.

This situation can be seen, as there are already 65 aerospace products manufacturing plants installed, with a workforce close to the 10,000 persons involved\(^1\), most of these established within a 5-year span. These companies are considered to be the last link in the chain, when in fact, they may require also raw materials or some other processes from other companies, which would increase the numbers

How to achieve competitiveness?, How to reduce costs, labor hours, cycle times, factory space, inventories?, How to increase productivity?. The possible answers to all these and more issues can be addressed by presenting a lean enterprise model proposal for the emerging Mexican aerospace industry.

\(^1\) Dr. Eduardo Solis Sanchez, External Commerce and Investment Promotion Office Chief, from the Economy Secretariat, Aeroexpo 2005.
Lean Aerospace Initiative Group

In the 80’s, many U.S. industrial organizations, started developing new production processes to better respond customer requirements and pressures of global competition. This new paradigm was called “lean production” or simply “lean”. In 1993, a consortium of defense aerospace firms and the U.S. Air Force aeronautical systems center started the Lean Aircraft Initiative (LAI) at the Massachusetts Institute of Technology (MIT). In 1998, there was an expansion to include government space products, and the program was renamed Lean Aerospace Initiative, whose vision is to “significantly reduce the cost and cycle time for military aerospace products throughout the entire value chain while continue to improve product performance”

Obviously, due to the nature of the vision and the goals of this initiative, it is being applied not only in the military and defense division, but also in the commercial as well, where the Mexican industry can have a greater participation

1.2.- Problem definition

There is a need to make small companies competitive in a global environment, and to achieve that, there are several management concepts that can be applied. However, a methodology that relies on the lean thinking concepts, and that is easy to understand and implement through specific activities to create value, suitable for the Mexican aerospace industry (and manufacturing sector in general) conditions has not been properly developed.

Therefore, this thesis aims to propose an effective model that can be applied.

1.3.- Justification

Lean thinking is the application of the lean principles to every single area of an organization, not only in manufacturing, but also in product development, procurement process, etc.

It was mentioned before, according to the LAI vision, that lean concepts can significantly reduce the costs and cycle time of products throughout the entire value chain, while continue to improve product performance. Therefore, it is necessary to develop a thesis like this one, where a Lean Enterprise Model (successfully applied to many manufacturing companies) can be related and applied, in general, to the emerging Mexican aerospace industry, where the possible requirements, benefits and advantages can be studied.

1.4.- Objectives

There are several objectives that this project will cover:

1.- Provide a better insight and knowledge of the aerospace industry (mainly American), in order to understand its economic and strategic importance, and to identify opportunity areas.

2.- Present and describe the lean thinking concepts, lean manufacturing tools and some of the most commonly used models to increase competitiveness that are currently applied.

3.- Propose a model, based on the lean thinking concepts, which can be related to the emerging Mexican aerospace industry, including the specific activities that are required for its deployment and implementation.

4.- Analyze, through case studies, the impact of applying the lean thinking philosophy in an aerospace related company.

1.5.- Hypothesis

It is expected that the aerospace companies established in Mexico, regardless if they are a branch of another company or a specific organization created for the purpose of providing parts to another supplier within the industry, will increase their competitiveness by reducing overall costs and increasing added value to their products and customer satisfaction.

All this, by making a conscious self-assessment required by the Lean Enterprise Model, where the critical starting point is to define exactly what “value” means and what is the stream to achieve that value.

1.6.- Thesis approach and layout

The approach of the thesis will be to present the fundamental concepts related to each chapter and then support those with relevant information, statistics or case studies that may be applied.

Layout:

Chapter 2: It will deal with the U.S. Aerospace industry, going from its basic introduction and its economic importance to the description of some of the main companies.
Chapter 3: It will cover the current relationship between the U.S. aerospace industry and Mexico, including its share of the market, current suppliers, etc.

Chapter 4: It will make the description of the lean thinking concepts, in order to understand why they may apply to an aerospace organization and will also present the models that are currently being used to increase competitiveness.

Chapter 5: It will present the proposal of a Lean Enterprise Model that can be implemented in an aerospace industry related organization.

Chapter 6: It will present some case studies and some examples of the results that can be achieved with a successful implementation.

Chapter 7: Conclusions and Further research.
Chapter 2. - The U.S. aerospace industry

2.- THE U.S. AEROSPACE INDUSTRY

What is the Aerospace Industry (AI)? This is the question that, regularly, the average person will answer as: “the industry related with space”, which, in fact, it is true. So now the question becomes: What is considered “space”? and most likely the scope of the answers will be larger, without having a complete idea what exactly it is and what is it that covers. For instance, in Mexico, it is normal to relate the term “aerospace” with the outer space, so the industry may easily be associated with satellites, space shuttles, rockets, etc. Complicated systems where it is thought that there is no opportunity to compete.

*This has lead to a misconception of the AI, and to a lack of vision for companies and investors to get inside this profitable market.*

AI is of great importance for the economies of the United States (U.S. Department of Commerce, 2001) and Europe (ASD 2003) where it is highly developed. Similarly, it could offer great benefits to Mexico, so, due to this importance, it is necessary to understand correctly its scope.

This part is mainly focused on the U.S. AI (to establish a relationship with Mexico), but sometimes, for comparisons or relevancy purposes, the European AI will be covered as well.

The most important goal of this chapter is to give an introduction and a main idea of what the AI is all about, and also try to explain why is so important. In order to do so, 5 main topics will be covered: 1.- What is considered the AI, 2.- Importance of AI from a worldwide perspective, 3.- Understanding the U.S. industrial activity classification (to reference the AI), 4.- Current market share in the U.S. AI by country and 5.- Main American companies of the U.S. AI. This will eventually lead to where is Mexico currently located in this industry and what are some of the potential opportunities that can be taken.

2.1.- What is considered the aerospace industry

The AI is a broad entity that encompasses several divisions within itself. According to the Aerospace Industries Association of America (AIA) “it is the industry engaged in research, development and manufacture of aircraft, missiles, space launch vehicles, also involved in the production of propulsion, guidance and control systems for the previous components, and finally it is also involved in the procurement of airborne or ground-based equipment necessary for the test, operation and maintenance of all aircraft and spacecraft”.

They also establish 3 main classification areas (See figure 1). 1.- The Defense division, which covers aerospace related products with military purposes.
2.- The Civil division, but still under Federal government scope, that covers non-military products such as weather satellites, space programs, regulations, etc.

3.- The Commercial division that is involved with aircraft manufacturing, parts manufacturing, airport operations, etc.

- Defense
  - Air (e.g., combat aircraft, airlift, unmanned aerial vehicles, guided missiles)
  - Space (e.g., space launch, communications, navigation and reconnaissance satellites)
  - Intelligence (e.g., air and space-based communications, reconnaissance)
- Civil (other government)
  - Air (e.g., air traffic management system, safety regulation, accident investigation, environmental permitting, noise and emission standards)
  - Space (e.g., weather satellites, air- and space-based earth monitoring, International Space Station, Space Shuttle, Hubble Space Telescope, robotic missions to the planets)

Another description is given by Hayward (1994), and explains that it was during the 1950’s when the aircraft industry was transmuted into an aerospace industry. There were broad categories of aircraft; civil and military within which size and specific function would serve further to differentiate types.

He also proposes a functional description in terms of a pyramid structure. “At the top there are a few fully capable prime contractors or system integrators, usually airframe manufacturers and an equally small group of engine makers. A larger group of discrete systems and equipment firms. Finally a lot of medium and small suppliers, sub-contractors (See figure 2).
This was an overview of how the AI can be defined and described. As mentioned before it has a complex structure but it offers a wide range of opportunities to get involved with.

Special attention should be made to the last level of the pyramid, which is where Mexicans suppliers could fit accordingly, as the first step to become involved. In fact this pyramid structure can illustrate the idea of tiers suppliers, same concept as the automotive industry. And therefore opportunity at a tier 3, 4 or even 5 levels must be considered, because they provide the pinpoint where advantages can be taken, being those labor intensive.

2.2.- Importance of the aerospace industry from a worldwide perspective

It was mentioned before that the AI is of great importance for the economies of the United States and Europe, where is extensively developed.

To illustrate this, let’s take a look at some of the facts: (aircraft carriers and airport operations are not being considered, only manufacturers and suppliers of all segments, direct employment only).
Chapter 2.- The U.S. aerospace industry

Table 1
Some AI relevant economic facts

<table>
<thead>
<tr>
<th>METRIC</th>
<th>U.S.</th>
<th>European Union (E.U.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales (U.S. dollars)</td>
<td>161 billion</td>
<td>96.2 billion</td>
</tr>
<tr>
<td>Trade balance (U.S. dollars)</td>
<td>34 billion</td>
<td>3 billion</td>
</tr>
<tr>
<td>Gross domestic product contribution</td>
<td>9 %</td>
<td>3%</td>
</tr>
<tr>
<td>Employment (Workers)</td>
<td>579,800</td>
<td>414,500</td>
</tr>
<tr>
<td>Average annual salary (U.S. dollars)</td>
<td>49,000</td>
<td>40,560</td>
</tr>
</tbody>
</table>

1 Aerospace Industries Association
2 U.S. Department of Labor
3 Using an exchange rate of 1.3 U.S. dollars per Euro
4 Aerospace and Defense Industries Association of Europe
5 Society of British Aerospace Companies

This information is provided only to show some important figures and what they represent for each region; it is not intended to say that one is better than the other.

The Employment numbers shown are related to direct positions. Indirect employment, as consequence of the AI, is estimated to be at 11 million workers at the U.S. (AIA) and 900,000 at the E.U. (ASD), which is significantly higher.

After explaining the previous facts, it is now possible to take a look at how the worldwide AI market is divided (e.g. who supply the products that the AI covers).
For the chart shown, data from 2002 was taken. The outcome of it should not be surprising:

<table>
<thead>
<tr>
<th>Region</th>
<th>2002 Market Share (%)</th>
</tr>
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<tbody>
<tr>
<td>Canada</td>
<td>5.40</td>
</tr>
<tr>
<td>USA</td>
<td>52.50</td>
</tr>
<tr>
<td>European Union</td>
<td>33.20</td>
</tr>
<tr>
<td>Japan</td>
<td>5.80</td>
</tr>
<tr>
<td>Rest of World</td>
<td>3.10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

As expected the U.S. and E.U. dominated the market with an approximated combined share of 85%, and if Canada and Japan are included more than 95% of the market is covered, so basically, it’s only divided among 3 countries and the E.U. counted as a whole.

**EADS**

Since the chapter is focused mostly in the U.S. AI, it is of relevance in this section, to mention the most important European company: EADS. (European Aeronautic Defense and Space Company). “The company came into being in the year 2000 emerging from the link-up of the French Aerospatiale Matra, CASA (Construcciones Aeronauticas S.A.) of Spain and the German DaimlerChrysler Aerospace AG” (EADS internet site).

The Group has integrated headquarters with the strategy, marketing and legal affairs functions in Paris; and the finance, sourcing and communications
function in Munich. It employs more than 110,000 people at more than 70 production sites predominantly in Germany, France, Great Britain and Spain.

EADS has 5 different divisions within, these are: 1.- Airbus, 2.- Military transport aircraft, 3.- Aeronautics, 4.- Space and 5.- Defense and security systems. They had revenues for $39 billion in 2004, and they cover basically every segment in the AI market (refer to figure 4).

![Figure 4 - Worldwide rank of EADS per AI segment](source: EADS website)

The worldwide relevance of this company is that represents the best competitor for the U.S. companies. It is a fully integrated company with presence all across Europe and serving every market, from commercial to military. Business opportunities with them should be considered in the near future as well, because it can represent an expansion of the market that is being studied.
2.3.- Understanding the U.S. industrial activity classification (to reference the AI)

If the U.S. market is to be observed, first of all, it is necessary to understand how the industrial activity is classified to determine the activity level and the countries that are involved.

The U.S. Department of Commerce (DOC), through its Economics and Statistics Administration (ESA) has a Census Bureau (CB) office. The CB is the final responsible to classify and register the industrial information, among other activities. The CB has a system called NAICS, which stands for North American Industry Classification System, created jointly with Mexico and Canada, to provide comparability in Statistics about business activity across North America (this system replaced the old U.S. Standard Classification called SIC).

Within this system, there is a big classification under the name of “Numerical list of manufactured and mineral products”. The mining sectors range from 211 to 213, meanwhile the manufacturing sectors range from range from 311 to 339. Index number 336 is the “Transportation equipment manufacturing”, and within this index are those related with the AI activities.

For illustration purposes and for the complete detail of each one please refer to figure 5, and for the description of each and every AI activity refer to appendix A. (This data has been taken from the U.S. Census Bureau website).

**Figure 5**

AI activity location within the NAICS classification
2.4.- Current market share in the United States’ aerospace industry by country

As mentioned in section 2.2, the U.S. based companies had more than half the market share of the world’s AI in 2003 (and this is the reason why this chapter is being focused only into the U.S. market). The next topic to investigate is how this huge market is being supplied. It is necessary to determine how much is being imported by the U.S. to understand why countries are interested in competing in this segment.

According to information by the U.S. Department of Commerce, these, were the imports from the world under the NAICS 336 classification (as previously seen, within this index are the AI activities), please refer to figure 6.

<table>
<thead>
<tr>
<th>Product</th>
<th>Value ($)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>3361-MOTOR VEHICLES</td>
<td>140,769,510,332</td>
<td>58.5 %</td>
</tr>
<tr>
<td>3363-MOTOR VEHICLE PARTS</td>
<td>65,012,913,067</td>
<td>27 %</td>
</tr>
<tr>
<td>3364-AEROSPACE PRODUCTS &amp; PARTS</td>
<td>24,672,914,801</td>
<td>10.3 %</td>
</tr>
<tr>
<td>3369-TRANSPORTATION EQUIPMENT, NES50I</td>
<td>5,349,537,348</td>
<td>2.2 %</td>
</tr>
<tr>
<td>All Others</td>
<td>4,627,907,730</td>
<td>1.8 %</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>240,417,284,136</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

Source: U.S. Department of Commerce

Figure 6

2004 U.S. AI imports under NAICS

It can be seen that the value of the imports of AI products for 2004 was close to $25 billion, only below the enormous market for the motor vehicles and their parts (which, by the way, is highly developed and competitive in Mexico). The imports’ tendency can also be evaluated by the following table:
Chapter 2.- The U.S. aerospace industry

In this table, it can be seen that after 2001 the market actually shrunk around 17%, and one logical reason for this are the September 11th terrorist events, which had a great negative impact for the industry worldwide, not only in the U.S. After that, it has been somewhat steady and predictions for 2005 (AIA) estimate that it will remain around the same percentage.

Now, it is possible to identify how is the market divided, and who are the main suppliers.

<table>
<thead>
<tr>
<th>Item</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Total</td>
<td>213,384,219</td>
<td>211,688,865</td>
<td>219,242,544</td>
<td>222,566,197</td>
<td>240,417,284</td>
</tr>
<tr>
<td>3361-MOTOR VEHICLES</td>
<td>126,283,839</td>
<td>124,239,758</td>
<td>131,842,426</td>
<td>132,141,396</td>
<td>140,758,510</td>
</tr>
<tr>
<td>3363-MOTOR VEHICLE PARTS</td>
<td>61,812,498</td>
<td>48,429,354</td>
<td>53,652,627</td>
<td>58,022,032</td>
<td>66,012,814</td>
</tr>
<tr>
<td>3364-AEROSPACE PRODUCTS &amp; PARTS</td>
<td>20,593,625</td>
<td>31,373,581</td>
<td>20,131,489</td>
<td>24,236,873</td>
<td>24,677,915</td>
</tr>
<tr>
<td>3369-TRANSPORTATION EQUIPMENT, NESOI</td>
<td>3,087,181</td>
<td>3,979,625</td>
<td>4,309,352</td>
<td>4,568,065</td>
<td>5,340,537</td>
</tr>
<tr>
<td>3362-MOTOR VEHICLE BODIES &amp; TRAILERS</td>
<td>1,988,947</td>
<td>1,375,010</td>
<td>1,261,921</td>
<td>1,472,285</td>
<td>1,843,083</td>
</tr>
<tr>
<td>3366-SHIPS &amp; BOATS</td>
<td>1,103,247</td>
<td>1,127,449</td>
<td>1,174,075</td>
<td>1,283,486</td>
<td>1,774,971</td>
</tr>
<tr>
<td>3365-RAILROAD ROLLING STOCK</td>
<td>1,014,883</td>
<td>1,163,088</td>
<td>870,655</td>
<td>852,581</td>
<td>1,009,554</td>
</tr>
<tr>
<td>336Z-TRANSPORTATION EQUIPMENT, NESOI</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Qualities in thousands USD)
Source: U.S. Department of Commerce

In this table, it can be seen that after 2001 the market actually shrunk around 17%, and one logical reason for this are the September 11th terrorist events, which had a great negative impact for the industry worldwide, not only in the U.S. After that, it has been somewhat steady and predictions for 2005 (AIA) estimate that it will remain around the same percentage.

Now, it is possible to identify how is the market divided, and who are the main suppliers.

Source: U.S. Department of Commerce

Figure 7
Countries suppliers of the U.S. AI
The previous chart showed all the countries that currently supply the U.S. AI, but the shipments differences are big. The detail of the shipments will be shown in table 3, and we can determine the most important ones (note that only up to the 25th place will be shown, for the complete list please refer to appendix B)

Table 3
25 top suppliers to the U.S. AI and value of shipments

<table>
<thead>
<tr>
<th>Partner</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Total</td>
<td>26,693,626</td>
<td>31,379,581</td>
<td>26,131,489</td>
<td>24,236,673</td>
<td>24,677,915</td>
</tr>
<tr>
<td>Canada</td>
<td>6,010,760</td>
<td>7,659,006</td>
<td>6,742,886</td>
<td>7,559,062</td>
<td>6,726,756</td>
</tr>
<tr>
<td>France</td>
<td>7,882,609</td>
<td>8,604,605</td>
<td>7,278,749</td>
<td>6,080,636</td>
<td>5,842,756</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3,888,856</td>
<td>4,505,806</td>
<td>3,327,419</td>
<td>2,805,417</td>
<td>2,677,252</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,465,564</td>
<td>1,971,733</td>
<td>1,865,775</td>
<td>1,852,694</td>
<td>2,518,166</td>
</tr>
<tr>
<td>Germany</td>
<td>3,264,800</td>
<td>3,695,921</td>
<td>2,427,369</td>
<td>1,776,169</td>
<td>2,103,274</td>
</tr>
<tr>
<td>Japan</td>
<td>1,563,165</td>
<td>1,891,552</td>
<td>1,438,020</td>
<td>1,356,338</td>
<td>1,491,618</td>
</tr>
<tr>
<td>Israel</td>
<td>452,511</td>
<td>515,349</td>
<td>547,647</td>
<td>552,459</td>
<td>571,284</td>
</tr>
<tr>
<td>Italy</td>
<td>446,734</td>
<td>496,894</td>
<td>566,725</td>
<td>403,057</td>
<td>409,826</td>
</tr>
<tr>
<td>South Korea</td>
<td>192,809</td>
<td>300,021</td>
<td>213,113</td>
<td>201,890</td>
<td>236,840</td>
</tr>
<tr>
<td>Switzerland</td>
<td>159,214</td>
<td>166,911</td>
<td>160,109</td>
<td>149,456</td>
<td>182,516</td>
</tr>
<tr>
<td>Netherlands</td>
<td>153,884</td>
<td>160,087</td>
<td>156,581</td>
<td>148,978</td>
<td>162,400</td>
</tr>
<tr>
<td>China</td>
<td>64,056</td>
<td>88,130</td>
<td>83,624</td>
<td>100,168</td>
<td>153,073</td>
</tr>
<tr>
<td>Singapore</td>
<td>90,466</td>
<td>119,780</td>
<td>123,971</td>
<td>120,885</td>
<td>146,610</td>
</tr>
<tr>
<td>Sweden</td>
<td>127,610</td>
<td>159,917</td>
<td>125,962</td>
<td>107,548</td>
<td>143,692</td>
</tr>
<tr>
<td>Spain</td>
<td>43,033</td>
<td>50,329</td>
<td>74,448</td>
<td>49,764</td>
<td>123,012</td>
</tr>
<tr>
<td>Belgium</td>
<td>112,052</td>
<td>128,416</td>
<td>106,637</td>
<td>113,380</td>
<td>111,330</td>
</tr>
<tr>
<td>Taiwan</td>
<td>61,576</td>
<td>73,797</td>
<td>50,196</td>
<td>77,102</td>
<td>109,405</td>
</tr>
<tr>
<td>Australia</td>
<td>107,943</td>
<td>135,221</td>
<td>120,532</td>
<td>114,105</td>
<td>105,328</td>
</tr>
<tr>
<td>Mexico</td>
<td>111,827</td>
<td>116,213</td>
<td>282,923</td>
<td>126,792</td>
<td>99,596</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>13,426</td>
<td>30,741</td>
<td>44,181</td>
<td>73,432</td>
<td>97,574</td>
</tr>
<tr>
<td>Austria</td>
<td>44,444</td>
<td>46,774</td>
<td>35,844</td>
<td>44,568</td>
<td>95,329</td>
</tr>
<tr>
<td>Turkey</td>
<td>84,447</td>
<td>88,713</td>
<td>68,613</td>
<td>70,786</td>
<td>88,660</td>
</tr>
<tr>
<td>Ireland</td>
<td>50,432</td>
<td>58,843</td>
<td>59,618</td>
<td>45,836</td>
<td>66,033</td>
</tr>
<tr>
<td>Norway</td>
<td>50,557</td>
<td>83,050</td>
<td>87,217</td>
<td>58,291</td>
<td>65,995</td>
</tr>
<tr>
<td>Poland</td>
<td>18,956</td>
<td>22,686</td>
<td>21,990</td>
<td>29,517</td>
<td>57,250</td>
</tr>
</tbody>
</table>

(Quantities in thousands USD)
Source: U.S. Department of commerce

Between Canada and France, they have more than 50% of the market with close to $12.5 billion in exports to the U.S. Mexico is located in 19th place as a trading partner, but more important is to notice the exports' decrement that has been going on since 2002. Remarkable is the position of Brazil, the only Latin American country ahead of Mexico on this table, located in the 4th position.
2.5.- Main American companies of the U.S. aerospace industry

In the previous section, the imports that the U.S. AI market did from 2000 to 2004 were reviewed. The amount per year was obtained, and it was concluded that, despite a contraction in the market since 2001, it is still an important one, that it is necessary to start getting involved with.

Now, it is of interest of knowing who are the most important companies in the U.S. that are related with this industry, with the purpose of knowing what areas are they into, and what are they known for. Only the top 5 American companies will be briefly described, (for a complete detail of the Top 30 AI companies worldwide refer to Appendix C). The ranking is given by the volume of sales in 2002.

Table 4
Brief description of the top 5 AI American companies

<table>
<thead>
<tr>
<th>COMPANY (U.S. ranking)</th>
<th>MARKET/PRODUCT OVERVIEW</th>
<th>2002 SALES ($ MILLION)</th>
<th>ESTIMATED NUM. OF EMPLOYEES</th>
<th>PRIMARY COMPETITORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.- The Boeing Company</td>
<td>- World’s largest company with 2 key industry segments: a) Commercial airplanes b) Integrated defense systems - Commercial aircraft: 767, 747 and 737 - Space operations: communications satellites, Delta rockets, missiles and Space Shuttle</td>
<td>54,069.0</td>
<td>166,000</td>
<td>- Airbus - EADS - Lockheed Martin</td>
</tr>
<tr>
<td><a href="http://www.boeing.com">www.boeing.com</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.- Lockheed Martin Corp.</td>
<td>- Leading worldwide defense contractor - Primary operations: Electronic systems, space systems, aeronautics, integrated systems and solutions and technology services</td>
<td>26,578.0</td>
<td>125,000</td>
<td>- Boeing - Northrop Grumman</td>
</tr>
<tr>
<td><a href="http://www.lockheedmartin.com">www.lockheedmartin.com</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continues in the next page)
### Chapter 2: The U.S. aerospace industry

<table>
<thead>
<tr>
<th>COMPANY (U.S. ranking)</th>
<th>MARKET/PRODUCT OVERVIEW</th>
<th>2002 SALES ($ MILLION)</th>
<th>ESTIMATED NUM. OF EMPLOYEES</th>
<th>PRIMARY COMPETITORS</th>
</tr>
</thead>
</table>
| 3.- Northrop Grumman Corp.  
www.northgrum.com | - The world’s # 2 defense contractor  
- Operations include: Electronic systems, information Technology, integrated systems and component technology | 17,206.0 | 117,300 | - Boeing  
- General Dynamics  
- Lockheed Martin |
| 4.- GE Aircraft Systems  
www.geae.com | - A business unit of GE-worldwide producer of engines for commercial and military aircraft  
- Aircraft types include: Jet, turboprop and turbo shaft engines | 11,141.0 | 26,000 | - Honeywell Aerospace  
- Pratt and Whitney  
- Rolls-Royce |
| 5.- Honeywell Aerospace  
www.honeywellaerospace.com | - Business unit of Honeywell International  
- Operations/products include: aircraft engines and systems, aerospace electronics and landing gear components | 8,855.0 | 4,000¹ | - Boeing  
- Lockheed Martin  
- United Technologies |

Source: World trade magazine 2003  
¹ Honeywell Aerospace

These are the types of companies that fit into the top and middle levels of the pyramid structure described in the first section of this chapter, which means that final assembly and main sub-systems are developed here. These companies, in turn, need for supply of raw materials, basic parts and components, sub-assemblies, etc., everything that can be integrated into the main sub-systems that will eventually be delivered for final assembly. Together, these companies have sales for more than $117,000 million and employ more than 438,000 persons.

**Consolidation**

These AI companies are not excluded from the worldwide trend going on right now on businesses: Consolidation. They have identified that, in order to compete in the global markets, it is necessary to have a solid structure to support operations. Mergers, joint ventures and acquisitions have been going on since the 80’s, and that trend increased in the 90’s. This provided a chance to strengthen weak areas, develop future businesses and, of course, gain market share.
Figure 8 shows the consolidation history for 3 of the AI companies: Lockheed Martin, Boeing and Northrop Grumman.

This has been an introduction to the most important AI American companies, and the products and systems that they build. Up to this level, it is still somewhat complicated to define exactly where can a Mexican company fit in this supply chain. It is more likely that it will fit in the bottom part of the pyramid structure, meaning, the very basic level of it, supplying parts even for other direct or indirect suppliers of the main companies.
3.- MEXICO AND THE U.S. AEROSPACE INDUSTRY

In the previous chapter, a general introduction on the aerospace industry was presented. Importance of the market was explained and some key statistics were shown, including: sales, trade balance and employment (among others) for the top markets of the AI: U.S. and Europe.

Then, the scope was narrowed down only to the U.S. market, and information of which countries are the main suppliers to this AI and who are the most important American based companies, including some of their relevant facts, was presented.

The purpose of having the first chapter as an introduction to the AI was to have a better understanding of it, and once this has been achieved, the next step is try to identify some potential opportunities for business, based on some of the facts already described.

The most important goal of this chapter is try to present the current situation of Mexico in regards with the AI, what is going on right now, and what can be done to get involved. In order to do so, 4 main topics will be covered: 1.- Mexico’s share on the AI, 2.- Main Mexican suppliers and their products, 3.- Geographical aspects of current Mexican suppliers locations and American suppliers sites and, 4.- Vision of Mexico’s needs to develop this industrial sector.

When the previous topics are properly described, and there is a clear conception of where Mexico has business opportunities, the expected vision of Mexico’s needs in this industry will be of relevance, and this will lead the work towards the idea that implementing a lean enterprise model makes sense to become more competitive.

3.1.- Mexico’s share on the aerospace industry

The exact share that Mexico currently has on the AI is difficult to determine. If search for it in different sites on the Internet, or published magazine articles or newspapers it can be found that the amount varies from each publication. To avoid these differences the only information that will be considered are the statistics from the U.S. Department of Commerce (DOC). In their site, they provide information for almost any trade activity, whether imports or exports, so this is the most reliable source.
According to the DOC, these were the Imports of the U.S. from Mexico for transportation products in 2004 (see figure 9), in which the aerospace parts and products can be located:

![Pie chart showing imports from Mexico by NAICS](image)

<table>
<thead>
<tr>
<th>Product</th>
<th>Value ($)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>3361 - MOTOR VEHICLES</td>
<td>18,768,235,640</td>
<td>50.4 %</td>
</tr>
<tr>
<td>3362 - MOTOR VEHICLE PARTS</td>
<td>17,922,668,686</td>
<td>48 %</td>
</tr>
<tr>
<td>3362 - MOTOR VEHICLE BODIES &amp; TRAILERS</td>
<td>333,332,226</td>
<td>0.8 %</td>
</tr>
<tr>
<td>3364 - AEROSPACE PRODUCTS &amp; PARTS</td>
<td>99,688,439</td>
<td>0.3 %</td>
</tr>
<tr>
<td>All Others</td>
<td>149,134,214</td>
<td>0.4 %</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>37,232,375,878</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

Source: U.S. Department of Commerce

Figure 9

2004 U.S. imports on transportation products from Mexico under NAICS

It can be seen that, out of more than $37 billion in imports from Mexico for this category, only an extremely low 0.3% represents the AI products. It is located on fourth place, but far behind from the leaders that are the motor vehicles (automobiles) and the motor vehicle parts. The difference is huge, with close to $18.7 billion in difference from the motor vehicles and $17.7 billion with the motor vehicle parts in 2004.

It's also possible to review the U.S. imports under this category for the past 14 years (since 1990), again the AI products can be located and the tendency could be observed as follows (refer to table 5):
### Table 5

**U.S. imports on transportation products from Mexico since 1990**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Total</strong></td>
<td>5,394,346</td>
<td>6,562,999</td>
<td>7,805,746</td>
<td>8,228,477</td>
<td>12,332,847</td>
<td>16,220,391</td>
<td>20,026,600</td>
<td>22,674,598</td>
<td>24,580,848</td>
<td>29,340,075</td>
<td>35,786,036</td>
<td>35,182,134</td>
<td>36,556,782</td>
<td>35,705,331</td>
<td>37,232,376</td>
</tr>
<tr>
<td>3361-MOTOR VEHICLES</td>
<td>2,440,014</td>
<td>2,842,133</td>
<td>3,108,944</td>
<td>3,726,984</td>
<td>4,786,686</td>
<td>7,829,490</td>
<td>11,266,026</td>
<td>12,095,228</td>
<td>13,172,096</td>
<td>15,787,098</td>
<td>20,986,709</td>
<td>21,295,596</td>
<td>20,887,049</td>
<td>16,169,775</td>
<td>19,788,236</td>
</tr>
<tr>
<td>3363-MOTOR VEHICLE PARTS</td>
<td>3,092,361</td>
<td>3,334,342</td>
<td>4,111,957</td>
<td>4,836,813</td>
<td>7,360,634</td>
<td>8,100,119</td>
<td>9,091,617</td>
<td>10,283,301</td>
<td>10,937,303</td>
<td>12,538,421</td>
<td>13,876,705</td>
<td>13,251,839</td>
<td>15,181,062</td>
<td>16,008,428</td>
<td>17,882,087</td>
</tr>
<tr>
<td>3362-MOTOR VEHICLE BODIES &amp; TRAILERS</td>
<td>3,333</td>
<td>12,480</td>
<td>37,572</td>
<td>53,307</td>
<td>100,254</td>
<td>139,735</td>
<td>120,257</td>
<td>136,596</td>
<td>185,107</td>
<td>280,035</td>
<td>242,630</td>
<td>229,409</td>
<td>132,701</td>
<td>294,744</td>
<td>333,333</td>
</tr>
<tr>
<td>3364-AEROSPACE PRODUCTS &amp; PARTS</td>
<td>65,068</td>
<td>65,264</td>
<td>52,755</td>
<td>47,266</td>
<td>46,524</td>
<td>44,381</td>
<td>54,906</td>
<td>74,124</td>
<td>85,943</td>
<td>125,013</td>
<td>111,627</td>
<td>119,213</td>
<td>282,923</td>
<td>125,792</td>
<td>99,966</td>
</tr>
<tr>
<td>3365-RAILROAD ROLLING STOCK</td>
<td>6,266</td>
<td>6,604</td>
<td>5,390</td>
<td>26,070</td>
<td>16,115</td>
<td>39,312</td>
<td>41,087</td>
<td>48,979</td>
<td>242,656</td>
<td>555,579</td>
<td>511,627</td>
<td>253,189</td>
<td>44,229</td>
<td>51,851</td>
<td>71,887</td>
</tr>
<tr>
<td>3366-SHIPS &amp; BOATS</td>
<td>1,267</td>
<td>967</td>
<td>983</td>
<td>729</td>
<td>175</td>
<td>384</td>
<td>340</td>
<td>2,557</td>
<td>714</td>
<td>347</td>
<td>726</td>
<td>126</td>
<td>11,618</td>
<td>42,581</td>
<td>63,876</td>
</tr>
<tr>
<td>3369-TRANSPORTATION EQUIPMENT, MISC</td>
<td>8,358</td>
<td>5,415</td>
<td>12,143</td>
<td>16,779</td>
<td>10,253</td>
<td>19,470</td>
<td>20,368</td>
<td>35,205</td>
<td>56,039</td>
<td>81,612</td>
<td>68,312</td>
<td>49,790</td>
<td>16,209</td>
<td>13,349</td>
<td>13,368</td>
</tr>
</tbody>
</table>

*(Quantities in thousands USD)*

Source: U.S. Department of Commerce
It is important to notice here, that the big difference between the AI and the automobile industry has always been going on (as shown in table 5). A bar graph showing this tendency can be plotted with the above data (refer to figure 10 and 11). Notice that the AI segment is being compared against the motor vehicle parts only, which has more significance rather than compare it with the whole car as a product, because it makes more sense that the actual AI parts that are currently being produced are merely basic parts or assemblies, not sub-systems, systems or complete products. Using these charts we can describe what has happened with these two industries and their development.

![Figure 10](image)

*Figure 10*

Tendency of U.S. imports on aerospace parts from Mexico since 1990

![Figure 11](image)

*Figure 11*

Tendency of U.S. imports on motor vehicle parts from Mexico since 1990
Based on figure 10, it can be concluded that the exports from Mexico on AI parts had a significant increment since 1997, and that the growth remained constant in 1998 and 1999. After that, it remained relatively steady, until 2002 when the exports rocketed to over $280 million, a 144% increase from the previous year. The first logical explanation for this behavior, are the terrorist attacks over the U.S. on September 11 2001.

After this event, there were a lot of concerns with the procurement of parts due to transportation and security related issues, so (as seen in the previous section, refer to table 3) a lot of countries suffered a shrinkage of their market share, while Mexico boosted theirs. A golden opportunity was missed here, where, should properly developed, would have represented a constant increase for it. It turned out that this advantage wasn't exploited, and in 2004 there were the same exports’ levels as of 1999.

In the other hand, the motor vehicle parts exports have been increasingly growing since 1990, with the only exception of the year 2001, so it is a very positive tendency, and it is expected to continue in this way, due to the improvements in both U.S. and Mexico economies.

**Why the AI parts industry and the motor vehicle parts industry are being compared?**

An explanation on the relation and differences in both industries is provided by A.T. Kearney Inc. (2003):

“The automotive sector may be the blueprint for the developments taking place in the aerospace industry. In fact, many top aerospace companies have hired experts from the automotive industry to advise them, albeit with mixed success.

The two industries have a lot in common. Their products are both highly complex and require significant engineering, manufacturing and supply chain management capabilities. Both products can be broken down fairly easily into major modules and systems, some of which relate mainly to electronics, some to mechatronics and some to mechanics. And both industries have a small number of manufacturers that rely on a broad spectrum of suppliers in several tiers, from parts manufacturers and sub-assembly suppliers to system integrators.

Still, there are a few differences. For example cycle times in the automotive industry are dramatically shorter than in aerospace, where in many cases products have a production life of 25 years. A car may consist of some 7,000 parts, whereas an airplane can consist up to 6 million parts. And the 75,000 hp that takes to power a Boeing 747 is far greater than the hp needed to run a car. In addition, the automakers have far higher production volumes, which give them a much sharper edge on implementing improvements. But these differences should not stand in the way of recognizing and building on the similarities”.
These are some of the reasons why the industries are being compared. And based on the fact that Mexico has a strong market for the motor vehicle parts, some advantages can be taken from here.

3.2.- Main Mexican suppliers and their products

Information regarding this topic could not be easily found. Since there is no such thing as a Mexican aerospace suppliers association or some organization like that, there is no central site to look for data or statistics about the actual products that are being manufactured, so there is no direction on where to go, should a company is interested in finding suppliers for AI parts.

This represent a great opportunity area, not only for the federal governments, but for the state and local ones, as well as for the universities and private companies to start working together to develop a structure that can support the industry and promote it around the world. In this way, facilitating the information search for customers and in order to develop future business opportunities.

One of the most industrial states in Mexico, Nuevo Leon, is pursuing the development of the AI, where several companies have established there in the past 2 years. The state government has been working with Tec de Monterrey (university), in order to perform some research about the status of the AI Mexico wide and what are the future opportunities for business. Since the state is very well developed in the automotive industry it is logical to explore the AI supplying option.

However, there is a map developed by the Economy Secretariat (see figure 12), that shows the location of the AI companies established in Mexico by state, it shows the big picture of where are the companies located.
Chapter 3.- Mexico and the U.S. aerospace industry

65 COMPANIES ESTABLISHED

Companies by State:

Baja California (30)
Sonora (12)
Chihuahua (4)
Nuevo Leon (4)
Yucatan (3)
Coahuila (2)
San Luis Potosi (2)
Jalisco (4)
Distrito Federal (2)
Querétaro (1)
Aguascalientes (1)


Figure 12
The aerospace industry suppliers in Mexico
The detail of each company will not be described (there is no information about sales, or employment or specific products that are being built), but top U.S. based companies can be observed such as Honeywell and Northrop Grumman, that have transferred some production to these facilities. Figure 13 shows graphically the main distribution of the AI suppliers in Mexico.

![Figure 13](image.png)

**Figure 13**
*Percentage of AI suppliers in Mexico by state*

It is important to notice the trend of these companies of locating in the border states, especially in Baja California Norte. This should not be strange, since California is the top state with AI business in the U.S (based on 2001 information by the AIA), significantly Texas is the second place (see Table 6) which can bring further opportunities to the states of Nuevo Leon and Coahuila.
Considering this fact, a discussion in applying lean concepts to logistics as a competitive advantage is justified. Now, some perspectives on the location between both can be seen, especially considering the existing transportation infrastructure that can help to the process of expanding the business.

3.3.- Geographical aspects of Mexican supplier locations and American suppliers' sites

The previous sections focused on explaining the current participation of Mexico in the U.S. AI and presenting brief information of where are the companies located. Also, table 6 presented the U.S. states with more participation in the AI.

Based on this information, it is of importance to relate potential suppliers (Mexican companies) and customers (U.S. companies) from the geographical perspective. What would if happen commercial relations are established? What would be the flow of the products?. To analyze this, reference to the highway systems from both countries must be made. This based on the assumption that, given the opportunity, ground transportation will be used because of the costs and delivery time involved. Let’s take a look at the U.S. highway system first: The Interstate highway system.

These are controlled-access freeways, designed for speeds up to 80 mph. They are spread all over the U.S., for civil purposes, but also for military defense purposes. This system represents the best option for ground transportation across the U.S., it is free, it is safe and it is fast. Figure 14 shows the big picture of the system.

Table 6
Top 10 U.S. states with AI business in 2001

<table>
<thead>
<tr>
<th>STATE</th>
<th>PLACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>1</td>
</tr>
<tr>
<td>Texas</td>
<td>2</td>
</tr>
<tr>
<td>Washington</td>
<td>3</td>
</tr>
<tr>
<td>Florida</td>
<td>4</td>
</tr>
<tr>
<td>New York</td>
<td>5</td>
</tr>
<tr>
<td>Illinois</td>
<td>6</td>
</tr>
<tr>
<td>Georgia</td>
<td>7</td>
</tr>
<tr>
<td>Arizona</td>
<td>8</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>9</td>
</tr>
<tr>
<td>Ohio</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: AIA, 2001
From this general map, it must be noticed that in the southern part, some of the highways end in the border with Mexico, which means that after a truck has crossed the border it can, immediately take advantage of the system.

Now, let’s take a look at the system in Mexico. According to information from the Transportation and Communications Secretariat in 2003, Mexico had 14 main highway corridors. These corridors may be composed of several highways within, but represent the major transportation routes from and to Mexico, and the main connection between the central area and the northern and southern states.

The system here is more complex, some are freeways and some other are toll ways, a particular situation must be analyzed before trying to reach a conclusion of the best way to move a product from a particular area. Figure 15 show these main highway corridors.

Also, it is important to notice here that 5 out of these 14 corridors end up in the border with the U.S., which represents an important opportunity for states and cities in the central and southern area.
This is no coincidence. The ends of these main highway corridors connect the border cities of Mexico with the borders cities in the U.S. that have a quick access to the Interstate transportation system.

It has to be recalled from table 6, that the first 2 states with the most AI business are California and Texas, and including the top 10 Arizona is also there. In 2001 27% of all the AI jobs were located in these states (AIA), and if the same amount is extrapolated to the business that means that around 25% of the market is in the southwestern area of the U.S. So, this explains why around 75% of the companies in Mexico currently involved in the AI are located along the border, and almost 50% alone in the state of Baja California Norte, border with California. This geographical relations and locations provide a great opportunity, not only for new business, but also for the improvement of the current operations, for the development of better and faster ways to move the products, and for the cooperation among the cities, the states and the countries to make the process cheap, efficient and safe, that will obviously result in a competitive advantage against other countries. (See Appendix D for the Mexico-US-Canada highway corridors).
3.4.- Vision of Mexico’s needs to develop this industrial sector

Previously, we have discussed that applying the lean enterprise model and lean thinking concept to these companies will result in a better competitiveness and benefits; however they are not the only things that need to be considered. This section will cover some other areas that require attention as well, but they are more out of the scope of this thesis.

Since the maquiladora program was created in the late 60’s, many companies have been established in Mexico. Maquiladora experienced a boom for its growth in the early 80’s right after the devaluation of the Mexican peso. U.S. companies foresaw a way to reduce their costs while keeping their sales rates, therefore increasing their revenues and margins, therefore moved their assembly operations. Although this movement brought factories and jobs to Mexico, it didn’t bring knowledge, engineering or development.

Now the NAFTA is in place, and has brought a new set of rules that have replaced the maquiladora program. However, the world environment has changed. Now, with globalization and trade agreements increasing among countries there are new alternatives to place manufacturing facilities, even with better perspective than locating them in Mexico. It is a fact that companies are shutting down in Mexico and moving operations to China where manufacturing wages are bout ¼ of those in Mexico. Labor intensive, low added value, low cost products are the ones most affected by this situation.

Interestingly, there is a sector that is away from these events (recall table 2). The automotive industry not only has kept the jobs that were transferred, first under the maquiladora program, and second under the NAFTA. This industry and their jobs have been constantly increasing for the past 10 years. The success here must be analyzed and must be applied to other areas. Since we have discussed that the AI have a great relationship with the automotive industry, it can be considered that the observations derived from here can apply to obtain a piece of the market and more important to increase the market share, for those companies that already have some.

Maquiladora program brought the first automotive jobs to Mexico during the late 60’s and 70’s. However it was during the 80’s that experienced the biggest growth (same as the other industries). The first jobs that were transferred were purely labor intensive; assembly lines, manual operations, re-work facilities, etc. The skills of the Mexican workers increased so much, due to the quality requirements of this industry and the proper programs for transferring assembly capabilities. After proving success with these jobs the second step was to establish a workforce of Mexican engineers to control and make improvements to the current operations. Now, the third step is taking place, and has been taking place for a few years: Design, innovation and full creation are being transferred as well. Mexican knowledge workers have proven creativity quality and reliability for product
development, which, at the end bring benefits to everybody; companies, workers, countries and economies. This industry became competitive.

Competitiveness is the term that describes what it is required to increase the market share. Mexico needs to be more competitive, not only in costs, but also in added value, in business solutions, as reliable partner, etc. According to the Council of Competitiveness, Mexico ranked 48th out of 104 analyzed countries in 2004. Table 7 shows some of the variables involved in the analysis of this ranking:

<table>
<thead>
<tr>
<th>Macroeconomic Environment</th>
<th>Public Institutions: Corruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology, Innovation and Diffusion</td>
<td>Domestic Competition</td>
</tr>
<tr>
<td>Human Resources: Education, Health and Labor</td>
<td>Cluster Development</td>
</tr>
<tr>
<td>General Infrastructure</td>
<td>Company Operations and Strategy</td>
</tr>
<tr>
<td>Public Institutions: Contracts and Law</td>
<td>Environment</td>
</tr>
</tbody>
</table>

Table 7
Variables involved in the competitiveness of a country

These variables are true, from a country level perspective, and surely some of this may be applied to the industry too. More specifically those of: a) Technology, innovation and diffusion, b) Human resources: Education, health and labor and c) Company operations and strategy.

Technology, innovation and diffusion

Develop own created technology, invest in research and development, create and improve processes, materials, standards, etc. These are the basic activities that a company must do to become competitive. The budgets allocated here are usually low, and there is still a lot of dependency from outsourcing.

Human resources: Education, health and labor

Companies need to support employee development. It is necessary to understand that long period of works is not the solution to improve productivity and efficiency. Stress, excessive workload and fair salary are some of the factors that affect workers. It is necessary to develop a working environment that maximizes the productivity, where workers can share their ideas.
Company operations and strategy

Each and every company must know exactly where it is heading. A mission statement, goal and objectives must be set, company wide, so everybody knows what they are working for. Continuous improvement strategies need to be established based on clearly and correctly defined indicators such as: effective throughput, waste, costs, inventory, etc. Costs are often the most important measurement here. Most of the time, the success of a company is measured with the costs incurred. Cost reduction programs are common all around the organizations.
4.- THEORETICAL CONTEXT

This chapter is intended to present a description of the lean thinking concepts, including manufacturing and logistics areas, to understand why they may apply to an aerospace organization. Also, several models that are currently being applied to support competitiveness will be introduced (based or not in lean practices), and general descriptions of them will be given.

4.1.- Lean thinking

In essence, “lean” is about working smarter to achieve greater value to the organization, and to contribute or benefit from its operations. The ideas of lean do not begin and end on the manufacturing floor; they extend to all systems and subsystems that interact with the company. This includes, but is not limited to: suppliers, customers, stockholders, etc. For lean to work, it needs to be a cultural value shared by everybody.

Lean must be adopted as a pre-dispositional culture in the organization, and needs to be internalized by it, from the lowest level employee, to the highest-ranking executive. In short a lean enterprise requires belief, observation, reflection, planning and action. In a lean enterprise, the focus and tools change the nature of the way the company does business. See table 8.

Table 8
The lean enterprise vs. Mass production

<table>
<thead>
<tr>
<th>AREAS AFFECTED</th>
<th>LEAN ENTERPRISE</th>
<th>MASS PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business strategy</td>
<td>Customer focused strategy, focused on identifying and exploiting shifting competitive advantage</td>
<td>Product-out strategy, focused on exploiting economies of scale of stable product designs and non-unique technologies</td>
</tr>
<tr>
<td>Organizational structure</td>
<td>Flat structures that encourage initiative and encourage the flow of vital information that highlights defects, operator errors, equipment abnormalities and organizational deficiencies</td>
<td>Hierarchical structures that encourage following orders and discourage the flow of vital information that highlight defects, operator errors, equipment abnormalities and organizational deficiencies</td>
</tr>
<tr>
<td>Operational capability</td>
<td>Product flow from suppliers to producers to customers. Smart tools that assume standardized work, strength in problem identification, hypothesis generation and experimentation</td>
<td>Dumb tools that assume an extreme division of labor, the following of orders and no problem solving skills.</td>
</tr>
</tbody>
</table>

A definition of lean thinking given by Womack (2003) is: “Actions and working methods that provide a way to do more and more with less and less: less human effort, less equipment, less time and less space; while coming closer and closer to providing customers with exactly what they want”. Figure 16 shows the lean thinking concepts schematically.
According to Womack, there are 5 basic principles that need to be followed in order to achieve lean thinking:

1.- Define value

What is value to our company? This is the question that must be answered, therefore the first step of lean thinking is define value in terms of specific products with specific capabilities offered at specific prices through a dialogue with specific customer. Value through the entire organization, not only focused to specific individuals, areas or departments.

2.- Identify value stream

The value stream is the set of all the specific actions required to bring a specific product through the 3 critical management tasks of any business: 1) The problem solving task running from concept through detailed design and engineering to production launch. 2) The information management task, running from order taking through detailed scheduling to delivery, and 3) The physical transformation task proceeding from raw materials to a finished product in the hands of the customer.
3.- Flow

Integrate the actions that were identified in the value stream. Focus on the actual object, specific design, specific order and product itself, never let it out of sight from beginning to completion. Ignore the traditional boundaries of jobs, careers, functions and firms. Finally, re-think specific work practices and tools to eliminate backflows, scrap and stoppages of all sorts, so that the design order and production of the specific product can proceed continuously. The correct tools should be developed and applied in this principle, these will be according to each organization.

4.- Pull

In the simplest terms means that no one upstream should produce a good or service until the customer downstream asks for it. This premise is related to the concept that no work should be wasted, and a specific order from a customer will deploy the activities to create value.

5.- Strive for perfection

After the previous four steps have been implemented the last step, which is more the goal of the entire effort is to strive for perfection. A wasteless environment with efficient and effective products, flowing through a flawless system where everybody can input suggestions and the information flow goes in all directions so every employee is aware of what is going on. That is a perfect system, and this is the condition that must be searched for.

4.2.- Lean manufacturing and processes

So, if a company is aiming to achieve leanness, there are some tools that can be applied and that can help in the process. Depending on each organization’s needs, some or all may apply. So, a definition of each one will be presented here, in order to understand them. It is important to notice, that these tools are mostly for manufacturing facilities, due to the scope of their topic, but if properly related they can apply to other areas as well.

But if the tools are to be presented, it is necessary to spend some time defining the problems that they trying to eliminate.
4.2.1.- The 7 wastes

According to Taichi Ohno (the father of the lean concepts), there are seven wastes that affect the manufacturing facilities:

1.- Overproduction
   - Which leads to excess inventory, paperwork, handling, storage, space, interest charges, machinery, defects, people and overhead
   - It is often difficult to see this waste as everyone seems busy

2.- Time in waiting
   - People waiting for parts or instructions
   - Mostly they are waiting for one another, which often happens because they have non-aligned objectives

3.- Transportation waste
   - Poor layouts lead to things being moved multiple times
   - If things are not well placed, they can be hard to find
   - It can aggravate alignment of processes

4.- Extra processing
   - Additional efforts may be required in an efficient process

5.- Unnecessary inventory
   - Excess buffer stocks a lot of mistakes in planning, quality, performance, etc., which will be uncovered (they will immediately appear if inventory is eliminated)

6.- Unnecessary movements
   - This includes movement of people, from simple actions when in one place to going somewhere else. Having everything on hand as it is reduces this waste

7.- Product defects
   - Defects cause rework and confusion. They upset a synchronized set of processes
4.2.2.- The 14 lean manufacturing tools (or building blocks)

There are 14 lean manufacturing tools that are usually studied:

1.- Value Stream Mapping

It is a method of visually identifying the flow of materials and information from the time products come as raw materials, through all manufacturing process steps and until they leave as finished products. This is the critical initial step in lean conversion.

Mapping out the activities in the production process with cycle times, down times, in-process inventory, material moves, information flow paths, will help visualize the current state of the process activities and serve as guide to the desired future state. This serves as a communication tool, business planning tool, etc. The goal is to identify and eliminate waste (not value adding activities) in the process.

Some of the benefits of value stream mapping are:

- Visualize the production process at the plant level
- Identify the sources of waste in the value stream
- Shows the linkage between the information flow and the material flow
- Makes decisions about the flow apparent
- Forms the basis of an implementation plan
2.- Quality at the source (Poka-Yokes)

Quality at the source refers to the principle that whatever activity is being done, needs to be done correctly at the first time. Therefore; tasks, operations, system and devices, must be designed to operate in this way.

Shigeo Shingo introduced the concept poka-yoke (mistake-proofing) in 1961. Poka-yokes are mechanisms used to avoid mistakes during the entire process, these devices ensure that proper conditions exist before actually executing a process step, preventing defects from occurring in the first place. Where this is not possible, poka-yokes perform a detective function eliminating defects in the process as early as possible.

These mechanisms can be electrical, mechanical, procedural, visual or human, or any other form that prevents incorrect execution of a process step.

Some of the benefits of poka-yokes are:

- Prevent mistakes to increase customer satisfaction
- Reduce waste
- Eliminate extra inspections
- Lower training costs
- Reduce documentation
- Improve operators’ confidence

![Figure 18](image)

*Example of a poka-yoke application*
3.- Workplace organization: 5S’s

The term 5S’s refer to five Japanese words that represent a technique to organize any work area. These Japanese terms have been converted in English to: Sort, Set-in-order, Shine, Standardize and Sustain.

1.- Sort (Seiri).- Eliminate unnecessary items from the workplace
2.- Set-in-order (Seiton).- Focuses on efficient and effective storage methods
3.- Shine (Seiso).- Thoroughly clean the work area on a scheduled basis
4.- Standardize (Seiketsu).- Standardize best practices in the work area
5.- Sustain (Shitsuke).- The most difficult to implement and achieve. Focuses on defining a new status quo and standard of the workplace

The first 3 S’s are expected to be an easy transition, once the necessary things are defined for an area. The problem are the last 2, standardize the operations requires the consensus of the people involved, so it can be categorized as a best practice. And finally sustain everything through time requires discipline and commitment of everyone.

Some benefits of the 5S’s are:

- Reduce lead times
- Reduce quality defects
- Increase productivity
- Reduce waste in materials, space and time
- Reduce changeover time
- Reduce equipment downtime
- Improve safety

![Figure 19](image-url)  
*Example of 5S’s application*
4.- Total productive maintenance (TPM)

Refers to a management system for optimizing the productivity of manufacturing equipment through systematic equipment maintenance involving employees at all levels, keeping the equipment in good working order to minimize production losses from repairs, assists and so forth. Under TPM, operators no longer limit themselves to simply use the machine and calling a technician when a breakdown occurs. They can inspect, clean, lubricate, adjust and even perform simple calibrations on their respective equipment.

The possible maintenance policies can be grouped under 4 categories: a) Corrective, b) Preventive, c) Predictive and d) Detective.

TPM requires the mastery of 4 equipment maintenance techniques:

1.- Preventive maintenance to prevent breakdowns.
2.- Corrective maintenance to modify or improve and equipment for increased reliability and easier maintenance.
3.- Maintenance prevention to design-install equipments that are maintenance free.
4.- Breakdown maintenance to repair equipment quickly after they break down.

Some benefits of the TPM are:

- Eliminate downtimes from breakdowns and changeover times
- Avoid equipment operating at lower working speeds
- Reduce process defects due to scrap and quality defects to be repaired

Figure 20
Pillars of the total productive maintenance
5.- Visual management

It is the administration of systems that search to make visible all the conditions that take part in a productive process inside the manufacturing facilities, so they can be perceived by any person at any time. This condition, assures that abnormal situations become evident, and costly consequences in the following steps of the productive process are avoided.

The concept “visual” can be extended to those stimulations perceived by the human senses, making it easier to identify the condition that is intended to be communicated. The most important contribution of having a visual management system is to evidence the occurrence of unusual conditions in real time that allows reacting and applying corrections avoiding waste.

Some benefits of the visual management are:

- Reduce response time due to process deviations
- Reduce costs due to the consequences of these deviations
- Improve information quality
- Deploy important process information to any person in the organization

6.- Set-up reduction (SMED)

Set-up reduction builds on the principles of the single minute exchange of dies (SMED) system (developed by Shigeo Shingo) to dramatically reduce or eliminate changeover time. The approach is to separate setup time into "internal" and "external" activities. An internal activity is one that can only be done with the machine stopped, an External activity is anything that can be done before or after the set up without stopping the machine.

According to this technique a quick set-up and change over of dies could be achieved by:

1.- Maximizing external activities.
2.- Converting internal activities to external where possible.
3.- Optimize through engineering all remaining internal activities.

Some of the benefits of set-up reduction are:

- Shorter lead times
- Less inventory
- Higher productivity
- Increased capacity
- Greater flexibility
7.- Batch size reduction (one-piece-flow)

Historically, manufacturing companies have operated with large batch sizes in order to maximize machine utilization, assuming that changeover times were “fixed” and could not be reduced. Because Lean calls for the production of parts to customer demand, the ideal batch size is one. However, a batch size of one is not always practical, so the goal is to practice continuous improvement to reduce the batch size as low as possible.

When the batch size of a given process is reduced, material or information can flow much faster across various process stages and, thus, it can reach the end customer earlier. There is less waiting time between workstations and workers can initiate the operation immediately. Therefore, the transformation of a classic production system using large batches into value streams of small batches, flowing continuously as they are pulled by the customer, can significantly raise production performance.

Some of the benefits of batch size reduction are:

- Reduce the amount of work-in-process (WIP)
- Reduce inventory carrying costs
- Reduce lead-times and cycle times
- Improve productivity

8.- Cellular manufacturing

A work cell is defined as a collection of equipment and workstations arranged in a single area that allows a product or group of similar products to be processed completely from start to finish. To implement cellular manufacturing is necessary to locate all the different equipment needed to manufacture the product together in the same production area.

Since differently processed products need different work cells, a large company with diversified products needs to build several, different work cells if single process flows are desired. Given enough volume of products to work with, work cells have been proven by experience to be faster and more efficient in manufacturing than 'batch and queue' systems.

Some of the benefits of cellular manufacturing are:

- Higher production efficiency
- Optimized use of floor space
- Reduced inventory levels
- Shorter production cycle times
- Higher effective manufacturing capacity
9.- Standardized work

Is defined as work in which the sequence of the job elements has been efficiently organized, and is repeatedly followed by a team member.

The objective is to clearly communicate to the operator exactly how the job should be performed. Variability, and the inefficiency that goes with it, is removed through scientific analysis of the operation, and by eliminating: “adjustment”, searching for tools and parts, excess movements, double-handling, and awkward ergonomics.

A standard worksheet is developed for every operation containing the following:
1.- Cycle time for producing a unit, this is equal to the time available per day divided by the number required per day.
2.- Work sequence, the exact sequence and method for performing each element of work.
3.- Standard inventory, the amount of in-process inventory that should be present at a workstation, including inventory mounted on machines.

Some of the benefits of standardized work are:

- Documentation of current processes for all shifts
- Reduction in variability
- Easier training of new operators
- Safety improvement
10.- Work balancing (TAKT-time)

To understand the importance of work balancing Takt time must be explained first.

Takt Time is used to match the pace of work to the average pace of customer demand. Takt is not a number that can be measured, and is not to be mistaken with Cycle Time, which is the time it takes to complete one task. Cycle Time may be less than, more than, or equal to Takt Time. You can never measure Takt Time with a stopwatch. You must calculate it. The formula for Takt Time is: 

\[ \text{Takt Time} = \frac{\text{Net Available Time per Day}}{\text{Customer Demand per Day}}. \]

And is expressed as “seconds per piece”, indicating that customers are buying a product once every so many seconds.

Therefore work balancing must attempt to properly separate the activities into workstations so the cycle time can be less or equal to the TAKT-time. Effective line balancing techniques seek to generate a balanced workload at multiple workstations while simultaneously reducing equipment and labor requirements.

Some of the benefits of work balancing are:

- Assure on-time delivery to customers
- Maximize the current working resources
- Keep control of the production rate

![Figure 22: Takt time determined by customer](image-url)
11.- Production leveling/smoothing

Production leveling (or smoothing) is the method by which the variance in production quantity is reduced as much as possible to optimize the resources needed.

A popular Japanese term that is applied for these concepts is called “Heijunka”, which is defined as the distribution of production volume and mix evenly over time. “Heijunka” converts uneven customer pull into even and predictable manufacturing processes, and it is the core concept to bring stability to them.

There are 4 aspects that need to be considered when leveling production:
1. The leveling of volume.
2. The leveling of mix.
3. The leveling of manpower.
4. The introduction of inventory to manufacturing operations.

Some of the benefits of production leveling are:
- Minimize costs
- Maximize resource utilization
- Absorb system instability
- Reduce inventories

![JIT versus Production Leveling](image)

**Figure 23**
JIT versus Product leveling
12.- Point-of-use systems

Point-of-use systems are the specific racks, devices or space where things are located to be effective for the system.

Some of the advantages of using point-of-use systems are:

- Space maximization
- Easy location of tools, documents, devices
- Improved materials control

![Figure 24](image)

*Example of a point-of-use system*

13.- Kanban

Kanban is the Japanese word for instruction label. Its main purpose is to be a working order, an automatic direction device that provides information about what is being produced, the quantity, equipment to use and transport.

It has 2 main applications: production control and process improvement. Production control because of the integration of the several processes and the development of a JIT system. Process improvement because it eliminates waste, reduces set-ups and organizes the working area.

Kanban is usually implemented in 4 phases:
1. Train the personnel in the Kanban principles and benefits.
2. Implement Kanban in the most problematic components, to make its manufacturing easier and to reveal hidden problems.
3. Implement Kanban in every component of the system.
4. Revise the implemented system, the reorder points and levels.
There are some rules associated with the use of Kanban:
1. Do not send defective products to the following processes.
2. The following processes will use only the required material.
3. Produce only what is required for the following process.
5. Do not speculate with the system.
6. Make the process stable.

The Kanban card typically has the following information:
1. Component part number and description.
2. Product name or number.
3. Quantity required.
4. Material handling type required.
5. Place to be located after produced.
6. Reorder point.
7. Assembly production sequence.

Some of the advantages of using Kanban are:

- Reduce inventory level
- Reduce work in progress
- Reduce downtimes
- Improve information about the process
- Avoid over production

<table>
<thead>
<tr>
<th>Item No:</th>
<th>SP-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprocket 3 inch</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lead Time:</th>
<th>Min:</th>
<th>Order Qty:</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

| Category/Sub: | SUP |
| Location:     | RINGDS |
| Rack/Bin:     | 1080 |

| Vendor:       | Cold Metal Products |
| Phone:        | (800) 410-7222 |
| Fax:          | (800) 410-7224 |
| Vendor Part No: | To Specifications |

Figure 25
Typical Kanban card
14.- Kaizen

A system of continuous improvement in quality, technology, processes, company culture, productivity, safety and leadership. The word Kaizen means "continuous improvement". It comes from the Japanese words "Kai" meaning school and "Zen" meaning wisdom.

Kaizen is a system that involves every employee. Everyone is encouraged to come up with small improvement suggestions on a regular basis. In most cases these are not ideas for major changes. Kaizen is based on making little changes on a regular basis, always improving productivity, safety and effectiveness, and reducing waste.

Suggestions are not limited to a specific area such as production or marketing. Kaizen is based on making changes anywhere that improvements can be made. The Kaizen philosophy is to "do it better, make it better, and improve it even if it isn't broke, because if we don't, we can't compete with those who do."

Kaizen involves setting standards and then continually improving those standards. To support the higher standards Kaizen also involves providing the training, materials and supervision that is needed for employees to achieve the higher standards and maintain their ability to meet those standards on an on-going basis.

Some of the advantages of using Kaizen are:
- Problems are identified at the source
- Small improvements which are realized can add up to major benefits for the business
- Improvements which lead to changes in the business quality, cost and delivery of products means a greater level of customer satisfaction, and business growth

4.3.- Lean logistics

This section will explain some of the important issues that should be addressed when reviewing and intending to have lean logistics.

4.3.1.- Why logistics?

There are several reasons why it is of great importance to focus on improving the logistics operations. Logistics is defined as the part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption in order to meet customer’s requirements” (Ballou, 2004). This can be graphically seen as follows: (refer to figure 26).
Chapter 4.- Theorical context

Logistics deals with several decisions, according to its definition. The main two areas in which have relevance are: a) Physical supply (materials management) and b) Physical distribution, both of these between the sources of supply, manufacturing and operations. All the decisions that Logistics must consider can be seen in figure 27. (Taken from Ballou, 2004).
According to the consulting firm AT Kearney, logistics costs represent 15.3% of the Mexican gross domestic product (GDP) or some $94.1 billion, and about 13% of the total Mexican sales.

The U.S. Department of Commerce, through its STAT-USA service, which provides business economic and trade information, also estimates (for Mexico) that only 30% of large companies have a logistics department, and that only 32% of companies use other methods, such as logistical outsourcing. According to them, 8% of the product cost is related to logistics, compared to the 5% estimated in developed countries. This means a lot when trying to compete globally for market shares that are based in efficiency and productivity, like the American and European markets.

“Logistics costs, substantial for most firms, rank second only to the cost of goods sold (or the purchase costs) that are about 50% to 60% of sales for the average manufacturing firm” (Ballou, 2004). Please refer to figure 28.

With up to 30% of the costs (or more) due to logistics decisions, it is definitely worth it to spend some time and review them.

Moreover, within the logistics decisions it is possible to identify two that have the greatest impact over the logistics costs: a) Transportation and b) Inventory carrying costs. In the U.S., Transportation costs represented around 60% of the logistics costs in 2001 (Bradley, 2002), meanwhile, inventory carrying costs represented around 30%. The amounts for the U.S. logistics costs in 2001 can be seen in figure 29.
To look at logistics improvements is to look at the company's operations and to define policies and practices that will benefit the entire organization, thus being coherent with the definition discussed for lean thinking being applied to Logistics.

This specifically can be applied in the AI, since most of the manufacturing for this industry is located in the Northern part of Mexico, close to the U.S. border. If transportation is analyzed, there is almost no need to use any other means than rail or truck (given some conditions like lead time, service level, etc) which means that the cost and delivery time can be improved balancing these variables according to each one's needs. Some of the strategies that can help reduce these costs will be discussed next.

### 4.3.2.- Logistics strategies to consider

The classic approach to formulating a logistics strategy consists in considering the firm's overall strategy (as for market share or product positioning) and then defining the actions that will enable the firm to reach their objectives. Thus, logistics is conceived as a functional support system and a tool for a global strategy (Cooper, 1994).

Figure 28 showed the total logistics costs in the U.S. for 2001, so, it will be assumed that Mexican companies have a similar cost structure. Therefore, transportation and inventory carrying costs strategies will be mentioned and briefly discussed.
Transportation strategies

Transportation (as mentioned before) represents 60% of the total logistics cost of a firm. It is extremely important, because it is the way that raw materials are sent to manufacturing facilities and finished products are sent to customer.

Transportation costs, by mode, in Mexico are estimated to be around 60% higher than in the U.S., except in the air mode, which are similar (Vega, 2000). Table 9 shows a comparison between the 2. These costs need to be carefully considered when choosing a strategy.

<table>
<thead>
<tr>
<th>Transportation mode</th>
<th>Shipment value in the U.S. ($/lb)</th>
<th>Shipment value in Mexico ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>$0.35</td>
<td>$0.56</td>
</tr>
<tr>
<td>Rail</td>
<td>$0.08</td>
<td>$0.128</td>
</tr>
<tr>
<td>Water</td>
<td>$0.06</td>
<td>$0.096</td>
</tr>
<tr>
<td>Air</td>
<td>$26.77</td>
<td>-</td>
</tr>
</tbody>
</table>

Sources:
1. U.S. Department of Transportation
2. Estimated according to Vega (2004)

Transportation costs have been reduced in a number of ways, including:

1.- Consolidation

Consolidation is the process of holding shipments for a certain time to complete a larger load, thereby taking advantage of the lower freight rates for larger or heavier shipments. Figure 30 applies for the relation of cost and shipment size.

![Figure 30](image)
Although it is clear that having a bigger shipment quantity will reduce the transportation cost per unit, this is also subjected to other constraints, especially when consolidating for a long time results in a greater inventory carrying costs.

2.- Routing and scheduling

Routing and scheduling are the strategies to follow when it comes to plan the trucking operations. A conscious analysis of the distribution requirements need to be done and rules for routing and scheduling must be set. The key to make this process efficient is a high utilization of the equipment and a high load factor of the trucks, so the metrics to analyze these must be created and considered.

There are some basic principles for good routing and scheduling that are defined by (Ballou, 2004):

a) Load trucks with stop volumes that are in the closest proximity to each other
b) Stops on different days should be arranged to produce tight clusters.
c) Build routes beginning with the farthest stop from distribution point.
d) The sequence of stops on a truck route should for a teardrop pattern (not crossings).
e) The most efficient routes are built using the largest vehicles available.
f) Pickups should be mixed into delivery routes, rather than assigned to the end of the routes.
g) A stop that is greatly removed from a route cluster is a good candidate for an alternate means of delivery.
h) Narrow stop time window restrictions should be avoided.

There are some methods that are commonly used to make routing and scheduling, these models do not represent the optimal arrangement that can be made, but they certainly are a helpful tool that were created with some of the considerations mentioned above, they will not be further explained, and they are only mentioned for reference purposes. 2 methods that can be applied for this task are the “Sweep” method and the Savings Method.

3.- Facility locations

These strategies will allow the system to have manufacturing plants, warehouses, ports, vendors, retail outlets, service centers or distributions centers near where they are required. Transportation costs can be reduced greatly if the distance that is being required to travel is minimized.

There are several factors that should be studied carefully, among them:

a) Market orientation, where is the product intended to be located.
b) Product orientation, locate near the consumer or near the resources.
c) The nature of the product, what type of product is being handled.
d) Communications, are roads, rails, air terminals located nearby.
Although these factors depend on the analysis made and tend to be subjective, there are also some models that can be applied to determine where a facility must be located, some of these models (that will not be discussed) are the Centroid method and the P-median problem.

**Inventory strategies**

Inventory is defined as “stockpiles of raw materials, supplies, components work-in-progress and finished goods that appear at numerous points throughout a firm’s production and logistics channel (Ballou, 2004). Inventory carrying costs are frequently, the second most costly element after transportation. According to Figure 28, they represent around 34% of the total logistics costs. These costs can be collected into four classes:

1.- Space costs.- that are charges made for the use of the volume inside the storage building.
2.- Capital costs.- refer to the cost of the money tied up in inventory.
3.- Inventory service costs.- insurance and taxes that are being paid, they depend of the amount of inventory that exists.
4.- Inventory risks costs.- costs associated with deterioration, shrinkage, damage or obsolescence.

Figure 31 shows the previous information graphically (done with info taken from Landeros, 1989).

![Figure 31 Percentages of cost elements in inventory carrying costs](image)

Why do inventories exist? Typically four main reasons: a) anticipation of future events, b) fluctuations in supply and demand, c) large lot-sizes, d) goods in transit. So the strategies to be considered must be aimed at reducing the inventory levels to relieve these costs, and some are:
1.- Forecasting

Forecast is the process of predicting what the future requirements will be for something: sales, production, demand, etc. The focus of this strategy is on predicting the demand that a product will have, thus reducing the uncertainty and the variability that a product may have, therefore reducing the inventory levels. Qualitative methods rely on judgment, intuition, surveys or comparative techniques to produce quantitative estimates. Historical projection methods rely on historical data to identify trends and seasonal variations, projecting these data into the future can be an effective way of forecasting for the short term. Some of these techniques are 1.- Moving average and 2.- Exponential smoothing.

2.- Inventory control systems

An inventory control system is a set of rules and procedures that allow for routing decisions on when and how much to order of each item in order to meet customer demand. Thus, the objective is to minimize the costs subject to have a customer service greater than the desired targeted level. A-B-C inventory classification is a useful way to classify the items that are stocked into few categories, based on volume or value or a combination of both. Figure 32 shows the meaning of this classification.

Based on this classification, the inventory control system approach can be applied more strictly to those items that are more important to the system, and its policy reviewed more often.

There are several models that are covered in this category, some of them are: Economic order quantities (EOQ) and its extensions, Dynamic lot sizing methods, The news vendor model, Power of two policies, etc.
4.4.- The lean extended enterprise

Applying lean thinking is not enough to gain all the benefits in efficiency, productivity and savings, because a single organization generally doesn’t cover the entire supply chain for a product.

The term "extended enterprise" represents the concept that a company is made up not just of its employees, its board members, and executives, but also its business partners, its suppliers, and even its customers. The extended enterprise can only be successful if all of the component groups and individuals have the information they need in order to do business effectively. This success, in every aspect related to business: financially, productively, savings, and of course leanness as well.

This means that the suppliers' network and the different customers that a company may have must be involved in these kinds of concepts as well, to have the complete benefit (see figure 33). This should not be surprising, for example using lean logistics concepts, where an effort is placed to optimize product flow, transportation and inventories, will be useless if the customer is not prepared, either physically or systematically to receive, say, just-in time deliveries. In this particular example, orders may arrive from such a customer with a lot of variability and without a pattern, which will cause to have safety stock of the products, which results in money invested in products that are not being sold.

![Figure 33](source: isixsigma.com)
As surprising as it may seem, the suggestions to avoid these complications are focused towards the proper selection of customers and suppliers.

Selecting a good customer is often difficult; most of the time customers are accepted without actually thinking if this will be beneficial to the organization in the long term; does it fit with the company’s plans?, does it have a proper structure that support continuous improvements and efficiency?, will it have the knowledge to fit into the lean extended enterprise?

Selecting suppliers is easier than customers, because that depends upon the proper organization to select whoever is best for that kind of job. And even more, it is also easier to establish development programs to fit into the lean concepts that are intended to achieve, because it is more feasible for the supplier to go along with the customer, and share benefits.

Once this careful selection of customers and suppliers is done, then the full potential of the lean enterprise model implementation, based on lean thinking ideas can be achieved.

4.5.- Some of the models used to increase competitiveness

In this section, some of the models that are being used to increase competitiveness in organizations will be described and analyzed, in order to detect some advantages and disadvantages.

4.5.1.- MIT’s Lean Enterprise Model

The first model that will be analyzed and considered is the Lean Enterprise Model (LEM) established by the MIT’s Lean Aerospace Initiative Group (see Chapter 1, section 1). “This model is a systematic framework for organizing the research and external data source results that have been gathered. It encompasses lean enterprise principles and practices and is populated by data derived from surveys, case studies and other research activities. It is intended to provide insights as to where they might direct lean efforts in the future”¹.

The entire model is based in 12 activities that have a specific purpose, and metrics are given to assure integration of each one. A brief description of these activities will be given here, however for the entire detail and explanations refer to Appendix E.

¹ The Lean Enterprise Model, Lean Aerospace Initiative, MIT, April 2004
12 steps of the Lean Enterprise Model
(Information taken from the MIT’s Lean Aerospace Initiative)

1.-Identify and optimize enterprise flow

**Purpose**: Optimize the flow of products and services either affecting or within the process, from concept design through point of use.

**Metrics**:
- Flow efficiency = actual work time/ Total flow time
- Throughput
- Order to point of use delivery cycle time
- Total product development cycle time, concept to launch

2.- Assure seamless information flow

**Purpose**: Provide processes for seamless and timely transfer of and access to pertinent information.

**Metrics**:
- Commonality of databases
- Information retrieval time
- Information sharing between customers and suppliers

3.- Optimize capability and utilization of people

**Purpose**: Assure properly trained people are available when needed.

**Metrics**:
- Training hours per employee
- Output per employee

4.- Make decisions at lowest level possible

**Purpose**: Design the organizational structure and management systems to accelerate and enhance decision making at the point of knowledge, application and need.

**Metrics**:
- Number of organizational levels

5.- Implement integrated product and process development

**Purpose**: Create products through an integrated team effort of people and organizations which are knowledgeable of and responsible for all phases of the product’s life cycle, from concept definition through
development, production, deployment, operations and support, and final disposal.

**Metrics:**
- Number of engineering changes after initial design release
- Improvement continuity through development cycle
- Total product development cycle time from concept to launch
- Supplier involvement in improvements

6.- Develop relationships based on mutual trust and commitment

**Purpose:** Establish stable and on-going cooperative relationships with the extended enterprise, encompassing both customers and suppliers.

**Metrics:**
- Number of strategic alliances/ Total number of direct suppliers
- Number of projects with customers for improvements
- % of procurement dollars purchased under long-term supplier agreements
- Number of years of relationships with suppliers
- Existence of formal communications programs

7.- Continuously focus on the customer

**Purpose:** Proactively understand and respond to the needs of internal and external customers.

**Metrics:**
- Customer access to supplier information
- % of projects with customers on improvements
- On time delivery from source to point of use

8.- Promote lean leadership at all levels

**Purpose:** Align and involve all stakeholders to achieve the enterprise’s lean vision.

**Metrics:**
- Lean metrics at all levels

9.- Maintain challenge of existing processes

**Purpose:** Ensure a culture and systems that use quantitative measurement analysis to continuously improve processes.

**Metrics:**
Chapter 4: Theoretical context

- Number of repeated problems
- Customer assistance to suppliers

10. Nurture a learning environment

*Purpose:* Provide for the development and growth of both, organizations' and individuals', support of attaining lean enterprise goals.

*Metrics:*
- Training hours per employee
- Use of “lessons learned” system
- Provision of supplier training programs

11. Ensure process capability maturation

*Purpose:* Establish and maintain processes capable of consistently designing and producing the key characteristics of the product or service.

*Metrics:*
- $C_{pk}$
- Scrap, reworks and repairs as % of costs
- Software productivity
- Number of suppliers certified
- Engineering changes (change traffic)
- Lean practices adoption

12. Maximize stability in a changing environment

*Purpose:* Establish strategies to maintain program stability in a changing customer driven environment.

*Metrics:*
- Schedule changes
- Number of baseline changes per year
- Number of program restructures
- Procurement quantity changes
- Program administration continuity

4.5.2. SCOR

The supply chain operations reference (SCOR) model was created by the Supply Chain Council as a method for benchmarking and measuring supply chain performance improvements. It is a cross-industry model that contains standard process definitions, terminology and metrics, matching supply chain processes
against best practices. The model was designed to help companies learn from others inside and outside their industry.

The model uses a four-level pyramid that defines the steps a company takes to measure and improve supply chain performance.

**4 levels of the SCOR model**

1.- Process-type level

Defines 5 management processes where the company creates its competitive position and operations strategy.

1.- Plan.- Defining resources and demand, planning inventory, distribution, production and rough-cut capacity planning.

2.- Source.- Acquiring raw materials, qualifying and certifying suppliers, monitoring quality, negotiating vendor contracts and receiving materials

3.- Make.- Making the end product: manufacturing, testing, packaging, engineering changes, holding and releasing products.

4.- Deliver.- Managing orders and credit, managing warehouse and transportation, delivery inventory and quality. Creating databases for customer products and prices.

2.- Configuration level

SCOR defines process categories that may be supply chain components. Organizations configure operations using these processes, going into detail to uncover inefficiencies and flatten the chain, doing “what-if” analyses to evaluate the impact of potential improvements.

3.- Process element level

Uses information gathered to set supply-chain improvement goals, define process elements, inputs and outputs, create performance metrics, investigating best practices, and creating systems to support them.

4.- Implementation level

Implementation is company-specific, focusing on putting improvements into action.
Chapter 4. - Theorical context

What does SCOR covers?

- All supplier and customer interactions
- All physical material transactions, from the supplier’s supplier to the customer’s customer
- All market interactions
- Returns

What does SCOR not cover?

- Sales administration processes
- Technology development processes
- Product and process design and development processes
- Post-delivery technical support processes

What does SCOR assumes but does not explicitly address?

- Training
- Quality
- Information Technology administration that is not part of the supply chain management process

4.5.3.- Value stream management

Value stream management (VSM) is a strategic and operational approach to the data capture, analysis, planning and implementation of effective change within the core cross-functional or cross-company processes required to achieve a lean enterprise. This methodology considers all the manufacturing tools that were described in section 4.2.2.

Traditionally, value stream management has 8 steps for its implementation:

8 Steps required by value stream management

1.- Commit to lean
2.- Choose the value stream
3.- Learn about lean
4.- Map the current state
5.- Identify lean metrics
6.- Map the future state
7.- Create kaizen plans
8.- Implement kaizen plans
However, the generality of these required a more detailed description.

There is a new approach that is proposed by Hines (Hines et al. 1998), which makes the previous 8 steps more specific, and easier to identify. In his description, he proposed 20 individual and consecutive stages as follows:

20 stages of VSM proposed by Hines

1.- Understand company mission, customer environment, needs and strategic direction.
2.- Delimit key processes.
   a) Customer facing such as order fulfillment
   b) Non-customer facing such as supplier integration
3.- Understanding existing roles and responsibilities.
4.- Understand existing organizational structure.
5.- Lean enterprise education for senior managers.
6.- Develop top level “big picture” of key processes.
7.- Define products and processes to be mapped in detail.
8.- Appoint senior level steering board.
9.- Appoint process champion for each key process to lean mapping activity.
10.- Lean enterprise education for process champions.
11.- Understand specific operating environment and wastes.
12.- Select second level mapping tools by process.
13.- Undertake detailed mapping.
14.- Identify areas where further analysis is required.
15.- Undertake third level analysis.
16.- Analyze objective and subjective data and develop timed implementation plan.
17.- Develop key control metrics by process area
18.- Educate and train implementation action teams
19.- Undertake implementation
20.- Measure progress against plan

4.5.4.- Lean deployment

Lean deployment is a strategy proposed by Nigel Wood (see references) based in the 5 lean principles described by Womack, also with his own inputs.

He basically describes the lean manufacturing tools as well, providing some examples of their implementation, without actually having a formal model or methodology.

However, he states that the sustainability of any change is not about the techniques used, it is about the people. People bring the change and they react to change both positively and negatively. The key to ensure involvement is a clear
understanding as to why the improvement is being undertaken, what it involves, when it is happening and how the results will be measured. According to him, the key to achieve all this is using a policy deployment.

Effective policy deployment is achieved through having:

- A clear vision of the future
- Targets at local level supporting business goals
- Actions prioritized by their impact on meeting the targets
- Staff at all levels accountable for results
- Visibility and tracking of the progress being made
- Evident executive engagement
- Objectives at each level supporting overall objectives

According to his proposal the metrics that should be used must be:

- Focused on quality, cost, delivery and people
- Cascade from group to team level
- Report on trends, issues and actions
- Reported at point of use
- Appropriate reporting frequencies
5.- LEAN ENTERPRISE MODEL PROPOSAL

This chapter will propose a lean enterprise model suitable for the Mexican industry conditions. The model shall be based on the previously existing models considering their weaknesses to improve it and to make it a useful tool.

In order to present it, 5 main sections will be covered: 1.- Comparison among the existing models, 2.- Considerations of the supply chain, 3.- Current lean status evaluation , 4.- Proposed lean enterprise model and 5.- General comments on the model. These sections will consider facts and information that has been already presented in previous chapters, so it is important to be familiar with them, to get the proper context and assumptions.

5.1- Comparison among the existing models

In this section, a comparison will be made among the models previously described, considering some key factors that must be included in order for them to be useful.

Some of the variables that can be analyzed are:

1.- Sequential (phased) structure
It refers to the deployment that can be done step by step, to have a clear starting point, and a clear time to change activities or goals.

2.- Clear activities
The activities of the model should be clear, easy to understand and apply to obtain the desired results.

3.- Flexible metrics
The model should allow having company defined metrics to highlight what is important to each organization and to track the desired results.

4.- Extended enterprise
It should consider the concept of the extended enterprise as a whole, not only local improvements; otherwise (as explained) it will not work properly.

5.- Certified model
This is related to the condition of the model of being recognized and approved by certified institutions that can guarantee, to some degree, the validation of the model.
6.- Continuous improvements
It must have activities or goals oriented towards the continuous improvements; it is not enough just to make the initial changes.

7.- Company wide
Refers to the possibility of the model to be applied in any area of the company

8.- Commercial software
If currently there is commercial software that supports its use.

For the comparison, please refer to table 10. An “√” sign means that the model has positive grade on that feature and a “X” sign means that doesn’t have it.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>1 SEQUENTIAL STRUCTURE</th>
<th>2 CLEAR ACTIVITIES</th>
<th>3 FLEXIBLE METRICS</th>
<th>4 EXTENDED ENTERPRISE</th>
<th>5 CERTIFIED MODEL</th>
<th>6 CONT. IMPROV.</th>
<th>7 COMPANY WIDE</th>
<th>8 COMMERCIAL SOFTWARE</th>
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<td>√</td>
<td>X</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>X</td>
</tr>
<tr>
<td>SCOR</td>
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<td>√</td>
<td>X</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Lean Deploy-</td>
<td>X</td>
<td>X</td>
<td>√</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>√</td>
<td>X</td>
</tr>
</tbody>
</table>

This analysis shows the similarities and differences that exist between the different models. It is clear that the Lean deployment concept is missing most of the key features.

After this comparison has been done, it is time to start considering all the features for the model proposal.

5.2.- Considerations of the supply chain

As previously discussed, the benefits of implementing lean practices through any methodology will only be gained if the lean extended enterprise concept is considered. Therefore, keeping in mind the supply chain activities that are involved in any business will allow taking the correct decisions.

5.2.1.- Selection of a site

If new operations are to be established, or evaluations for a distribution center or a branch are being made, it is necessary to make the right selection of a site that can reduce the costs impacts that may occur. Before deciding where the go, it is necessary to do some research.
The following index provides a guide on some of the information that must be considered:

1. Work Environment
   - Operating costs
   - Availability
   - Technical and Professional education
   - Skills and knowledge
   - Employees rotation
   - Working culture
   - Labor unions

2. Transportation
   - Shipment services
   - Transportation costs
   - Airports
   - International and domestic flight frequency
   - Main highways and their connections
   - Railways

3. Infrastructure and public services
   - Industrial water availability and sewage
   - Telecommunications
   - Electricity
   - Natural gas

4. Real state
   - Industrial parks
   - Shelter services
   - Real state agencies
   - Contractors and architects
   - Consultants
   - Business development

5. Government
   - Attitude towards business
   - Financial incentives and support
   - Inter-government relations

6. Local taxes

7. Local procedures to establish a new company

---

1 The index information has been taken from the Nuevo Leon’s Economical Development Secretariat, from the “Critical Factors” document, Feb. 2005
After this information has been carefully reviewed and evaluated a selection may be made. Remembering from Figure 12 (The aerospace industry suppliers in Mexico) and Table 6 (Top 10 U.S. states with AI business in 2001) it is of special interest of considering a location along the border with the U.S., (See figure 34) because they will always represent an advantage in transportation costs and relations with customers. Also, it has to be recalled that these states concentrate close to 80% of the companies related to the AI and therefore provide an option for support, collaboration, projects and shared benefits.

5.2.2.- Selection of suppliers

Once the selection of the site has been decided, the next step is to focus on the selection of the suppliers that will help the company. Due to the suggestion of establishing near the border suppliers may be considered from both countries and especially for the aerospace sector it is of great importance because the availability of materials, parts, products or processes required may be limited in Mexico.

Supplier selection is not an easy task; it requires evaluation in several areas, among them must include:

- Evaluation of the supplier goals, they need to be compatible with the organization’s future plans (including productivity, quality and lean efforts)
- If it is fully ISO 9000 approved (or similar)
• If it could provide a timely response for emergencies
• If it demonstrates ability to assimilate technology and to develop new processes to create a sustained competitive advantage
• If it has strong commitment to research and development
• If it has a complete understanding of process capabilities
• If it has well documented processes and techniques (manufacturing and administrative)

The relationship that naturally occurs between aerospace and automotive has to be recalled, and therefore, automotive suppliers must always be considered to be aerospace suppliers as well. Technology, materials, processes, manpower, training, practices, etc., can serve as foundation. Not only will this benefit directly interested companies, but also will open new possibilities for those suppliers eager to expand their products to new markets, or looking to fulfill plant capacities and utilization.

Another important topic is supplier development. This needs to have even more caution than the just a simple selection. Supplier development requires time and money investment with a particular potential partner; it involves transferring technology and knowledge, and if properly applied, may result in good option for continuing business.

Of course a mixture of the previous points is more likely to happen, some suppliers directly selected, some domestic, some international, some others that are being developed, etc. The important part is that always need to be aligned with the company’s objectives.

5.2.3.- Logistics strategies

Since the suppliers have been selected, the next step is to create a plan with them that addresses the logistics strategies that will be followed for the working relationship. As discussed in Chapter 4 (section 3), lean logistics must strive to make all the logistics processes efficient, profitable for the organization. It has to be remembered that they represent up to 30% of the sales costs, so, it will always be opportunities to improve.

The strategies must consider the best practices for:

- Transportation:
  • Consolidation
  • Routing and scheduling
  • Facility locations

- Inventories
• Forecasting
• Inventory control systems

Depending on each company’s conditions, the planning and execution of the strategies can be done in house, but due to the importance of them for costs reasons, it can also be considered to be developed by outsourcing to Professional services in logistics.

5.2.4.- Evaluation

When the strategy has been placed the only issue remaining in the process is the evaluation of its performance. And the most objective way to do it is developing metrics to assist this. Aligned metrics can help in shifting the focus to attain operational goals, directing the attention and effort to the areas requiring improvements.

There are several metrics that can be used to accomplish this, a summary of some that can be used for this purpose are shown in Table 11.

<table>
<thead>
<tr>
<th>Supply Chain Perspectives</th>
<th>Key Performance Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finance</strong></td>
<td><strong>Accounts Payable/Receivable</strong></td>
</tr>
<tr>
<td></td>
<td><strong>NOPAT (Net Operating Profit After Tax)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Inventory Turnover Rate</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Cost Breakdown (e.g. warehousing)</strong></td>
</tr>
<tr>
<td><strong>Customer Relations</strong></td>
<td><strong>Retention Rate</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Downstream In-Stock Ratio</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Order Fill Rate</strong></td>
</tr>
<tr>
<td><strong>Internal Process</strong></td>
<td><strong>Record Accuracy</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Adherence to Production Schedules</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Forecasting Accuracy</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Lead Time Variability</strong></td>
</tr>
<tr>
<td><strong>Learning &amp; Growth</strong></td>
<td><strong>Employee Satisfaction</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Revenue from New Products</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Employee Productivity</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Utilization of New Delivery Channels</strong></td>
</tr>
</tbody>
</table>

Source: Supply chain executive board research

5.3.- Current lean status evaluation

This section will discuss 2 tools that exist in order to determine the current lean status that applies to an organization.
Lean Enterprise Self Assessment Tool (LESAT)\(^1\)

LESAT enables an organization’s management to assess the “leanness” of the company, as well as the readiness to transform itself in accordance with lean principles and practices. It has a table-chart format divided into 3 sections: 1) Lean transformation/ leadership; 2) Life cycle processes and 3) Enabling infrastructure, and focuses specifically at the enterprise level.

A set of lean practices is identified for each of the 3 sections with a total of 54 lean practices included in the LESAT maturity matrices. While not intended to be all-inclusive, these practices do represent some of the more important behaviors of the lean organizations. Assessing the enterprise against this subset of leading indicator practiced would provide a good snapshot of how well an organization is progressing along its lean journey.

Section one covers the transition to lean roadmap, therefore, its elements describe and measure a logical sequence of primary activities associated with this process, these are:

- Lean transformational leadership
- Enterprise strategic planning
- Adoption of lean paradigm
- Focus on the value stream
- Development of lean structure and behavior
- Creation of, and refinement to, the transformation plan
- Implementation of lean initiatives
- Focus on continuous improvement

Section two measures the status of the company’s product life cycle with respect to the lean paradigm. The product development process, from early conception to design, manufacturing distribution and service are included in this section. The elements measured are:

- Program management
- Requirements definition
- Product and process development
- Supply chain management
- Production operations
- Product distribution
- Product service

Section three measures individual or company performance with regard to the enterprise enabling infrastructure. The enabling infrastructures are those

\(^1\) Tool developed by MIT’s LAI
processes that support leadership and operational processes, for example information technologies, which is required for information flow.

Figure 35 shows the suggested methodology for employing LESAT\(^1\).

\[\text{Figure 35} \]

\textit{Suggested methodology for employing LESAT}

The general format of the LESAT is shown if figure 36.

\(^1\) Taken from MIT’s LAI presentation, 2001
Chapter 5 - Lean enterprise model proposal

Section 1A: Lean Transformational Leadership - In this section, we look at your company's strategy for lean both internally and externally in the company itself. This section hopes to understand development, deployment, and management of a lean implementation plan. This plan should reflect the major effects of a lean transformation, namely: 1) long-term sustainability, 2) increasing competitive advantage, 3) qualification and satisfaction of stakeholders, and 4) smoothing irregular cash flows that traditionally plague small businesses.

Figure 36

Source: MIT's LAI

LESAT general format
Lean concepts status survey

The second tool that can be exploited is the lean concepts status survey, developed by Gerardo Vidal (April 2005).

He proposed a survey format covering 2 parts: Enterprise profile and current status for lean manufacturing concepts. Regarding lean concepts, the questions involved the 5 principles defined by Womack: 1) Value, 2) Value stream, 3) Flow, 4) Pull and 5) Perfection.

Vidal structured the survey as follows:

1.-Value
All the aspects and characteristics that a product has and that the customer is willing to pay. 20 questions were created for this principle.

2.- Value stream
Optimal process to create a product with the maximum value to the customer. 15 questions were added here.

3.- Flow
The value stream in the most continuous way. 32 questions were asked.

4.- Pull
Process ready to respond to customer demands when required or needed. 20 questions were asked.

5.- Perfection
Continuous improvement search. 18 Questions added.

This survey may be an alternative to LESAT, although it doesn’t cover the complete details for an assessment, it can provide the idea of the current status. (Please see references for the complete information on his research).

5.4.- Proposed lean enterprise model

After the lean status of the company has been carefully decided the model can be proposed. The model has a pyramidal structure, each level representing an implementation phase. Within each phase, there will be some activities that will help the process. This pyramidal structure is also based in a model presented by Shields et al. in 1997. However, there will be changes in the name, number and activities of the phases involved in it. Please refer to figure 37.
Figure 37
Pyramidal structure of the model
Figure 38 shows the estimated importance of each phase to achieve a successful implementation, based on the requirements and complexity of the activities involved.

![Pie chart showing phase importance](image)

**Figure 38**

*Estimated importance of each phase to have a successful implementation*

### 5.4.1.- Lean infrastructure deployment

The following list, are the proposed activities to establish the lean infrastructure deployment, which is basic for the upcoming phases. It can be seen that the list contain activities from the very beginning of a project, going through the lean concepts establishment and commitment from everybody involved, including suppliers and customers.

1. Mission, vision and values definitions, commitment from management.
2. Objectives agreement: short, medium and long term.
3. Establish linkages with suppliers and customers (extended enterprise necessity).
4. Development metrics or Key performance indicators (KPI’s).
5. Identify current and needed skills to implement the changes.
6. Knowledge and deployment of lean concepts, consider training and consulting support.
7. Identify, business issues, goals and a general lean strategy to follow.
8. Deployment of the lean strategy.
9. Development of an information technology strategy to support all the activities.

A crucial activity that was written was the development of metrics and/or key performance indicators (KPI’s). It is important to realize that based on what is defined here, the objectives and goals will be set, therefore table 12 presents some
of the most common metrics that are used by companies. Also, some other metrics are shown in Chapter 4, section 4.5.1

Table 12
Some common metrics used by companies

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>METRICS</th>
</tr>
</thead>
</table>
| Customer satisfaction | • Complains number  
|                   | • New customers number  
|                   | • Lost customers number  
|                   | • % On time shipments and deliveries  
|                   | • % Returns  
|                   | • Warranty applications                                                 |
| Human resources  | • % Daily assistance  
|                   | • Personnel rotation  
|                   | • Training hours  
|                   | • Training efficiency                                                  |
| Employee satisfaction | • Complains number  
|                   | • Company organized events participation  
|                   | • % employee suggestions implemented                                    |
| Suppliers        | • % On time deliveries  
|                   | • Order fulfillment number  
|                   | • % scrap  
|                   | • Complains number                                                     |
| Safety           | • Accidents number  
|                   | • Training hours  
|                   | • Training efficiency                                                  
|                   | • % of audit suggestions implemented                                    |
| Productivity     | • Quality rejections number  
|                   | • % reworks  
|                   | • % scraps (raw materials, workforce, etc.)  
|                   | • Preventive maintenance hours and cost  
|                   | • Corrective maintenance hours and cost  
|                   | • Equipment stoppages                                                   
|                   | • Raw materials inventory levels                                         
|                   | • WIP inventory levels                                                   
|                   | • Finish product inventory levels                                        
|                   | • Over time amount                                                       
|                   | • Man-hours time per product                                             |

5.4.2.- Organization's flow redesign

Flow here is considered to be the path or direction that information or products follow through an organization in order to create value, which ultimately is the existence purpose of any particular company.

1 Table taken and translated from Treviño, Manuel A. “Metodología para la aplicación de los principios de manufactura esbelta en la pequeña y mediana empresa” 2002.
A flow redesign is being proposed to assure that only necessary activities are done to create value; eliminating wastes, reducing costs and time for the entire process. Although it may be related easily with the manufacturing operations the list of activities applies also for administrative, management and related issues.

It is up to each organization to make the correct flow definition that defines the stream value process, so, an external consulting firm could be use in this step to clearly define all the current activities, which will be the base point for improvements, the more defined the current activities are, the more chance for improvements.

The activities are as follows:

1.- Define what is value for the organization.
2.- Map the stream value process, identifying all the activities involved.
3.- Understand the flow process through each activity.
4.- Propose changes to the current flow, eliminating unnecessary activities.
5.- Reduce, as much as possible, the number of flow paths.
6.- Establish models and/or simulations to permit understanding and evaluation of the flow process.
7.- Establish multidisciplinary teams, organized around processes and products.
8.- Empower people to make decisions at the point of work.
9.- Minimize documentation while ensuring necessary data traceability and availability.
10.- Link databases for key functions throughout the value chain.
11.- Standardize new activities and processes.
12.- Make the flow visible to the organization (through metrics evaluation).

This phase is the most critical one, because it establishes what is important for the organization and also the actions that are taken to achieve what is important. After this phase is completed, and the new flow and activities proposed, then is necessary to establish management rules that will keep pace of the changes that are taken place.

5.4.3.- Operations management development

Operations management development refer to all the activities that must be in place to assure that the new system that is being proposed will work effectively. This means that efforts need to be directed to empower the people that will make the changes directly into their areas, to obtain the transition. Also, the information systems devised in phase 1 must be implemented here as well, to support the entire process, in order to run smoothly.
Among the activities in this phase are:

1. Assure consistency of enterprise strategy with management direction.
2. Structure programs to absorb changes with minimal impact.
3. Design in capability for potential growth and adaptability.
4. Establish career and skill development programs for each employee.
5. Use systems engineering approach in product design and development, manufacturing operations and administrative processes.
6. Implement manufacturing information systems.
7. Implement pull production systems.
8. Provide for interchange of knowledge from and within the supplier network.
9. Periodical basis reviews of the metrics and/or KPI’s that were set to document results.
10. Rewarding system as the proposed goals are being achieved.

Now, it is necessary to apply the tools that had been discussed in chapter 4 to make the all the processes lean and efficient.

5.4.4. Process improvements

Process improvements refer to the very specific actions that need to be taken to make every single activity better, lean, efficient, simple, cheaper, etc. This phase requires the involvement of every person in the organization to make changes in their particular area. Again, this phase is easier to relate it with manufacturing processes, but it must cover the others as well to have a lean organization. Lean manufacturing and lean logistics concepts must apply here, and each company must emphasize them according the particular needs.

It must be recalled that process improvements intend to eliminate the 7 wastes that were defined according to the Toyota Production System in chapter 4:

1) Overproduction.
2) Time in waiting.
3) Transportation waste.
4) Extra processing.
5) Unnecessary inventory.
6) Unnecessary movements.
7) Product defects.

Some of the activities are:

1. Establish structured processes for generating, evaluating and implementing improvements at all levels.
2. Fix problems systematically using data and root cause analysis.
3.- Rely on CAD/CAM systems for evaluations
4.- Define and control processes throughout the value chain.
5.- Review of the 14 building blocks (the lean manufacturing tools)
6.- Improve the quality at the source.
7.- Implement Total Productive Maintenance programs.
8.- Establish visual management controls.
9.- Strive for minimum quantity flow.
10.- Implement cellular manufacturing where needed.
11.- Establish production leveling.
12.- Use Kanban for the production system control.
13.- Use statistical tools to predict operations behavior.
14.- Correctly document every single successful case and learning experience for future improvements and replications.
15.- Establish the proper communication channels to deploy the changes and share the results.

It is important to mention that these improvements are meant to be applied in parallel, not sequentially, whenever possible. In such way some improvements may correlate between each other and even more gains will be seen.

5.4.5.- Continuous improvements

After all the previous phases have been implemented and stabilized the last phase of the model is to apply continuous improvements activities. At this point, results of the targeted goals must be seen, and benefits in costs, quality, time, etc., gained.

Some activities for continuous improvement include:

1.- Create and maintain relationships with customers in requirement generation, product design, development and solution-based problem solving.
2.- Build stable and cooperative relations internally and externally.
3.- Provide for mutual sharing of benefits from implementation of lean practices.
4.- Analysis of previous successfully implemented cases.
5.- Process and operations Kaizen’s (long and short).
6.- Perform benchmarkings to compare with competitors.

5.5.- General comments on the model

1.- Comparing the proposed model against table 10, it can be seen that It covers the variables that were analyzed, except those that refers to the certification of the model and the commercial software support, however, the specific activities that are inside each phase can be supported separately by different programs.
2.- The model is intended to be used by:

a) New organizations or individuals interested in participate in new businesses related with the aerospace industry, as a tool for help in being competitive and efficient.

b) Current organizations or individuals that are involved in the aerospace industry, and that are seeking ways to improve operations and to add more value to their products.

c) Universities, governments and consultants, as a research proposal to discuss, implement and improve through time.

d) Manufacturing industry in general.

It will be particularly useful to plant, production, operations, materials and maintenance managers, whose actions have a direct impact on the outcome of the implementation.

3.- About the timing, it is not possible to establish a unique time frame to implement this model. Due to individual size, specific problems, needs and goals of each organization, the time frame for each phase and for the entire model to be implemented is different. However we can relate the importance of each phase to the time that need to be spent for each one. Phase 2 is the key of the entire model, because it is about breaking paradigms and current inefficient practices, it is about changing the status quo. In the other hand, Phase 4 is the one that demands more physical work, being the phase were the work activities are improved and testing and evaluation is necessary.

Therefore the time for the model to be implemented must be carefully decided in Phase 1, where the top management commitment is obtained, resource allocation and general plan is considered.

4.- The methodology may vary, and could be partially implemented, according to the current lean status evaluation of each organization (refer to sec. 5.3). Depending on this status, some of the Phases may be skipped or even a mixture of them can be studied to cover the entire implementation according to this proposal.
6.- SOME RESULTS THROUGH CASE STUDIES

Now, it is time to show some of the results that can be achieved by applying the lean thinking philosophy that had been discussed.

The best way to do it, in this thesis, is to search for cases that have been implemented in the aerospace industry, so the concepts can be directly related with the aerospace operations environment. Because of this preference, this section will be divided as follows: 1) A specific case study result (The 737 fuselage case study report), 2) The summary of the results that have been observed, over the years, by the LAI organization, as consequence of applying lean concepts; and 3) Possible impacts of applying these concepts in the Mexican companies.

6.1.- The 737 fuselage case study report

Introduction

“The Boeing 737 “Next Generation” (NG) is the follow-on to the longest continuous production line in commercial aircraft history. The original 737(-100) was launched in February 1965, followed by the -200, -300, -400 and -500 models, and by completion of the “classic” program in 1993, 3132 737’s had been delivered. The 737 NG represented a radical design of the aircraft, including the -600, -700, -800, -900, “Combi” (-700C), and business jet (BBJ models) to be superior to competitors”\(^1\)

This project represented a great challenge for the Boeing Commercial Aircraft Company-Wichita operations. They needed to come up with something that will allow them to produce at the pace that the demand was expected to be, due to an excellent timing in the marketing efforts.

They were able to achieve great results, because some of the lean practices were being developed there even before they had this opportunity. They were having Quality circles, continuous quality improvement, kaizens, etc. The results of these practices were known as the Boeing Production System (BPS), which was based in the Toyota Production System. Another key factor that allowed this transformation was the relationship that Boeing Wichita had with Alcoa, which is their largest supplier (providing all the aluminum used for sheet metal skins, forgings, bar stocks, etc.). Alcoa was also in their way to become lean, so, when integrated into these concepts (the Boeing Way), it fitted perfectly. (Remember what was discussed in section 4.5.- The lean extended enterprise).

The plan

\(^1\) Taken from the case study: “737 Fuselage case study report”
Boeing developed a 9-point production acceleration plan to achieve the desired results, and the detail is as follows. Although is outside the scope of the implemented case, it is a good opportunity to make a relation of this plan with the proposed model of chapter 5 to see if they can be matched. Table 13 will show the activities that were defined by them and how can they be related to the model.

Table 13  
Matching the Boeing plan against the proposed model activities

<table>
<thead>
<tr>
<th>No.</th>
<th>ACTIVITIES</th>
<th>RELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Assemble a more complete aircraft per month using larger sub-assemblies with fewer parts.</td>
<td>Phase 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 4</td>
</tr>
<tr>
<td>2</td>
<td>Establish &quot;market-driven&quot; target costing as the driver of factory unit cost targets.</td>
<td>Phase 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 7</td>
</tr>
<tr>
<td>3</td>
<td>Rely on CAD for geometries, assembly and tolerances.</td>
<td>Phase 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 7</td>
</tr>
<tr>
<td>4</td>
<td>Factory teams with metrics for: cycle time, unit cost, quality, safety, attendance.</td>
<td>Phase 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 3</td>
</tr>
<tr>
<td>5</td>
<td>Investments in necessary capital equipment.</td>
<td>Phase 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 4</td>
</tr>
<tr>
<td>6</td>
<td>Flexible-tooling to have a rapid transition among the different models.</td>
<td>Phase 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 5</td>
</tr>
<tr>
<td>7</td>
<td>A Total Productive Maintenance (TPM) program was implemented using Autonomous Improvement Workshops (AMW) to assure that equipment breakdowns were not cause of bottleneck.</td>
<td>Phase 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 7</td>
</tr>
<tr>
<td>8</td>
<td>The overall business metric used was the Economic Profit (EP), and all business decisions were made using the impact on EP as the guiding principle. (Refer to figure 39)</td>
<td>Phase 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 4</td>
</tr>
<tr>
<td>9</td>
<td>Individual lines were created to support single-piece flow, these kinds of lines produced 1 part every 60 seconds.</td>
<td>Phase 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity 9</td>
</tr>
</tbody>
</table>

![Shop Floor Metrics](image)

Source: 737 Fuselage case study report

Figure 39  
Boeing economic profit calculator
By implementing this plan, based and linked to lean concepts, Boeing was able to obtain impressive results, such as:

**Results**

1. Plant ramp-up from 10 to 28 planes per month.
2. Flow time in factory reduced by 21%.
3. Capacity to add work content from the Boeing final assembly line in Renton, Washington.
4. Labor hours per unit were reduced by nearly 50% from 1998 to 2000.
5. Unit cost was reduced by 25% over the same time period.

**Personal comments on this plan**

It is my opinion that, either Boeing didn’t consider some phases/activities, or the case didn’t properly explain the whole concepts on the following topics:

- There are no considerations on how the human factor was affected. In other words, Phase 1, Activity 5 (identify current and needed skills to implement the changes) was not assessed. It may be, due to the fact that Boeing already had implemented the Boeing Production System, and therefore already had some qualified persons to take care of the job.

- They mention for their point number 1, that they need to assemble a more complete aircraft per month using larger sub-assemblies with fewer parts. However, the complete analysis and the value stream mapping are not shown. Therefore, it may be considered that they could optimize other parts of the flow process and get some improvements even before modifying assemblies. These two processes should have gone together.

- There are no considerations, whatsoever; of what kind of continuous improvements activities will they follow to support the new changes. This means completely skipping the Phase 5 of the proposed model and their activities, if there are no continuous improvements considered, the last part of the lean thinking philosophy is missing, which is striving for perfection of the whole process.

- Finally, another important omission in this plan was the establishment of the Operations management development activities, Phase 3. Although the point number 5 (Investment in necessary capital equipment) is a decision that was linked to this phase, no other actions were mentioned, leaving a gap on commenting how the new activities would be managed.

All these clarifications are necessary when documenting a case. For example, if continuous activities are planned, the results could be improved, even more for
what they had done up to that point. Also, it would leave traceability when remembering a successfully implemented case.

Using the Boeing’s experience, it is observed that having the lean tools implemented is not enough to obtain good results. The supplier (in this case Alcoa) played a key role. Also, having the vision of coming up with a proper plan, back it up with management support and, of course, the relation with other company’s departments (like Marketing) ended up in a successful project.

It is necessary to properly establish the time interval when the results are to be expected. It is to be remembered that when this challenge started at Boeing, they were already having some time working with the concepts, so, for each case; a careful study must be done to define it.

6.2.- Quantitative savings gathered by LAI consortium members

As explained in Chapter 1, the Lean Aerospace Initiative Group is composed by defense aerospace firms, the U.S. Air Force and the MIT. This group has been going on for over 12 years now. And during that time, they have documented successful case studies that were implemented, and consolidated the results obtained.

This section will present the results as they have been published by the LAI group\(^1\). The methodology to consolidate the results was as follows:

“At its November 13, 1998 meeting, the LAI Executive Board members agreed to submit letters by December 4, 1998 summarizing the following:

- The benefits which have been realized from implementation of lean practices in their organization, with an emphasis on specific and quantitative results
- The contributions of the LAI in achieving these benefits

28 letters were received from 16 industry organizations, 11 government agencies and the MIT (to see the list of submitters refer to Appendix F), the citations have been taken as they are, without attribution or verification”. Only the consolidated results table will be shown, please refer to table 14 (for the complete results by area refer to Appendix G).

As it can be observed in the table, the benefits of implementing these concepts through the lean enterprise model are present, and that results in an overall increment of competitiveness.

\(^1\) Taken from the LAI paper: “Benefits of implementing Lean Practices and the Impact of the Lean Aerospace Initiative in the Defense aerospace industry and Government agencies”
Chapter 6: Some results through case studies

6.3. Possible impacts in the Mexican companies

For the case of Mexican companies the approach will be a little different from the previous 2 sections. In the first section of this chapter a documented case was shown, describing the practices that were implemented, the plan, the actions and the results that were obtained. In section 2 the summary of the results according to the LAI were presented, all based in cases related with the aerospace industry. In this section, some if the impacts that this may have in Mexican companies will be discussed.

Table 14: Consolidated results cited by LAI consortium members

<table>
<thead>
<tr>
<th>Metric</th>
<th>Range of Measurements of Relative Improvement</th>
<th>Number of Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production/manufacturing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td>11% to 30%</td>
<td>5</td>
</tr>
<tr>
<td>Labor hours</td>
<td>10% to 20%</td>
<td>6</td>
</tr>
<tr>
<td>Productivity</td>
<td>27% to 30%</td>
<td>5</td>
</tr>
<tr>
<td>Cycle time</td>
<td>20% to 30%</td>
<td>13</td>
</tr>
<tr>
<td>Factory floor space</td>
<td>25% to 30%</td>
<td>6</td>
</tr>
<tr>
<td>Travel distances (people or product)</td>
<td>42% to 45%</td>
<td>8</td>
</tr>
<tr>
<td>Inventory or Work in progress</td>
<td>31% to 40%</td>
<td>4</td>
</tr>
<tr>
<td>Scrap, rework, defects or inspection</td>
<td>20% to 30%</td>
<td>7</td>
</tr>
<tr>
<td>Set up time</td>
<td>17% to 25%</td>
<td>4</td>
</tr>
<tr>
<td>Lead time</td>
<td>16% to 20%</td>
<td>3</td>
</tr>
<tr>
<td><strong>Design/engineering/EMD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor hours or cost</td>
<td>30% to 80%</td>
<td>3</td>
</tr>
<tr>
<td>Cycle time</td>
<td>46% to 50%</td>
<td>2</td>
</tr>
<tr>
<td><strong>Enterprise</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle time, price, productivity</td>
<td>15% to 58%</td>
<td>4</td>
</tr>
<tr>
<td><strong>Business/Acquisition Processes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle time or labor for orders, proposal processing</td>
<td>50% to 83%</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: LAI, MIT
First of all, let’s take a look in the size of all the manufacturing companies in Mexico, regardless of the specific sector taking information from the Mexican Enterprise Information System (Sistema de Información Empresarial Mexicano, SIEM).

<table>
<thead>
<tr>
<th>Size</th>
<th>Micro</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturing</strong></td>
<td>27,838</td>
<td>8,251</td>
<td>4,392</td>
<td>2,223</td>
<td>42,704</td>
</tr>
<tr>
<td>%</td>
<td>65.2</td>
<td>19.3</td>
<td>10.3</td>
<td>5.2</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 40
Distribution of manufacturing companies in Mexico by size

Note: According to Mexican regulations, the size of the company is based on its number of employees, for the case of the industrial sector is as follows:

<table>
<thead>
<tr>
<th>Size</th>
<th>0-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>0-10</td>
</tr>
<tr>
<td>Small</td>
<td>11-50</td>
</tr>
<tr>
<td>Medium</td>
<td>51-250</td>
</tr>
<tr>
<td>Large</td>
<td>&gt;251</td>
</tr>
</tbody>
</table>

The statistics are clear on the distribution of the companies, around 85% are Micro and Small companies, which mean that up to 50 employees participate, so what may be some of the potential economical and operational impacts of applying the Lean concepts?, please refer to table 15.
Chapter 6. - Some results through case studies

Table 15
Economical and operational impacts in the Mexican companies

<table>
<thead>
<tr>
<th>AREA</th>
<th>IMPACT</th>
</tr>
</thead>
</table>
| 1.- Economical| • These companies always operate with a limited budget; very tight controls must be placed in order to assure economic integrity, these concepts provide specific metrics to follow and keep track of  
• Credits are often requested to financial institutions, therefore a quick payback must be demanded and obtained, make the most of any new investment.  
• Profits will be increased due to more efficient operations  
• Revenues may increase due to better use of capacity  
• Savings in real state expenses due to improved space utilization  
• Savings in manpower |
| 2.- Operational| • Machinery will be used efficiently  
• Productivity metrics will be followed, detecting any deviations that may occur and correcting them immediately  
• Improvements are obtained in company-wide operations, not for any specific project or area  
• Less time to develop new products, or to make modifications to current  
• Efficient product flow through the operations  
• Improved quality on the products  
• Improved safety in the facilities  
• Possibility to compete with bigger companies within specific segments, processes or tasks  
• Reduced inventories due to educated planning and considerations for their levels and necessity |

A search for specific results of applying lean manufacturing concepts in Mexican industries was done; however there were no specific results found for a particular project. In other words, general results such as the ones that were shown in section 6.2 are often presented in other thesis and research works.

This situation must not limit the application or the believability of the model that was presented here, and the models that have been proposed by other authors. The results, if properly implemented, tend to follow similar patterns regardless of the company, the amount of benefits surely change, according to the ideas, projects, changes and commitment of the organizations.
7- CONCLUSIONS AND FURTHER RESEARCH

7.1.- Conclusions

*From the aerospace industry introduction, and relationship with Mexico*

1.- The aerospace industry encompasses, within itself, 3 main divisions: defense, civil and commercial. From these, the division which is more open to general participation is the Commercial one, with 2 more sub-divisions: 1) Air, which includes aircraft manufacturing, air carriers and general aviation and 2) Space, which includes launch vehicles, satellite manufacturing, telecommunications etc. *Mexico should pay special attention to the Commercial division, because it is where business opportunities may happen and are likely to be developed.*

2.- There are a lot of similarities between the AI and the automotive industry. AI suppliers can also be divided into tiers: Tier 1, being somebody that delivers directly to an aircraft (or final product) manufacturer. Tier 2, being somebody that delivers a part or product to a tier 1, and so on. *There is an opportunity for Mexico to enter the market as a tier 3 or tier 4 supplier* (the bottom level on the pyramid), because this require labor intensive operations, manufacturing and low-level engineering, which all have been experienced and developed from the automotive industry, that now is even in a much higher level.

3.- The U.S. market for AI parts was around $25 billion in 2004. Canada and France together have around 50% of this market. Mexico was located in 19th place as supplier of these kinds of parts. Brazil is the only Latin American country ahead of Mexico, located in 4th place.

4.- Boeing is the world’s largest AI company. It has 2 main segments which are: 1) Commercial airplanes and, 2) Defense systems. Because Boeing is one of the few companies at the top of the functional description pyramid, they provide aircrafts and systems to their customers, so, it is likely that if Mexico becomes involved as a third or fourth tier level supplier, the manufactured products will eventually get to them.

5.- Consolidation process has been a constant for almost every AI company in order to survive. Joint ventures, acquisitions and mergers have proven to be right to keep companies going on. American companies had done it and European companies also had done it. It is important to realize that this demanding market requires knowledge from several areas, so this trend is understandable. *The best idea that can be applied for Mexican companies is to have an association or joint venture with an established company. It is necessary to have a technological partner involved in the business.* They will not only support operations, but also could share part of their market, if they get benefited too by manufacturing opportunities. This association must beneficial
for both partners and it is likely to happen, as U.S. companies look to reduce labor costs.

6.- It is not easy to find information about the current suppliers to the AI in Mexico, not in private companies or government websites. This shows the lack of organization in promoting the industry and the businesses, despite the fact that around 65 companies were identified to be in this sector, according to a study performed by Mexico’s Economy Secretariat in April 2005.

7.- The free Interstate highway system of the U.S., and the mixed (free and toll) main highway corridors of Mexico represent one of the keys in the geographical relations advantages that both countries need to rely on for commerce trade. In the specific case of the AI the highways provide an excellent opportunity for business with California, Texas and Arizona, 3 of the top 10 U.S. states with most AI business. All of this, given the fact that ground transportation is the most cost-effective, lead time-convenient way.

From the Lean thinking concepts

1.- Lean thinking is a working philosophy that strives to be efficient everywhere within an organization. However, this is not only responsibility of the implementation team or a specific department, lean thinking is a culture that must be absorbed and practiced by every single member of a company, from the top management to the line workers, otherwise it just won’t work, without the proper commitment.

2.- Logistics costs represent an important part of the overall costs for the companies, therefore, it is necessary to invest time and resources to make a complete review on how the logistics operations are being done. Logistics decisions are several, but 2 in particular require more attention: Transportation and inventory carrying costs. These 2 subjects are estimated to account for around 2/3 of the total logistics costs. Lean logistics must be considered as the tool to improve the operations.

3.- The Lean Extended Enterprise must be considered when trying to obtain lean thinking concepts benefits. If the suppliers and the customers are not familiar or involved with them as well, it will be practically impossible to see the benefits, so special attention and consideration must be made when selecting both.

4.- The MIT’s Lean Enterprise Model, the SCOR, the VSM, and the Lean deployment are some of the models that are currently being used to increase
competitiveness, however they all have gaps if they are considered to be implemented in the Mexican industry conditions.

**From the lean enterprise model proposal and case study results**

1. A 5-phase model with specific activities to follow is appropriate for the Mexican industry conditions, since it gives direct instructions on what to do to achieve better results according to the KPI’s that were defined. The pyramidal structure avoids confusions and provides the guidelines on how to proceed for each phase and when to move to the next one. This model can cover for some of the gaps that current models have in areas such as difficulty of implementation, specific activities to develop and phases, among others.

2. The second phase is the most critical one, because it establishes what is important for the organization and also the actions that are taken to achieve what is important. Paradigms must be broken, new working visions must be implemented to eliminate wastes. If this phase is properly established the future phases will run easier and smoothly.

3. The implementation time for the model varies according to the company. This variation goes according to the size, complexity, objectives, goals and needs of each company, however the time frame must be carefully decided in Phase 1, so the other phases know exactly when to finish and present results.

4. The Boeing 737 fuselage case study got amazing results, almost producing 3 times what they were producing originally, not only that; they also added work from other Boeing facilities to cover for the excess capacity that they got in the different areas. The 9-point plan that they developed could be successfully matched to some of the activities that were proposed in the model.

5. The results that are summarized by the LAI consortium must be carefully reviewed, because these are the gathering from the companies that have been involved in this lean effort, and all of them report results that are very important to any company. In the case of the Mexican industry, if only a fraction of these numbers can be achieved it will represent the opportunity to continue and expand business in the area.

**7.2.- Further research**

Due to the nature of this thesis there are several topics that can be further researched, among them are:

1. This thesis is focused on the American AI and the possible relation with Mexico. A similar thesis may be done considering only information from Europe, this is
the second biggest market, only behind the U.S., and if there is interest to get a share in the U.S. market, it is reasonable also to get a share into the European market. The work may be focused solely in a relation with EADS, which is the biggest company there, and could cover topics such as Requirements for being a supplier, opportunity areas and future projects.

2.- Boeing is the world’s largest AI company. An in-depth study should be done to determine all the opportunities that this company has, how can a company become a supplier for them, what kind of products do they need more often, who are they main sub-systems suppliers, where are they located. There is a lot of information to research about this company, especially since they have a big project coming soon, the 7E7, and cost-reduction, improvements and new projects can materialize.

3.- It is easy to observe the difference that exists between the U.S. and Mexico for sharing related AI information. U.S. has their Aerospace Industries Association, where statistics, links, information, trends and news are placed. It is a single internet site that shows plenty of information; also, there are sites like the U.S. Department of Commerce with statistics on the trade that has been going on in the past, etc. It is necessary for Mexico to initially develop 2 strategic activities: 1.- Some kind of association for the companies that are involved in the AI, where they can share ideas, technologies, contacts and so on. 2.- A web site with all the relevant information, and where customers can go and locate any suppliers that they may be interested to work with.

4.- A deeper study on the impact that the Interstate highway system of the U.S. and the main highway corridors of Mexico can have on the AI trade must be made. Furthermore, not only limited to consider ground transportation, but also considering inter-modal services such as truck-ship, truck-rail, or truck-air. The entire infrastructure could be considered and scenarios for trade can be developed.

5.- A lean enterprise model suitable for Mexican companies was proposed in this work. However the actual implementation and results were observed through case studies developed in the U.S., due to lack of support and contacts with a particular AI company established in Mexico. It is necessary to present a specific work, focused in one particular company, where the model can be applied, defining the correct scope and time interval to see and document the results, only then, what is being proposed will be completely validated.

6.- A discrete event simulation can be performed to propose changes into the enabling practices that were described. Once a particular area has been defined, and a company has been chosen, operation times can be obtained for the activities, and improvements can be evaluated via discrete simulation software.
ACRONYMS

Throughout the entire work, there are several acronyms that are continuously used, this chart will present their definition for reference.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI</td>
<td>Aerospace Industry</td>
</tr>
<tr>
<td>AIA</td>
<td>Aerospace Industries Association</td>
</tr>
<tr>
<td>EADS</td>
<td>European Aeronautic Defense and Space Company</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>JIT</td>
<td>Just In Time</td>
</tr>
<tr>
<td>KPI’s</td>
<td>Key Performance Indicators</td>
</tr>
<tr>
<td>LAI</td>
<td>Lean Aerospace Initiative</td>
</tr>
<tr>
<td>LEM</td>
<td>Lean Enterprise Model</td>
</tr>
<tr>
<td>LESAT</td>
<td>Lean Enterprise Self Assessment Tool</td>
</tr>
<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>NAFTA</td>
<td>North America Free Trade Agreement</td>
</tr>
<tr>
<td>NAICS</td>
<td>North American Industry Classification System</td>
</tr>
<tr>
<td>SCOR</td>
<td>Supply Chain Operations Reference</td>
</tr>
<tr>
<td>SMED</td>
<td>Single Minute Exchange of Die</td>
</tr>
<tr>
<td>TPM</td>
<td>Total Productive Maintenance</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollars</td>
</tr>
<tr>
<td>VSM</td>
<td>Value Stream Management</td>
</tr>
<tr>
<td>WIP</td>
<td>Work In Progress</td>
</tr>
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</table>
REFERENCES


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APPENDIX A

DESCRIPTION OF EACH AND EVERY AI ACTIVITY UNDER NAICS

<table>
<thead>
<tr>
<th>NAICS Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3364111</td>
<td>MILITARY AIRCRAFT (INCLUDING ALL AIRCRAFT FOR U.S. MILITARY AND ANY OTHER AIRCRAFT BUILT TO MILITARY SPECIFICATIONS)</td>
</tr>
<tr>
<td>33641111</td>
<td>Military aircraft (including all aircraft for U.S. military and any other aircraft built to military specifications)</td>
</tr>
<tr>
<td>3364111100</td>
<td>Military aircraft (including all aircraft for U.S. military and any other aircraft built to military specifications)</td>
</tr>
<tr>
<td>3364113</td>
<td>CIVILIAN AIRCRAFT</td>
</tr>
<tr>
<td>33641130</td>
<td>Civilian aircraft</td>
</tr>
<tr>
<td>3364113000</td>
<td>Civilian aircraft</td>
</tr>
<tr>
<td>3364113004</td>
<td>Civil aircraft unladen weight not exceeding 2,000 kg (4,409 lb)</td>
</tr>
<tr>
<td>3364113007</td>
<td>Civil aircraft with unladen weight exceeding 2,000 kg (4,409 lb)</td>
</tr>
<tr>
<td>3364113011</td>
<td>Civil aircraft with unladen weight exceeding 15,000 kg (33,069 lb)</td>
</tr>
<tr>
<td>3364113014</td>
<td>Helicopters with unladen weight not exceeding 2,000 kg (4,409 lb)</td>
</tr>
<tr>
<td>3364113017</td>
<td>Helicopters with unladen weight exceeding 2,000 kg (4,409 lb)</td>
</tr>
<tr>
<td>3364113021</td>
<td>Other civil aircraft (nonpowered) and kits</td>
</tr>
<tr>
<td>3364115</td>
<td>MODIFICATION, CONVERSION, AND OVERHAUL OF PREVIOUSLY ACCEPTED AIRCRAFT</td>
</tr>
<tr>
<td>336411501</td>
<td>Modification, conversion, and overhaul of previously accepted aircraft</td>
</tr>
<tr>
<td>33641150104</td>
<td>Modification, conversion, and overhaul of U.S. military aircraft and all other aircraft built to military specifications for civilian customers</td>
</tr>
<tr>
<td>3364117</td>
<td>OTHER AERONAUTICAL SERVICES ON COMPLETE AIRCRAFT, NEC</td>
</tr>
<tr>
<td>33641171</td>
<td>Other aeronautical services on complete aircraft, nec</td>
</tr>
<tr>
<td>3364117101</td>
<td>Research and development on complete aircraft for military customers</td>
</tr>
<tr>
<td>3364117104</td>
<td>All other aeronautical services on complete aircraft for military customers</td>
</tr>
<tr>
<td>3364117107</td>
<td>Research and development on complete aircraft for civilian customers</td>
</tr>
<tr>
<td>3364117111</td>
<td>All other aeronautical services on complete aircraft for civilian customers</td>
</tr>
<tr>
<td>3364121</td>
<td>AIRCRAFT ENGINES AND ENGINE PARTS</td>
</tr>
<tr>
<td>33641211</td>
<td>MILITARY AIRCRAFT ENGINES (AND ANY OTHER AIRCRAFT BUILT TO MILITARY SPECIFICATIONS)</td>
</tr>
<tr>
<td>3364121100</td>
<td>Military aircraft engines (and any other aircraft built to military specifications)</td>
</tr>
<tr>
<td>3364123</td>
<td>CIVILIAN AIRCRAFT ENGINES</td>
</tr>
<tr>
<td>33641230</td>
<td>Civilian aircraft engines</td>
</tr>
<tr>
<td>3364123000</td>
<td>Civilian aircraft engines</td>
</tr>
<tr>
<td>3364123004</td>
<td>Turbojet and turboprop aircraft engines of a thrust not exceeding 25 kN (5,620 lb)</td>
</tr>
<tr>
<td>3364123007</td>
<td>Turbojet and turboprop aircraft engines of a thrust exceeding 25 kN (5,620 lb)</td>
</tr>
<tr>
<td>3364123011</td>
<td>Turbojet and turboprop aircraft engines of a power not exceeding 1,100 kW (1,520 hp)</td>
</tr>
<tr>
<td>3364123014</td>
<td>Turboshaft civil aircraft engines of a power exceeding 1,100 kW (1,520 hp)</td>
</tr>
<tr>
<td>3364123017</td>
<td>Other civil aircraft engines, including auxiliary power units, excluding missile and space engines</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3364125</td>
<td>AERONAUTICAL SERVICES ON AIRCRAFT ENGINES</td>
</tr>
<tr>
<td>33641251</td>
<td>Aeronautical services on aircraft engines</td>
</tr>
<tr>
<td>3364125101</td>
<td>Research and development work on U.S. military aircraft engines and all other engines built to military specifications</td>
</tr>
<tr>
<td>3364125104</td>
<td>Research and development work on civilian aircraft engines</td>
</tr>
<tr>
<td>3364125107</td>
<td>All other aeronautical services on U.S. military aircraft engines and all other engines built to military specifications</td>
</tr>
<tr>
<td>3364125111</td>
<td>All other aeronautical services on civilian aircraft engines</td>
</tr>
<tr>
<td>3364127</td>
<td>AIRCRAFT ENGINE PARTS AND ACCESSORIES</td>
</tr>
<tr>
<td>33641271</td>
<td>Parts and accessories for spark ignition reciprocating or rotary internal combustion military aircraft engines</td>
</tr>
<tr>
<td>3364127101</td>
<td>Parts and accessories for spark ignition reciprocating or rotary internal combustion military aircraft engines</td>
</tr>
<tr>
<td>33641272</td>
<td>Parts and accessories for other military aircraft engines</td>
</tr>
<tr>
<td>3364127204</td>
<td>Parts and accessories for other military aircraft engines</td>
</tr>
<tr>
<td>33641273</td>
<td>Parts and accessories for spark ignition reciprocating or rotary internal combustion civilian aircraft engines</td>
</tr>
<tr>
<td>3364127307</td>
<td>Parts and accessories for spark ignition reciprocating or rotary internal combustion civilian aircraft engines</td>
</tr>
<tr>
<td>33641274</td>
<td>Parts and accessories for other civilian aircraft engines</td>
</tr>
<tr>
<td>3364127411</td>
<td>Parts and accessories for other civilian aircraft engines</td>
</tr>
<tr>
<td>336413</td>
<td>AIRCRAFT PARTS AND AUXILIARY EQUIPMENT, NEC</td>
</tr>
<tr>
<td>3364131</td>
<td>AIRCRAFT PROPELLERS AND HELICOPTER ROTORS</td>
</tr>
<tr>
<td>33641311</td>
<td>Aircraft propellers and helicopter rotors</td>
</tr>
<tr>
<td>3364131101</td>
<td>Complete aircraft propellers, excluding helicopter rotors</td>
</tr>
<tr>
<td>3364131104</td>
<td>Aircraft propeller blades</td>
</tr>
<tr>
<td>3364131107</td>
<td>Aircraft propeller parts, except propeller blades</td>
</tr>
<tr>
<td>3364131111</td>
<td>Helicopter rotors and parts</td>
</tr>
<tr>
<td>3364133</td>
<td>RESEARCH AND DEVELOPMENT ON AIRCRAFT PARTS (EXCEPT ENGINES)</td>
</tr>
<tr>
<td>33641331</td>
<td>Research and development on aircraft parts (except engines)</td>
</tr>
<tr>
<td>3364133101</td>
<td>Research and development on U.S. military aircraft parts (except engines)</td>
</tr>
<tr>
<td>3364133104</td>
<td>Research and development on civilian aircraft parts (except engines)</td>
</tr>
<tr>
<td>3364135</td>
<td>AIRCRAFT PARTS AND AUXILIARY EQUIPMENT, EXCLUDING HYDRAULIC AND PNEUMATIC SUBASSEMBLIES AND ENGINES</td>
</tr>
<tr>
<td>33641351</td>
<td>Aircraft mechanical power transmission equipment for civilian and U.S. military aircraft</td>
</tr>
<tr>
<td>3364135101</td>
<td>Aircraft mechanical power transmission equipment for U.S. military aircraft and all other aircraft built to military specifications</td>
</tr>
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APPENDIX B

SUPPLIERS TO THE U.S. AI AND VALUE OF SHIPMENTS

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## APPENDIX C

### TOP 30 AI COMPANIES WORLDWIDE

<table>
<thead>
<tr>
<th>COMPANY (RANKED BY SALES)</th>
<th>MARKET/PRODUCT OVERVIEW</th>
<th>2002 SALES (MILLION)</th>
<th>2002 NET INCOME (MILLION)</th>
<th>EST # EMPLOYEES</th>
<th>PRIMARY COMPETITORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 The Boeing Company</td>
<td>World's largest aerospace company with two key industry segments: Commercial Airplanes and Integrated Defense Systems</td>
<td>$94,060,000</td>
<td>$549,200</td>
<td>100,000</td>
<td>Boeing, Airbus, EADS, Lockheed Martin</td>
</tr>
<tr>
<td>#2 European Aeronautic Defence and Space Company (EADS)</td>
<td>A conglomerate of three companies: DaimlerChrysler Aerospace, Aérospatiale Matra, and Construcciones Aeronáuticas S.A.</td>
<td>$31,339,000</td>
<td>(31,34)</td>
<td>103,967</td>
<td>BAE Systems, Boeing, Lockheed Martin</td>
</tr>
<tr>
<td>#3 Lockheed Martin Corporation</td>
<td>Leading worldwide defense contractor</td>
<td>$26,578,000</td>
<td>$590,000</td>
<td>125,000</td>
<td>Boeing, Northrop Grumman</td>
</tr>
<tr>
<td>#4 Airbus S.A.S.</td>
<td>Worldwide maker of commercial jetliners --- #2 behind Boeing owned by EADS and BAE Systems</td>
<td>$20,333,00</td>
<td>NA</td>
<td>46,000</td>
<td>Boeing, Bombardier, Embraer</td>
</tr>
<tr>
<td>#5 Northrop Grumman Corporation</td>
<td>The World's #2 defense contractor behind Lockheed Martin</td>
<td>$17,226,000</td>
<td>$54,0</td>
<td>117,300</td>
<td>Boeing, General Dynamics, Lockheed Martin</td>
</tr>
<tr>
<td>#6 Raytheon Company</td>
<td>Aerospace subsidiary of this company produces civil aircraft</td>
<td>$15,481,000</td>
<td>(40,25)</td>
<td>70,411</td>
<td>Boeing, Embraer</td>
</tr>
<tr>
<td>#7 BAE SYSTEMS</td>
<td>Largest European defense contractor</td>
<td>$12,953,000</td>
<td>(12,109,3)</td>
<td>68,100</td>
<td>Boeing, EADS, Lockheed Martin</td>
</tr>
<tr>
<td>#8 GE Aircraft Engines</td>
<td>A business unit of GE --- world's largest producer of engines for commercial and military aircraft</td>
<td>$11,141,000</td>
<td>NA</td>
<td>26,000</td>
<td>Honeywell/Aerospace, Pratt &amp; Whitney, Rolls-Royce</td>
</tr>
<tr>
<td>#9 Rolls-Royce plc</td>
<td>Second largest aircraft engine maker in the world behind GE's Aircraft Engines division</td>
<td>$9,283,000</td>
<td>$58,500</td>
<td>39,000</td>
<td>GE Aircraft Engines, Honeywell, Pratt &amp; Whitney</td>
</tr>
<tr>
<td>#10 Honeywell Aerospace</td>
<td>Business unit of Honeywell International</td>
<td>$8,855,000</td>
<td>NA</td>
<td>NA</td>
<td>Boeing, Pratt &amp; Whitney, United Technologies</td>
</tr>
<tr>
<td>COMPANY (RANDED BY SALES)</td>
<td>MARKET/PRODUCT OVERVIEW</td>
<td>2002 NET INCOME (MIL)</td>
<td>EST. # EMPLOYEES</td>
<td>PRIMARY COMPETITORS</td>
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<td>-------------------</td>
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</tr>
<tr>
<td>#11 Pratt &amp; Whitney</td>
<td>Division of United Technologies that manufactures and services commercial &amp; military aircraft engines • Other interests: aerospace propulsion systems</td>
<td>$7,641.0</td>
<td>NA</td>
<td>30,000</td>
<td>GE Aircraft Engines • Lockheed Martin • Rolls-Royce</td>
</tr>
<tr>
<td>#12 Parker-Hannifin Corporation</td>
<td>Maker of aerospace components such as fuel systems and traction control equipment products</td>
<td>$6,144.1</td>
<td>$130.2</td>
<td>48,175</td>
<td>Eaton • Honeywell International</td>
</tr>
<tr>
<td>#13 Smiths Group plc</td>
<td>Aerospace Division produces civil and defence navigation and avionics systems</td>
<td>$5,073.1</td>
<td>$77.3</td>
<td>33,000</td>
<td>EADS • Lockheed Martin • GE Aircraft Systems</td>
</tr>
<tr>
<td>#14 Goodrich Corporation</td>
<td>Leading producer of aerospace products &amp; systems including Airframe, Systems, Electronic Systems and Engine Systems</td>
<td>$5,101.0</td>
<td>$117.9</td>
<td>22,900</td>
<td>EADS • Honeywell International • United Technologies</td>
</tr>
<tr>
<td>#15 Rockwell Automation, Inc.</td>
<td>Worldwide producer of industrial automation products &amp; services • Operations include Control and Power Systems</td>
<td>$3,906.0</td>
<td>$121.0</td>
<td>22,000</td>
<td>Honeywell • International • Siemens • UNIOPA</td>
</tr>
<tr>
<td>#16 Cessna Aircraft Company</td>
<td>Subsidiary of Textron that manufactures business, utility &amp; military aircraft • Leading manufacturer of business jet aircraft</td>
<td>$3,323.9</td>
<td>NA</td>
<td>NA</td>
<td>Boeing • Cessna Aircraft • Gulfstream Aerospace</td>
</tr>
<tr>
<td>#17 Dassault Aviation SA</td>
<td>Primary manufacturer &amp; luxury jets • Other products: produced military aircraft, e.g., fighter jets &amp; IRRs • Partially owned by EADS</td>
<td>$3,005.5</td>
<td>$32.7</td>
<td>12,022</td>
<td>Boeing • Dassault Aviation • EADS • Gulfstream Aerospace</td>
</tr>
<tr>
<td>#18 Hamilton Sundstrand Corporation</td>
<td>A subsidiary of United Technologies that manufactures aerospace &amp; industrial products • Top lasers customers include NASA, commercial airliners &amp; the U.S. military</td>
<td>$1,430.0</td>
<td>NA</td>
<td>16,700</td>
<td>Honeywell International • Northrop Grumman • Woodward</td>
</tr>
<tr>
<td>#19 Gulfstream Aerospace Corporation</td>
<td>A subsidiary of General Dynamics that makes business jets • Other interests: after-market maintenance &amp; sale of its used airplanes</td>
<td>$2,935.0</td>
<td>NA</td>
<td>11,000</td>
<td>Boeing • Cessna Aircraft • Dassault Aviation • Gulfstream Aerospace</td>
</tr>
<tr>
<td>#13 Embraer – Empresa Brasileira de Aeronáutica S.A.</td>
<td>Leading worldwide manufacturer of aircraft, including jets and turboprops • Other interests: manufacture of transport and surveillance aircraft for the military</td>
<td>$2,235.8</td>
<td>$222.0</td>
<td>11,000</td>
<td>Boeing • Cessna Aircraft • Dassault Aviation • Gulfstream Aerospace • Fairchild Comr</td>
</tr>
<tr>
<td>COMPANY (RANKED BY SALES)</td>
<td>MARKET/PRODUCT OVERVIEW</td>
<td>2002 SALES (MIL)</td>
<td>2002 NET INCOME (MIL)</td>
<td>EST. # EMPLOYEES</td>
<td>PRIMARY COMPETITORS</td>
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<td>-----------------------</td>
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<td>-----------------------------------------------------------------------------------</td>
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</tbody>
</table>
| #21 Rockwell Collins, Inc. | * Maker of aviation electronics and communication equipment for commercial and military aircraft  
  * Primary customers are domestic based                                                   | $2,262.0         | $290.0                | 14,500          | BAE Systems  
  Honeywell International  
  Raytheon                                                                             |
| #22 Raytheon Aircraft     | * Large manufacturer of business jets such as the Hawker Horizon  
  * Raveler 800XP and Beechjet 400,  
  * Other interests include aircraft, charter, maintenance, and management services       | $2,150.0         | NA                    | 11,800          | Gulfstream Aerospace  
  Learjet  
  Tornade                                                                                |
  Lockheed Martin  
  Raytheon                                                                                |
| #24 Woodward Governor Co. | * Producer of industrial controls for industrial engines, turbines, and flight control systems  
  * Components for aircraft engines                                                        | $680.0           | $42.7                 | 3,129           | Hamilton Sundstrand  
  Parker Hannifin                                                                            |
| #25 Meggitt PLC           | * Maker of towed and unmanned vehicles for military use also produces avionics and aerospace sciences | $647.7           | $20.1                 | 3,220           | Goodrich  
  Rockwell Collins  
  Smiths Group                                                                           |
| #26 E2Aerospace, Inc.     | * Leading maker of cabin components for commercial passenger aircraft and business jets  
  * Products include aircraft seats, coffee makers, galley structures, and emergency oxygen systems | $500.0           | $708 (2003)           | 3,700           | Bittar  
  CRJ Aerospace                                                                              |
| #27 Jet Aviation Management | * Worldwide provider of chartered jet travel organized and managed  
  * Aircraft include corporate jets and private jets and helicopters                        | $182.8           | NA                    | 3,500           | BBA Group  
  Nakjets  
  Nihon Group                                                                             |
| #28 Garmin, Inc.          | * Maker of navigational systems for use in satellite communications  
  * Products include handhelds, portable products, and communication devices               | $465.1           | $141.8                | 1,575           | Loran Electronics  
  Orbital Sciences                                                                           |
| #29 Aerojet General Corp. | A subsidiary of GenCorp that makes missiles, space propulsion systems,  
  * Ammunition, and other defense products  
  * Products include solid and liquid rocket engines, motors, control systems,  
  * For rockets & missiles                                                                   | $277.0           | NA                    | NA              | Boeing  
  Northrop Grumman  
  Allied Telesis                                                                            |
| #30 Aeronautics Corporation | * Maker of mechanical aircraft instruments and aircraft instrument testing equipment  
  * Products include altimeters, airspeed indicators, vertical speed indicators, and doths | $27.4            | $1.0                  | 214             | Honeywell International  
  Rockwell Automation  
  Smiths Group                                                                              |
APPENDIX D

MEXICO-US-CANADA HIGHWAY CORRIDORS

Selected North American Corridors

[Map showing various highway corridors across North America]

Source: ICF Consulting, 2001
The Lean Enterprise Model

The Lean Enterprise Model (LEM) is a systematic framework for organizing and disseminating MIT research and external data source results of the Lean Enterprise Initiative (LEI). It encompasses lean enterprise principles and practices and is populated by MIT and external data derived from surveys, case studies and other research activities. The LEM is available at LEI consortium members as a reference to help them understand better the leanness of their own organizations and processes. It is intended to provide insights as to where they might direct their efforts in the future.

### ENABLING PRACTICES

- **Identify and Optimize Enterprise Flow**
  - 1.0 Cycle Time to Market
  - 2.0 Cycle Time to Order
  - 3.0 Cycle Time to Fault

- **Assure Seamless Information Flow**
  - 1.0 Reduce cycle time from order to payback
  - 2.0 Reduce cycle time to order
  - 3.0 Reduce cycle time to decision
  - 4.0 Reduce cycle time to order

- **Optimize Capability and Utilization of People**
  - 1.0 Provide opportunities to improve processes
  - 2.0 Provide opportunities to reduce waste

- **Make Decisions at Lowest Possible Level**
  - 1.0 Lower level of decision-making
  - 2.0 Lower level of decision-making

### METRICS

- 1.0 Cycle Time
- 2.0 Cycle Time
- 3.0 Cycle Time
- 4.0 Cycle Time

### QUALITY YIELDS

- 1.0 Defects per Unit
- 2.0 Defects per Unit
- 3.0 Defects per Unit
- 4.0 Defects per Unit

### DEVELOP RELATIONSHIPS BASED ON MUTUAL TRUST AND COMMITMENT

- 1.0 Build trust and commitment
- 2.0 Build trust and commitment
- 3.0 Build trust and commitment
- 4.0 Build trust and commitment

---

The Lean Enterprise Model (LEM) Summary Chart with Enabling Practices • Reprinted April 2014
© Massachusetts Institute of Technology
The LEM: An On-Line Tool

The LEM is presently available on-line for all LAI members and their authorized suppliers. For more information about on-line access, please visit http://web.mit.edu/lean or contact your organization's LAI Champion for more details.

"A complete member listing with the correlating "network of champions" is also available on-line at http://web.mit.edu/lean – please refer to "LAI Communities."

---

**METRICS**

<table>
<thead>
<tr>
<th>METRIC</th>
<th>DESCRIPTION</th>
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<tr>
<td>1. Cycle time (industry comparison, % reduction)</td>
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<tr>
<td>2. Cost Improvement</td>
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<tr>
<td>3. Key release / project Phase</td>
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</table>

---

**THE LEM LEADERSHIP AT ALL LEVELS**

- "Align the organization to achieve the enterprise's lean mission."

**ENABLING PRACTICES**

- Establish structured process for identifying and implementing improvement at all levels (2.3, 5.4, 5.10.11)
- Involves all levels throughout the enterprise in all onsite and offsite processes (5.2, 5.3, 5.10.11)
- Assures consistency with local leadership and practices (5.2, 5.3, 5.10.11)
- Involves all leadership in planning and implementing lean practices (5.3, 4.5.10.10.11)

---

**THE MAINTAIN CHALLENGE OF EXISTING PROCESSES**

- "Establish a culture and systems that are able to continue improvements and maintain a sustainable level of performance."

**ENABLING PRACTICES**

- Establish structured process for identifying and implementing improvement at all levels (2.3, 5.4, 5.10.11)
- Establishes the Lean management system (5.3, 4.5.10.11)
- Assures consistency with local leadership and practices (5.2, 5.3, 5.10.11)
- Involves all leadership in planning and implementing Lean practices (5.3, 4.5.10.11)

---

**THE NURTURE A LEARNING ENVIRONMENT**

- "Provide for continuous improvement and training for the organization and maintain support of organizational change."

**ENABLING PRACTICES**

- Establish structured process for identifying and implementing improvement at all levels (2.3, 5.4, 5.10.11)
- Establishes the Lean management system (5.3, 4.5.10.11)
- Assures consistency with local leadership and practices (5.2, 5.3, 5.10.11)
- Involves all leadership in planning and implementing Lean practices (5.3, 4.5.10.11)

---

**THE ENSURE STABILITY IN A CHANGING ENVIRONMENT**

- "Sustain management to maintain program stability in a changing environment."

**ENABLING PRACTICES**

- Establish structured process for identifying and implementing improvement at all levels (2.3, 5.4, 5.10.11)
- Establishes the Lean management system (5.3, 4.5.10.11)
- Assures consistency with local leadership and practices (5.2, 5.3, 5.10.11)
- Involves all leadership in planning and implementing Lean practices (5.3, 4.5.10.11)
APPENDIX F

SUBMITTERS OF THE LETTERS TO CONSOLIDATE BENEFITS OF IMPLEMENTING LEAN PRACTICES

Industry

1.- Boeing military aircraft and missile group
2.- Boeing space and communications group
3.- Boeing phantom works
4.- GE military engines operation
5.- GenCorp Aerojet
6.- Hughes space and communications company
7.- Lockheed Martin aeronautics sector
8.- Lockheed Martin space and strategic missiles sector
9.- Northrop Grumman corporation
10.- Pratt and Whitney large military engines
11.- Raytheon company
12.- Raytheon systems company
13.- Rockwell Collins
14.- Sunstrand aerospace
15.- Textron systems
16.- TRW space and electronics group

Government

1.- Aeronautical systems center
2.- Air Force research laboratory, ManTech program
3.- Defense contract management command
4.- Deputy undersecretary of defense for acquisition and technology
5.- C-17 systems program office
6.- F-22 systems program office
7.- Flight training systems program office
8.- Joint strike fighter systems program office
9.- National reconnaissance office
10.- Space and missiles systems center
11.- U.S. army aviation and missiles command

Academia

1.- Massachusetts Institute of Technology
APPENDIX G

QUANTITATIVE SAVINGS CITED BY LAI CONSORTIUM MEMBERS

Complete Products

- Product order to delivery time reduced from 24 to 10 months with 15% annual price reduction and performance exceeding goals for a munitions product
- 50% fewer cycle days for lightweight airframe product
- Production hours under budget by 11% for EMD and 16% for LRIP for major airframe product
- 50% reduction in cycle time for production and launch of commercial launch vehicle
- For a major aircraft system, production rate doubled with same workforce, repair and rework reduced by 88%, last 30 units delivered to field early.

Major Components or Sub-assemblies

- Horizontal stabilizer reductions of 20% in weight, 90% in parts, 81% in fasteners, 70% in tools, and 50% in cost
- Horizontal tail reductions of 61% in parts and tools, 48% in design cycle time, 38% in design hours, 50% in assembly, 62% in defects
- Engine pylon reductions of 10% in cycle time, 10% in labor hours, 89% in people travel with all safety issues eliminated and 5S score improved by 58%
- Nose installation reductions of 60% in cycle time, 85% in set-up time, 77% in people travel distance and with increase in productivity of 60% and elimination of 2 safety issues
- Landing gear pods reduction of 32% in cycle time, 17% in set-up time, 16% in lead time, 42% in people travel distance, 83% in product travel distance with 32% increase in productivity

Production Operations

- Enterprise-wide 35% improvement in productivity
- After 1 year of Kaizen workshops, average improvement of 27% in productivity and reductions of 50% in inventory, 25% in floor space, 50% in lead-times with significant improvement in quality and reductions in set-up time
- After several Kaizen workshops, reductions of 47% in cycle time, 31% in inventory, 34% in floor space, with 100% improvement in throughput in certain areas
- HPWO led to reductions of 28% in scrap, 20% in rework, 60% in cycle time
- Kaizen workshops led to reductions of 47-71% in labor hours, 76-92% in travel distance, 54-80% in setup time, 65-81% in floor space and 20-97% in cycle time for certain production operations
• Reductions of 51% in space, 79% in travel distance, 80% of work in progress, 36% in direct labor, 50% in defects, 66% in capital equipment requirements, 80% in thru-put time
• Reduction from several thousands to 420 defects per million opportunities
• 50/60/70% reductions in implementing critical processes are being proposed and achieved on several major space related products
• Selected demonstration projects for new aircraft program documented reductions of 67% in manufacturing cycle time, 80% in inventory and 60% in cycle time variations.
• Kaizen workshop with supplier led to reductions of 28% in unit cost, 70% in floor space, 98% in work in progress, 95% in distance traveled, 38% in cycle time
• Just-in-time delivery of titanium billet reduced inventory by $8-10M, lead time by 50%, suppliers to 2 from 31

Product Development

• Pilot efforts in improved information flow between engineering and manufacturing resulted in cost reductions of approximately 30% in engineering, 15% in manufacturing with a 25% reduction in overall cycle time
• IPPD led to reductions in hours of 80% for design, 50% for NC programming, 50% for inspection and 67% for fabrication of flying testbed
• For prototype development, 1/3 less time for 90% drawing release milestone

Procurement Processes

• Material release order processing time reduced from average of 6 days to one day or less
• Contract change proposals process managed by 50% fewer people (3 compared to 6)
• 36% improvement in total negotiated savings/cost avoidance due to SPI
• Newest contracts on a major system awarded in record time due to successful use of one-pass negotiations.
• Complex high dollar contracts executed in significantly less time than normally required, while customer needs met or exceeded for price, delivery and timeliness of service
• 50% reduction in cycle time for reviewing Engineering Change Proposals
• 50% reduction in lead time with 0.02% cost increase to program with fixed-price purchase orders before final sizing completed
BIOGRAPHICAL SKETCH

Carlos Alberto Calleros Martínez was born in Monterrey, Nuevo León, México, on January 24th 1977. He received his elementary education at Colegio Franco Mexicano school. His secondary education was completed at Centro Universitario Franco Mexicano, and his high school education at Universidad de Monterrey Bachilleres Gonzalitos high school, all of these institutions located in Monterrey.

Carlos entered the Instituto Tecnológico y de Estudios Superiores de Monterrey (Monterrey Tech) in 1994, majoring in Mechanical-Electrical engineering. In 1996 had a chance to study the junior year of college as an exchange student at the University of Nebraska-Lincoln in the U.S.A. Finally, earned his degree in May 1999.

Upon graduation he worked for John Deere Mexico as a test and reliability engineer for 9 months. In September 2000 he joined Yazaki Service Co, Inc. where he worked as a mechanical design engineer for almost 4 years. During this period he joined the Monterrey Tech’s Manufacturing Systems Master’s program, in August of 2001, combining work and studies for 3 years. In August 2004 he started his second master’s degree program, now, in Industrial Engineering at Arizona State University, in Tempe, Arizona U.S.A., supported with a scholarship offered by the University and the United States Agency for International Development (USAID). Currently, he is working as a staff engineer, in the Technological Vice-Presidency in Cemex Mexico.

Permanent address:

M.M. del Llano 1328 ote.
Centro 64000
Monterrey, N.L.
MEXICO

ccalleros@hotmail.com