Methodologies for
Design of a Low-Volume, International Automotive Assembly Plant,
with Emphasis on Site Selection and Body Shop Design

by

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B.S. Electrical Engineering, University of Texas at Austin, 1991

Submitted to the Sloan School of Management and the
Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degrees of

Master of Business Administration

and

Master of Science in Engineering

at the

Massachusetts Institute of Technology

June 1997

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JUL 01 1997
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Abstract
This thesis will study the process of transforming a “greenfield” site (often literally a green sugar cane field) into a low-volume international automotive assembly plant. Research conducted at Chrysler Corporation on a greenfield assembly plant in Brazil will serve as a basis for the discussion. We have divided the process into two parts: determination of strategic decisions and development of tactical implementation.

The first section develops a strategic guideline for international expansion. We outline different global strategies and manufacturing strategies. Site selection is a major part of achieving strategic goals and developing long term competitiveness. The thesis presents a methodology for selecting an international manufacturing site. A fundamental economic model was developed to analyze the basic quantitative and qualitative decision criteria and to frame the final site decision. In order to support globalization, we study the effects of coordination of the organization.

The second section proposes a methodology for designing a body shop in an assembly plant. Launching a body shop is not unlike launching a product, thus we have used product development concepts to guide our methodology. The thesis will study the design processes of tracking progress, planning system-level design, building in quality and flexibility, and finishing detailed design. Finally, we will apply product development concept selection tools, House of Quality and Pugh charts, to choosing an optimal body shop design. This methodology strives to standardize the body shop design process as prescribed by the Chrysler Operating System.

Thesis Advisors:
Professor Donald Rosenfield, Sloan School of Management
Professor David E. Hardt, Mechanical Engineering
Acknowledgments

I gratefully acknowledge the support and resources made available to me through the MIT Leaders For Manufacturing program, a partnership between MIT and major U.S. manufacturing companies. I would like to thank my advisors, Don Rosenfield and Dave Hardt, for their valuable guidance and feedback.

Many people from Chrysler Corporation gave their valuable input to make this study possible. I would like to thank my supervisors, Tom Breneiser and Eugene Dziadon, and members of the International group, including Chris Knowlton, Dick Ott, George Owens, Roger Patel, Diego Torres, Don Vormelker, and Dick Winde. I thank Curtis Wilson and Charles Strackbein for teaching me so much about automotive manufacturing while on our trip to Austria. I would also like to thank Dario Verdugo for his insight into site selection and for a productive and exciting trip to Brazil. I would like to thank all my international hosts on my visits to Venezuela, Austria, Belgium, and Brazil.

I would like to acknowledge the LFM Detroit crew, including Melanie Dever, Kevin Florey, Tony Kramer, Cheryl Leland, Robert Moeller, Eunmee Park, and Brian Sullivan. Our regular meetings where we shared input on the internship experience and toured each other’s facilities (whether they were in the US, Canada, or Belgium) were an invaluable part of my internship experience. Thank you for making the internship so enjoyable for me. Thanks also to other members of the LFM Class of ’97 for supporting me through the writing of this thesis upon our return to Boston.

Finally, I would like to thank my family, my parents, Penny, and Peter, for their unwavering love, support, and guidance, throughout my academic and professional career. The solid foundation that they gave me has helped me in current endeavors and will hold me steady in the future.
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1. Introduction

1.1. Summary of Thesis

This thesis will study the process of transforming a “greenfield” site (often literally a green field of sugar cane) into a low-volume international automotive assembly plant. We have divided the process into two parts: determination of strategic decisions and development of tactical implementation. The first section will explore the decision process of expanding internationally, planning a competitive strategy, selecting a location, and choosing a management structure and coordination level.

Once the decision has been made to build an assembly plant overseas, we need a process to design and implement. The second section proposes a methodology for designing the body shop of an assembly plant. Launching a body shop is not unlike launching a product, thus we have used product development concepts to guide our methodology. The thesis will study the design process of tracking progress, planning system-level design, building in quality and flexibility, and finishing detailed design. Finally, we will apply product development concept selection tools, like House of Quality and Pugh charts, to selecting an optimal body shop design. In the spirit of the Chrysler Operating System (COS), this methodology will standardize the body shop design process.

1.2. Background

Research for this thesis was performed during an MIT Leaders for Manufacturing internship at Chrysler Corporation. The department sponsoring the project was the International Manufacturing Operations (IMO) group. This group was responsible for design and build of Chrysler’s international manufacturing facilities. IMO was also responsible for operations of the Steyr Grand Cherokee plant and Eurostar minivan plant located in Austria. Operations of the remaining eight international manufacturing plants fell under the domain of the International Operations (IO) group. IO was also a source for research material. IMO’s ten manufacturing facilities are indicated in Figure 1.1.
1.2.1. International Operations History

In 1980, Chrysler Corporation's international business came to an abrupt halt. The company was in deep financial trouble and in danger of bankruptcy. In what remains one of the largest government bailouts in US history, the federal government extended Chrysler $1.5 billion in loans. Chrysler has since repaid the loans. As terms of the agreement, Chrysler agreed to divest itself from all non-core businesses, including all international operations.

It was not until 1987 that Chrysler re-entered the international arena with the acquisition of American Motors Corporation (AMC). AMC had been building Jeeps around the world since before World War II. Thus, Chrysler inherited AMC's international holdings in China, Venezuela, and Egypt. Chrysler has since expanded its manufacturing operations to include ten world-wide plants, the last two of which are still under construction. They sell vehicles in more than 100 countries around the world.

Figure 1.1: Chrysler's Michigan, USA Headquarters and 10 International Manufacturing Sites

1.3. Scope of Thesis

In an effort to manage the scope of this thesis, we agreed that the topic would be limited to low-volume, complete knock-down, international assembly plants, with a
concentration on the body shop. Most of IMO’s operations fall under this description, so the limited scope has minimal impact on the applicability of the thesis. We will further define the scope in the remainder of this section.

1.3.1. Knock-Down Operations Defined

In high-volume domestic operations, we were accustomed to seeing free flow supply of parts to the plant. Here, the plant would negotiate separately with multiple component suppliers. The suppliers would independently bring parts to the plant according to their particular contracts.

Most low-volume IMO plants are supplied by knock-down kits delivered from the US. Complete knock-down (CKD) kits contain all parts needed to build one batch of vehicles. Due to local content and financial constraints, some parts may be supplied from the local country giving rise to knock-down (KD) kits.

Figure 1.2 indicates the method in which KD kits are shipped. For example, a cargo ship originating from the US might carry 10 freight containers holding parts needed to build 24 Grand Cherokees in Venezuela. When the kits arrive at their destination, they are unboxed and brought to the production line. The international plant would then be responsible for assembling the vehicle. By limiting international plants to assembly rather
than fabrication operations, Chrysler minimized foreign capital investment costs, 
maintained economies of scale in domestic component plants, and derived profit from 
selling kits (as in the case of independent licensed assemblers).

1.3.2. Body Shop Defined

The scope of this thesis is limited to vehicle assembly operations. We will not 
consider sheet metal stamping operations or component fabrication operations. Vehicle 
assembly, as illustrated in Figure 1.3, consists of three major areas: body shop area, paint 
shop area, and trim/chassis/final (T/C/F) area. Formed sheet metal body panels are 
received by the assembly plant from the stamping plant or from KD kits. In the body 
shop, these panels are welded together to form the metal shell of a vehicle. This shell, 
named a body-in-white (BIW), is sent to the paint shop to be painted. Trim and chassis 
components are then assembled to the painted body in the T/C/F area. The completed 
vehicle is tested and certified before being shipped out for sale.

![Diagram of vehicle assembly process]

**Figure 1.3: Basic Production Processes Needed to Assemble a Vehicle**

The second half of the thesis will concentrate on design of the body shop. The 
process of body shop assembly is illustrated in Figure 1.4. Body panels are assembled 
into subassemblies, like the front floor, dash, and plenum subassembly, the underbody 
subassembly, and side aperture subassemblies. These subassemblies then converge at the 
toy tab station, where tabs are bent or plastic tabs are inserted to loosely hold the 
structure together. The form is sent to the main framer where the dimensional structure 
is set and subassemblies are joined together. The framed body moves to the respot line, 
where additional welds are added to provide structural strength.

The following is a detailed example of how the front floor and dash subassembly 
is produced. The front floor pan is laid in a tooling fixture. Sealer is applied. The dash
panel is positioned correctly in relationship to the front floor pan in the fixture. Clamps are closed manually or with hydraulic controls. The clamps hold the dimensional relationship between the front floor pan and the dash panel. An operator or a robot uses a welding gun to join the body panels with spot welds. If the welding is manual, the operator positions the weld gun in the proper position around two pieces of metal, pushes the correct button on the gun, which sends a current across the weld gun tips and through the metal, and thus fuses the two pieces.

![Diagram of body shop process layout](image)

Figure 1.4: Body Shop Process Layout

In the second section of the thesis, we will propose a methodology for design of the body shop. The design will include specifications for the assembly flow, the manpower assignments, and facility floor layout. Detailed design will be defined for the tooling fixtures.

1.3.3. Low-Volume Production Defined

Chrysler has adopted a conservative investment strategy for international manufacturing. Their goal is to service high-end niche markets rather than to capture high-volume market share. In accordance with this strategy, they have built a few low-fixed-cost plants producing low volumes of vehicles. They use these manufacturing sites to gain entrance into markets where they can sell high-margin built-up (BUX) units
exported from the US. Much of the profits are gained by selling knock-down kits and built-up units.

For purposes of this thesis, we have limited the scope to low-volume production. We define this to range from one job per hour (jph) to 20 jph. This translates to an annual production ranging from 1,920 to 38,400 vehicles (assuming 8 hours per shift, single shift, and 240 working days per year). In contrast, a domestic plant might produce ten times as many vehicles in a year.

The topic of this thesis focuses on the development of a low-volume body shop. Table 1.1 compares a high-volume body shop with a low-volume body shop. Both body shops build Dodge Dakota trucks. The high-volume body shop is based on Warren Truck Assembly located in the US. It uses automation and robotics to attain high line speeds and quality. The low-volume body shop is based on a recently announced truck assembly plant in Brazil. It takes advantage of low labor costs with manual welding and clamping, and manual transfer of bodies from one station to another.

<table>
<thead>
<tr>
<th>High-Volume Body Shop</th>
<th>Low-Volume Body Shop</th>
</tr>
</thead>
<tbody>
<tr>
<td>76 jobs per hour</td>
<td>10 jobs per hour</td>
</tr>
<tr>
<td>47 second cycle time</td>
<td>6 minute cycle time</td>
</tr>
<tr>
<td>Robotic Welding</td>
<td>Manual Welding</td>
</tr>
<tr>
<td>Automatic Transfer</td>
<td>Manual Transfer</td>
</tr>
<tr>
<td>300 Operators Typical</td>
<td>30 - 60 Operators Typical</td>
</tr>
<tr>
<td>3,000,000 ft² Plant Size</td>
<td>~ 250,000 ft² Plant Size</td>
</tr>
</tbody>
</table>

Subsequent chapters will further define international manufacturing operations.
1.4. Goals and Impact of Thesis

The Chrysler Operating System (COS) is a manufacturing initiative designed to instill discipline, standardization, and lean manufacturing ideas in the production process. As a COS activity, this thesis standardizes the body shop design. The thesis creates a framework for designing an automotive body shop in a low-volume production facility overseas. The ultimate goal of the thesis is to develop an approach save the company time and money. The details are listed below:

- *Develop a Strategic Guideline:* The thesis will provide a strategic guideline for approaching future projects. Strategies will be presented for international growth, site selection, and coordination of the organization.

- *Optimize Design:* The thesis presents design guidelines, tools for optimal design selection, and benchmarks of best practices. The goal is to continuously improve low-volume body shop design.

- *Reduce Cost on Future Projects:* It is estimated that Chrysler outsources 70% of its operations. IMO expects to deliver a guideline to future suppliers as a basis for understanding IMO's design principles. This framework should cover the basic concept development stage so that the work need not be duplicated with each new project. The reduced effort should decrease the cost of outsourcing.

- *Reduce Development Time on Future Projects:* By using the thesis as a baseline of knowledge, the company hopes to speed up the learning curve for new projects and new team members. IMO's goal is to gain a competitive advantage from faster facility launch and faster time to market.

1.5. Chapter Summary

The following is a summary of the contents to be presented in each chapter of the thesis.

**Chapter 1:** will present the thesis introduction. Background information will be supplied on Chrysler Corporation's International Manufacturing Group (IMO) where research was performed during the Leaders for Manufacturing internship. We will present basic information to define the international mode of operation, body shop...
operation, and low-volume operation. We will discuss the intended goals and impact of the thesis. Finally, a chapter summary will introduce the topics and content of the subsequent chapters.

Chapter 2: will present the international strategies of automotive companies, including Chrysler. The chapter discusses the implications of globalization and the reasons why automotive companies are racing towards globalization. We will present different global strategies among automotive companies and determine the nature of international competition. Specifically, we will present Chrysler's international manufacturing strategy that will influence all other areas of study in the thesis.

Chapter 3: will present a methodology for international site selection. The site selection methodology consists of three phases: site selection strategy phase, plant and site concept phase, and site selection decision phase. To illustrate the concepts, we have used Chrysler's selection of an assembly plant site in Brazil as a case study.

Chapter 4: will present a coordination analysis for an organization. We propose a methodology for coordination analysis that consists of four phases: plotting the organizational structure, understanding current coordination levels, analyzing and determining desired coordination levels, and developing recommendations. We will study the implications of an increase in their coordination level.

Chapter 5: will present a framework for the design process of a body shop. We transferred concepts from product development to frame the body shop design process. The five-phase methodology includes: concept development, system-level design, detailed design, build, and production ramp-up. The chapter will introduce each of these phases. The remainder of this chapter will present program management tools that can organize and track the design process.

Chapter 6: will present system-level design of the body shop. We will present the design process for three major subsystems: assembly flow, manpower, and facility layout. The assembly flow section will study how the level of CKD assembly is determined and how the assembly scroll is compiled. We propose a methodology for
developing the manpower requirements. We will introduce solutions to manpower challenges in the low-volume production environment. Finally, we present the process of designing the facility layout.

**Chapter 7:** will present quality and flexibility issues involved in the design of a body shop. We make recommendations for quality measures by studying Chrysler's operations in Graz, Austria. We will discuss flexibility in the body shop, including demand growth flexibility, multiple model flexibility, and model changeover flexibility.

**Chapter 8:** will present the final three phases of body shop design: detailed design, build, and production launch. We will develop evaluation tools for selection of an optimal body shop design. To create these tools, we have modified product development concept selection tools, including Don Clausing's House of Quality and Pugh charts. We will use Chrysler's body shop designs to illustrate the use of these evaluation tools.

**Chapter 9:** will present a summary and conclusions from the findings of this thesis. We will also present further areas of research.
2. **International Automotive Strategy**

This chapter presents international competitive strategies of automotive companies, including Chrysler. We will discuss the implications of globalization and the reasons why automotive companies are racing towards globalization. To study the nature of international competition, we will compare areas of global strategy for three companies, Ford, Toyota, and Chrysler. Specifically, we will present Chrysler’s international manufacturing strategy that will influence all other areas of study in the thesis.

2.1. *What is Meaning of Globalization?*

The competitive fields for companies span the spectrum of domestic, multinational, and global markets. We maintain that Chrysler is a multinational company that is trying to define a global strategy. We are all familiar with domestic companies that compete in familiar local markets. This was true of Chrysler in the early eighties when they pulled out of international markets after near-bankruptcy. With the acquisition of AMC, Chrysler became a multinational company. We use Michael Porter’s definition of a multinational company as one in which competition in each country is essentially independent of competition in other countries. Since then, Chrysler has been developing a global strategy where they are integrating their worldwide activities to leverage linkages among countries.

The world has gone through fundamental changes that now make it desirable for companies to incorporate a global strategy in the way they do business. A few of the macro-level changes are indicated in the table below:
<table>
<thead>
<tr>
<th>Then</th>
<th>Now</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevailing local tastes and local products</td>
<td>Converging tastes and global products</td>
</tr>
<tr>
<td>Local communications (local news, less-efficient travel)</td>
<td>Global communications (CNN, satellites, global air travel)</td>
</tr>
<tr>
<td>Localized technologies and national preferences. (US preferences for</td>
<td>Global technologies and standards of excellence</td>
</tr>
<tr>
<td>drum brakes, automatic transmissions, and air conditioning. European</td>
<td>Shared customer preferences although regional preferences still exist</td>
</tr>
<tr>
<td>preferences for disk brakes, manual transmissions, and radial tires)</td>
<td>Consolidation of the supplier industry</td>
</tr>
<tr>
<td>Local Trade Barriers</td>
<td>Broader Regional Trade Pacts (NAFTA, EU, ASEAN, Mercosul, Andean Pact, etc.)</td>
</tr>
<tr>
<td>Widespread and duplicated resources</td>
<td>Concentrated and leveraged resources</td>
</tr>
<tr>
<td>Extended research and development, widespread facilities creating</td>
<td>Increased attention to economies of scale and scope</td>
</tr>
<tr>
<td>diseconomies of scale in distant markets</td>
<td></td>
</tr>
</tbody>
</table>

2.2. *Why Do Automotive Companies want to Expand Globally?*

To different degrees, all high volume automotive manufacturers are expanding their sales and operations to the global arena. There are many compelling reasons for this globalization that we have structured into three groups: the state of world economics, the state of home markets, and the nature of the industry.

2.2.1. *State of World Economics*

Macro economic trends are making foreign investment more attractive now than ever before in history. Analysts at the WEFA Group predict that world growth for the coming 20 years will average 4%. Such a high growth rate for an extended period of time is prompting economists to call this the dawn of a golden age. Rising standards of living for the world are creating potential for legions of first-time car buyers. Companies are optimistic that they can tap these new consumer markets because of indications of widespread decreases in regulation and increases in commerce. Automakers are increasing international investment to tap the increased prosperity, economic freedom,
and pent-up demand for Western products. Elimination of controls on international capital make investment a reality. In an effort fuel continued growth, countries like South Korea and Russia are relaxing controls on foreign investment. There are also trends towards broad regionalized trading blocs. Trade within pacts, like the North American Free Trade Agreement (NAFTA), European Union (EU), and Association of South East Asian Nations (ASEAN), is growing faster than between pacts. As these trading groups impose non-tariff barriers, like local content, volume quotas, or voluntary export restraints, it may become necessary to set up regionalized manufacturing bases to access the wider trading region.

2.2.2. State of Home Markets

The state of markets in the home countries of high volume automakers is also fueling the pressure to expand globally. The combination of stagnant market growth, fierce competition, overcapacity, and changing labor pool makes home a less friendly environment. Total vehicle sales in the developed markets of North America and Europe have remained fairly flat. Automakers have been battling each other for domestic market share gains in essentially a zero-sum game. This is in contrast to growing sales in emerging markets. US corporate receipts from foreign direct investment were $93.5 million in 1996. This figure experienced 9.3% growth in 1995 and 30% growth in 1994. Competition has heated up, particularly over price.

Increasing price pressure in home markets is also fueling global expansion. Car makers have been unable to raise domestic prices to stay ahead of inflation of the dollar. Price increases on 1997 models was only 1.6% average. In an “Epic Cost Down” program at Toyota, the 1997 Camry dropped its price by $360 under the previous 1996 model. Although auto companies can not count on high margins overseas that they once did, they may spread costs over a greater worldwide volume thus boosting overall margins.

Overcapacity of manufacturing plants at home have automakers searching for new sales channels to increase demand. For example, Mazda estimates that it has
overcapacity of more than half a million units and has plans to increase worldwide sales to avoid closure of its Hiroshima or Hofu plant.\textsuperscript{8}

The demographics of the existing labor force in developed countries is also aging and expecting high wages. The need for labor and customers is prompting companies to invest in more populated developing nations. In conclusion, signals in the developed domestic markets are pointing towards expansion in emerging international markets.

2.2.3. State of the Industry

In order to take advantage of economies of scope and to ease the risk inherent to the automotive industry, manufacturers are expanding operations to the developing world. Geographical diversification can dampen the downswings of business cycles that US automakers have historically faced. The theory is that not all world economies can be in a slump simultaneously, thus allowing manufacturers to offset future regionalized downturns. We define economies of scope as the efficiency with which a firm employs the breadth of its activities when competing in an industry.\textsuperscript{9} By globalizing, companies can gain economies of scope by recouping product development costs, manufacturing costs, and possibly marketing costs in multiple markets. Efficiencies gained by becoming a global player can translate into a formidable competitive advantage against national players with no niche to hide in. The message according to MacCormack et. al., is “get global, get eaten, or get out.”\textsuperscript{10}

2.3. Risks of Expanding Globally

While the benefits of “going global” can be great, they are not without risks. Possible risks that global companies must contend with include the following:

\textit{Not Understanding the Foreign Customer:} When attempting to service new and distant cultures, there is the danger of not understanding the customer and designing the wrong car for the market. For example, US automakers are finding it hard to crack Southeast Asian markets in part because consumers find American products too big, too powerful, and too expensive.\textsuperscript{11} Thailand, Malaysia, and Indonesia are all right-hand drive markets but, before 1996, the Jeep Cherokee and Ford Probe were of the few US products that
offered a right-hand steering option. Firms must take great efforts to avoid "Detroit myopia." For example, companies are now sending armies of market researchers to China to explore and destroy simplistic marketing myths developed when companies started targeting the country five or 10 years ago.¹²

Large Scale Mistakes: In order to leverage economies of scope, Ford has centralized its product development. The risk in this strategy is that a single mistake could propagate through multiple markets to become a global disaster. "If you misjudge the market, you are wrong in 15 countries rather than only in one," says one European executive.¹³

Loss of Focus Profitability: In the rush for market expansion and market share control, a company must not lose sight of cost and profitability. In particular, Ford has been unable to control costs and boost profit margins (return on sales is 3%). Chrysler has been very cognizant of reaching a high level of return on its conservative international assets.

Technology Protection: Companies with global exposure risk the loss of technology secrets and patent and trademark infringement. Chrysler's board of directors nixed a deal to assemble minivans in China after the government demanded Chrysler share engineering secrets and manufacturing know-how.¹⁴ The US federal government has been working with China to settle these issues.

Insurgence of Protectionism: It has been argued that rapid growth of the developing world comes at the expense of industrialized nations. As Europe faces high unemployment, there is a threat of increased protectionism. However, the workforce in countries like Germany is shrinking and experts are predicting an eventual labor shortage that may decrease the danger of protectionism.

Political, Social, and Currency Upheaval: China and Indonesia are candidates for political upheaval. Russia is undergoing social transition. And the European Union faces pains of transition to a common currency.

Missing the Boat or Prisoner's Dilemma: There is the risk of not globalizing when your competition already has. On the other hand, second movers must guard against causing overcapacity when entering new markets. Carmakers from around the world are pouring
billions of dollars into Brazil. But some observers worry the [Brazil auto] industry could wind up with the same sort of overcapacity plaguing much of the developed world.\textsuperscript{15}

The preceding risks are shared by all companies involved in global expansion. The risks must be acknowledged, analyzed, and planned for. However, the risks do not seem to be enough to deter auto manufacturers from entering the global arena.

2.4. \textit{Spectrum of Philosophies from Multi-National to Global}

In this section, we will study the international strategies of three automotive companies: Ford, Toyota, and Chrysler. These companies span the spectrum of global philosophies. Arguably, Ford is the most global and Chrysler is the least. We will analyze their International History, Customer Focus, Product Scope, Organizational Structure, and Manufacturing Presence.

\textit{Table 2.1: Comparison of Operations of Chrysler, Toyota, and Ford}

<table>
<thead>
<tr>
<th></th>
<th>Chrysler</th>
<th>Toyota</th>
<th>Ford</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of manufacturing</td>
<td>1987 (restarted)</td>
<td>1959</td>
<td>1911\textsuperscript{16}</td>
</tr>
<tr>
<td>overseas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume sold outside</td>
<td>240,000</td>
<td>2.1 million\textsuperscript{17}</td>
<td>2.8 million\textsuperscript{18}</td>
</tr>
<tr>
<td>home mkt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overseas sales volume</td>
<td>8 %\textsuperscript{19}</td>
<td>50%\textsuperscript{20}</td>
<td>41%\textsuperscript{21}</td>
</tr>
<tr>
<td>to total(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overseas revenue</td>
<td>$ 5 B</td>
<td>5,000 B\textsuperscript{22}</td>
<td>$ 42 B</td>
</tr>
<tr>
<td>($ billions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example of product</td>
<td>Jeep</td>
<td>Camry/Scepter</td>
<td>Contour/Mondeo</td>
</tr>
<tr>
<td>lines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marketing strategy</td>
<td>niche</td>
<td>localized</td>
<td>world car</td>
</tr>
<tr>
<td>Manufacturing scale</td>
<td>low volume</td>
<td>high volume</td>
<td>high volume</td>
</tr>
</tbody>
</table>

2.4.1. \textit{International History}

The history of automakers can not be ignored as it shapes present day attitudes about globalization. It is not surprising that Ford Motor Company was among the first to
launch wide-scale globalization efforts. In 1908, only five years after its founding, Ford opened its first overseas sales branch in France. By 1911, it had set-up manufacturing operations in Britain. Ford currently controls 13% of world market share\(^{23}\), but it is still working to define what it means to be a global company. Toyota has always traditionally been an export-focused company. Among the three, Chrysler Corporation’s modern international operations has been existence for the shortest period of time. In 1980, overseas business came to an abrupt halt. The company was in deep financial trouble and was in danger of bankruptcy. In what remains one of the largest government bailouts in US history, the federal government extended Chrysler $1.5 billion in loans. As terms of the agreement, Chrysler agreed to divest itself from all non-core businesses, including all international operations. It was not until 1987 that Chrysler re-entered the international arena with the acquisition of American Motors Corporation (AMC). As part of the deal, Chrysler gained AMC’s Jeep manufacturing facilities in China, Venezuela, and Egypt. Chrysler’s tumultuous international history may partially account for its cautious re-entry into the global market.

2.4.2. Customer Focus

Each of the three companies approaches its global customers differently. Ford has the most traditional Western-style marketing methods where they conduct product evaluation clinics and other survey research on randomly selected buyers.\(^{24}\) Toyota relies extensively on customer involvement when planning new products that match regional needs. Chrysler takes a less conservative approach. Bob Lutz, former President of Chrysler says, “[The customer] can tell you what he likes among the choices that are already out there. But when it comes to the future, why I ask, should we expect the customer to be the expert in clairvoyance or in creativity? After all, isn’t that really what he expect us to be?”\(^{25}\)

2.4.3. Product Scope

Ford will base its product development on the “world car.” These are global platforms that can be tweaked for specific markets but will generally service the world. By consolidating product development resources around global platforms, Ford hopes for
faster delivery of more new models while saving up to $3 billion per year. Efficiencies
did not materialize on their first attempt at a world car, the Contour or Mondeo, which
took six years and $6 billion to develop.

Toyota may have pioneered the global car concept, but they maintain that one-
size-fits-all world cars have limited appeal and salability. With only the most subtle
changes, products like the Toyota Camry, are sold in markets worldwide. But Toyota
maintains that it designs vehicles differently for its three major markets in Japan, North
American and Europe. To lower product development costs, they have (1) rationalized
development - making as few platforms as is practical with derivatives based on those
basic platforms, and (2) commonized parts - designing more interchangeable parts to
service the three major markets.

Chrysler calls its Jeep vehicles “world products” but the product line was truly
developed and positioned to capture the US market. Overseas, they target niche customer
groups who are interested in owning American vehicles. To their benefit, the Jeep label
was the third most-recognized brand name in all of the world when Chrysler acquired it.
In recent years, Chrysler has added right-hand drive, diesel engines, heavier suspensions,
and other localized design modifications to their American versions.

2.4.4. Organizational Structure

At the end of 1995, Ford undertook a massive restructuring, Ford 2000, to roll-up
its Carmaking fiefdoms into a single global Ford Automotive Operations group.
Development is now organized around five program centers (large cars, minivans, sport-
utility vehicles, and trucks based in the US and small cars based in Europe). Avoiding an
insular environment in Detroit will be a challenge. “I worry that Ford is not going to get
enough international input,” says one former Ford executive. Toyota has research and
development centers in Japan, United States, and Europe with the intent that they build
vehicles geared specifically for those areas. Chrysler’s product development
organization is centralized solely in the US.
2.4.5. Manufacturing Presence

Ford has production operations in 33 countries. Toyota has substantial manufacturing facilities outside of Japan. Whether operating at or away from home, Japanese are still the most efficient producers according to a report issued by the US Department of Commerce’s Office of Technology Policy. Japanese plants average 14.7 hours per vehicle while the Big Three automakers average 20.7 hours per vehicle. Chrysier’s manufacturing strategy has been to build a few assembly plants which were often scaled down to assemble only complete knock-down kits from the US. Production volumes were low, but selected products were mainly high profit margin vehicles. Tom Gale, Vice President of International, indicated that Chrysler was not interested in making the same huge financial investment building manufacturing complexes that GM and Ford have made. Instead, Chrysler’s strategy had been to selectively build assembly plants only where they could benefit from a large market, fulfill local content requirements, gain entrance into other trading pacts, and receive duty reductions on fully assembled vehicles (BUX) sent from the US.

2.5. Conclusion

There is no single correct formula for competitive success in global markets. As we have seen, there are as many different international strategies as there are companies. Ford has been sharply criticized in the press for forcing a one-size-car-fits-all strategy. The first global product, the Contour and Mondeo, cost a “budget-busting $6 billion.”28 Clearly, this was not the efficiency that Ford had in mind. However, they will be introducing the Escort in 1999 under a new globally-leveraged organizational structure. It is still too early to evaluate all the implications of strategic changes at Ford.

Toyota has set its sights on 10% world market share, up from their current 9.5% level.29 They hope to achieve this by focusing on cutting production costs, reductions in product development time, and aggressive marketing. With the yen continuing to weaken against the dollar and with savings in operating costs of $2.5 billion, Toyota’s economic position looks very favorable.
Chrysler has concentrated its efforts on the US market. Chrysler’s global operations have been consistent with their conservative international strategy. However, they are now striving to double the size of their operations. In subsequent chapters, we will study measures that Chrysler has been taking to achieve international growth.
3. Methodology for International Site Selection

3.1. Background

The purpose of this section is to design a methodology for selecting an international manufacturing site. This methodology is one approach by which a company can frame the problem, organize the issues, and find other bodies of research regarding the site selection process. The approach was developed from research and work performed during the Leaders for Manufacturing internship at Chrysler Corporation.

Alan MacCormack, Lawrence Newman III, and Donald Rosenfield suggest that manufacturing site location is an important part of optimal configuration of an organization’s production resources. 30 Donald Lessard and John Lightstone indicate that by carefully selecting manufacturing sites, a company can manage their operating exposure. 31 In this chapter, we propose that site selection is an important part of achieving the goals of an international manufacturing strategy and of delivering an optimized automotive assembly plant.

The site selection methodology will track the decision process from the time a company decides to enter the global arena to the time it selects a particular piece of property. On a macro-level, the site selection process follows the flow illustrated below:

![Diagram](image_url)

**Figure 3.1: Site Selection Flow**

The process has been divided into three phases: the Site Selection Strategy phase, the Plant and Site Concept phase, and the Site Selection Decision phase. These phases are further described in the table below:
Figure 3.2: Three Phases of Site Selection

<table>
<thead>
<tr>
<th>Phase</th>
<th>Process Step</th>
<th>Scope</th>
<th>Relevant Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Site Selection</td>
<td>To What Degree Do We</td>
<td>What Strategy Guides Our Global Expansion?</td>
</tr>
<tr>
<td></td>
<td>Strategy</td>
<td>Go Global?</td>
<td></td>
</tr>
<tr>
<td>Phase II</td>
<td>Plant and Site</td>
<td>Which Trading Region?</td>
<td>What type of Manufacturing Plant</td>
</tr>
<tr>
<td></td>
<td>Concept</td>
<td>Which Country?</td>
<td>will Meet Our Global Expansion Strategy?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Which State?</td>
<td></td>
</tr>
<tr>
<td>Phase III</td>
<td>Site Selection</td>
<td>Which Real Estate</td>
<td>Which Property will Meet Our Strategy and Plant Concept?</td>
</tr>
<tr>
<td></td>
<td>Decision</td>
<td>Property?</td>
<td></td>
</tr>
</tbody>
</table>

The remainder of the chapter will focus on the implementation of a global strategy, beginning with the selection of a suitable site. Every company must independently decide its optimal site location decision depending on the characteristics of the total system in which it must operate.

3.2. Phase I: Develop a Site Selection Strategy

3.2.1. Phase I: Site Selection Strategy Framework

The first phase of site selection is to develop a high-level site selection strategy that guides global expansion. The site selection strategy must support the business strategy for there to be a consistent and effective message. A company must begin with a coherent business strategy. It must then make a frank assessment of its capabilities, competitive advantages, and level of resources and capital. From that, a site selection strategy can be developed by examining the following: regionalized trading economies, flexible manufacturing network, competitive environment, and risk management. These criteria are explained in greater detail below:

1. **Regionalized Trading Economies** - Consider locating where we can gain access to larger trading blocs.
There is a current trend towards the development of large, regionalized trading economies. Trading blocs encourage increased and freer commerce between member countries. Examples include NAFTA (North American Free Trade Agreement), ASEAN (Association of South East Asian Nations), and Mercosul (Common Market between Argentina, Brazil, Uruguay, and Paraguay). The evolution of a world trade system based on regional blocs creates incentives for firms to follow direct investment strategies that give them a manufacturing presence in each region of significant demand and unrestricted trade. These policies are forcing global companies to shift from export-based centralized manufacturing to a network of smaller decentralized manufacturing plants that allow access to larger trading blocs.

2. **Flexible Manufacturing Network** - Consider locating flexible manufacturing sites where we can achieve a regional presence.

After World War II, the United States was the most sophisticated consumer market in the world. The US had the highest level of technology, most refined products, and widest distribution network. Most product innovation occurred in the US and was then shipped overseas. In this world structure, the trend was for an export-based strategy with manufacturing centralized in the US. The benefits to this structure were economies of scale and learning curve advantages that were proportionate to cumulative volume.

According to Lester Thurow in *Head to Head*, overseas consumers are now far more sophisticated. Consumers anywhere in the world might experience little or no technology lag, be early users that shape product innovation, or have exposure and access to the latest products. With these pressures and increased global competition, companies are finding a shorter window of opportunity to get the right products to the customer. Honda recently launched a new vehicle simultaneously in Japan and Thailand. This environment is driving companies towards more flexible manufacturing facilities that can better respond to customer demands.
3. **Competitive Environment**: Consider locating in areas where we can lock in the first mover advantage versus consider locating near our competition to generate momentum and take advantage of an existing supply base.

The first step is to understand how a firm competes. Companies compete on four dimensions: cost, quality, delivery (time-to-market) and flexibility. The site selection strategy must be consistent with mode of competition.

There are advantages to being the first mover to enter a global market. A company might be able to act first with joint venture partners or secure the best distribution outlets. In the case of automobiles, first movers may be able to sign exclusive arrangements with "blue chip" dealers. Building overwhelming capacity and taking market share may be an effective barrier to entry for the competition. According to John Preston of the MIT Technology Center, there is a benefit to locating near your competition.\textsuperscript{34} By doing so, companies create a "cluster of excellence" that helps them stay innovative in light of the external competitive forces.

But when considering entrance into emerging markets, sourcing concerns may outweigh first mover advantages. A company may consider locating near an existing competitor so that they can benefit from the manufacturing capabilities that their competitors may have already developed in the area. The competitor may have already built an infrastructure, attracted suppliers, trained or attracted skilled workers, or set precedence with government agencies. A managing director of the auto-consulting division of Maritz Marketing & Research Inc. says, "No one wants to be the first plant in the region and have to establish their own network."\textsuperscript{35} This second-mover advantage may be especially important in less developed countries or emerging markets.

In order to decide between the two strategies, a company must understand its international growth objectives and its investment strategies.
4. Market Demand Characteristics: Consider locating where we can access our target customer and lead users.

A company must understand the customer profile of its target market segment. Manufacturing sites need to be located where they can service this market. Access to the most demanding customers is also desirable as lead users can force a company to innovate. For example, German customers set very high standards for quality and have been known to check the door gaps on vehicles they plan to purchase. By locating near these lead users, a company may harness external pressure to encourage quality improvement.

5. Political Imperatives: Political regulations have a strong impact on the site selection process. The following are example of political issues:

Local Content Requirements - Consider locating where governments require manufacturing presence to access the market. Consider locating manufacturing site where we can access a supply base to attain local content requirements.

Tax Abatements - Consider locating site where we can leverage the most competitive agreement from governments on taxes, utility rates, duty rates, loans, etc.

Political Advocates - Consider locating site where we can access supportive government agencies.

6. Risk Management: Consider locating where we can minimize currency exchange rate volatility. Consider locating where we can manage our capacity. Consider locating where we can contend with the risk of government instability.

There is a benefit to having extra capacity in multiple manufacturing sites so that we can shift marginal production to a site with the most favorable exchange rate. The emphasis is on marginal or relatively small volume shifts in production. This requires a company to have an in-depth understanding of capacity loading in its network of flexible manufacturing plants. Toyota successfully moved marginal production from its Japanese plants to its
American plants in 1996 when the value of the yen was at an all-time high. American-built vehicles were being shipped back for sale in the home market. By 1997, they were moving production back to Japan to take advantage of the declining yen. In order to exploit the yen’s weakness, Toyota rapidly increased exports to the US from its factories in Toyota City, Japan by 17%.\(^{36}\)

This strategy should not be used indiscriminately as there are other ways to mitigate currency exchange risk without adding extra manufacturing capacity. “In the long run, changes in the nominal dollar-foreign currency exchange rates tend to be about equal to the difference between the US and foreign inflation rate in the price of traded goods.”\(^{37}\) This long-term offset between exchange rates and inflation is called purchasing power parity (PPP). PPP implies that operating profits can be protected in the long run. It is in the short run (six months to several years), that companies can be greatly affected by exchange rate volatility.\(^{38}\) Financial instruments, including options, futures, and forwards, can be used to hedge the foreign exchange risk.

3.2.2. Phase I Case Study: Chrysler Corporation’s Site Selection Strategy in Brazil

The first question Chrysler had to ask in the site selection flow was “do we want to expand globally?” The answer was yes. The next question was “where and with what strategy?” When looking for international investment opportunities, Chrysler found the market in Brazil to fit the profile of an attractive new market. In its favor, Brazil had the following characteristics:

- *Large and growing population*: according to Hiroyuki Okube, director of Toyota’s Brazilian operations, “When you think about a country the size of Brazil and look at its total vehicle population - only about 15 million vehicles - that means less than 10 percent of the population is enjoying the car life.”\(^{39}\)

- *High local content requirements*: federal regulations required that 60 percent of a vehicle’s components be sourced locally.
• **Access to larger trading block:** Brazil, Argentina, Uruguay, and Paraguay were members of the Mercosul common market. Mercosul legislation encouraged freer trade among member countries.

• **Opportunities for duty reductions:** companies that attained "manufacturer status" were allowed to import fully-assembled (BUX) vehicles at half the duty rate applied to vehicles imported by automakers that were not full members of Brazil's automotive regime.\(^{40}\)

• **Pent-up demand for Western products:** the federal government was opening the formerly closed economy and people were clamoring to buy products, including autos, that were previously off-limits.

Based on these circumstances, there was strong incentive for Chrysler to enter the Brazil market. They decided on a two pronged attack. First, they planned to sell built-up vehicles (BUX's) imported from the United States. In order to implement this plan Chrysler had to develop a dealer and distribution network in Brazil. With models priced up to $75,000 USD, Chrysler vehicles were aimed towards a niche segment of ultra-wealthy buyers. Dealerships had to be located in areas accessible to this market, appeal to their buying habits, and qualify under the Chrysler standards. Although they were targeting the high-end, Chrysler did negotiate with the government to reduce tax on BUX vehicles and thus decrease the sticker price. The previous duty tax was prohibitive to sales as it could double the price of a vehicle. By qualifying for Brazilian Manufacturer Status, Chrysler could reduce the duty rate in half.

Thus the second prong of the strategy was to develop a local manufacturing presence. The manufacturing intent should not be overemphasized as the real financial goal was to sell BUX vehicles with very high profit margins. Chrysler chose a conservative manufacturing strategy of low cost investment, low production volumes, complete knock down units, and assembly operations only. Plans to build an assembly plant for mid-sized trucks with a modest initial capacity of ten jobs per hour were sufficient to meet the requirements for Manufacturer Status. And thus, Chrysler qualified for discounted import duty rates.
3.2.3. **Phase I Conclusion**

Site selection strategy can be as varied as the types of business strategies. For example, one company might have an international strategy to aggressively captivate market share and thus control the market. The goal of their site selection strategy should give them broad market access so that they can achieve their business goals.

Chrysler’s overall business strategy has been to focus efforts on the US market. Their conservative investment plan in international operations has been in line with their strategy to “do the most with the least.” Chrysler was searching to expand to international sites where they could make a profit with a minimal capital investment.

Brazil represented a very attractive opportunity for Chrysler as the world’s fastest-growing new-car market, already larger than Canada and Italy. Chrysler’s site selection was guided by the desire to achieve the following:

1. Access to a larger Latin American trading bloc, Mercosul.
2. A decentralized network of small manufacturing plants with low capital investment.
3. Political compliance to reduce tax and duty rates, especially on profitable BUX units.

Thus, Chrysler’s site selection strategy was to locate a low-volume manufacturing site in Brazil that minimized their investment but met government requirements to allow duty reductions on high-profit BUX vehicles. This was part of a larger strategy that included another manufacturing plant in Argentina, another member of Mercosol.

3.3. **Phase II: Develop a Plant and Site Concept**

In Phase II, we will develop a methodology for generating a concept for a manufacturing plant and possible site. The concept is an articulation of the team’s vision of what the plant should look like and how it should be integrated into the site. The deliverable from this phase will be a high-level guideline of the following characteristics:

- the product to be produced at the site
- the production capacity and technologies
- the structure of the enterprise and the organization
- the scale (including the production capacity)
- the scope (including the level of vertical integration and supplier involvement)
By deciding the preceding criteria, the manufacturing engineering group obtains enough information to generate a basic design for the plant. The design will include approximated values of the following variables: investment costs, layout of the facility, size of plant, and production infrastructure requirements. These concept requirements will be used later to drive the decision for a specific property site.

It may be useful to benchmark the concept to other known facilities to determine whether the team is on the right track. If not, then benchmarking should help the team understand and justify the differences. We will use Chrysler as an example to study the methodology.

3.3.1. Phase II Site Concept Framework

Now that we understand our business and manufacturing strategy, what will our manufacturing plant look like? We will use the following criteria to frame the answer:

1. **Product** - *What product will appeal to the target market? What products will allow us to best compete with existing products?* Chrysler decided to launch a medium-size pickup truck in Brazil. Pickup trucks are becoming fashionable to Brazilian consumers. There are still rents to be gained in this market segment as compared to the very competitive compact car market, exemplified by GM's entry-level "Popular Car."

2. **Production Technologies** - *What are our desired operating costs, investment costs, and return on investment? What volume do we want to produce? What technologies will we incorporate?* The plant was targeted to produce 6 vehicles or jobs per hour (jph), expandable to 10 jph. This growth factor was later revised to a production rate of 20 jph. Consistent with their international manufacturing strategy, the initial investment and production volumes in Brazil were low to moderate.

3. **Enterprise Structure** - *Will the site be developed from a "greenfield" site or an existing plant? Will it be wholly-owned, a joint venture, or a licensed assembler?* In order to answer this question, a company must understand its available resources, including capital, managerial, and time-based resources. If a company wants control
and is willing to invest the resources, then it should consider a wholly-owned greenfield site. Benefits of this organizational structure include greater control over managerial, operational, financial, and profit generating functions. Other organizational structures should be considered if the company does not have the resources to develop a manufacturing site on its own, if political regulations necessitate a partner (China has strict rules for foreign countries entering the country), or if a partner will enhance the ability to do business in that country. Chrysler decided that substantive control benefits justified the cost of developing a wholly-owned, greenfield site.

4. **Scale and Scope** - *Will products be developed for the local market only or also for export? Will materials arrive in kits (Complete Knock Down, CKD) or will material arrive in continuous flow? Will the manufacturing plant be limited to assembly or will it include a stamping plant, engine plant, etc.?* The Brazil plant will be limited to vehicle assembly. Stampings, subassemblies, and other material will arrive in kits from the US. Engines would be sourced in Brazil to help achieve the local content requirement. Knock-down facilities minimize the amount of investment needed to build a production system. Minimal investment is congruous with our manufacturing and business strategy.

5. **Supply Chain** - *How do local content requirements drive supplier relationships? How should we develop our suppliers?*

In an effort to cut costs and decrease delivery time, automakers have been developing closer relationships with their suppliers. Volkswagen’s new truck plant in Brazil’s state of Rio de Janeiro has taken JIT and keiretsu ideas to the edge of the envelope. Several hundred suppliers have been reduced to just seven final assemblers that “live” in-house. “The $250 million plant makes the biggest leap yet: seven main suppliers will make components in the plant using their own equipment, then their own workers will actually fasten the components together into finished trucks and buses.”

While Volkswagen has incorporated innovative
ideas in its supply chain management, it is still too early to assess the overall financial success of this plant.

Figure 3.3: Impact of VW's Virtual Factory

<table>
<thead>
<tr>
<th>Positive Impact</th>
<th>Negative Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Faster Delivery</strong> - improvements by suppliers in the assembly process have cut work hours in the [in-factory] pilot plant by 12% versus a typical factory.</td>
<td><strong>Complicated Logistics</strong> - VW will have to coordinate a massive inflow of material to suppliers in the plant.</td>
</tr>
<tr>
<td><strong>Less Capital Investment by VW</strong> - suppliers purchased their own tools and fixtures.</td>
<td><strong>JIT Realities- many 2nd and 3rd tier</strong></td>
</tr>
<tr>
<td><strong>Less Inventory Costs</strong> - parts will be truly supplied just-in-time, thus decreasing work-in-process costs and clutter.</td>
<td><strong>Brazilian suppliers are inexperienced in the rigors of JIT delivery. Without the proper infrastructure and processes, these suppliers may cause production delays.</strong></td>
</tr>
<tr>
<td><strong>Better Communication</strong> - proximity and close relationships should promote better exchange of ideas.</td>
<td><strong>Breaking Organizational Paradigms</strong> - there will be no room for traditional plant hierarchy or rivalry as close teamwork is essential.</td>
</tr>
</tbody>
</table>

Based on the answers to the preceding questions, Chrysler was able to generate a high-level design for the Brazil assembly plant. The characteristics of the plant concept included: investment costs, layout of the facility, size of plant, and production infrastructure requirements. The values of the concept variables are listed in Figure 3.4. The concept requirements will be used in Phase III to determine an appropriate site.

3.3.2. Phase II Benchmarking

By benchmarking competitors, companies can identify superior performance in critical activities. This information can help them develop action plans and identify target milestones. There is now controversy over the usefulness of benchmarking activities. J. P. Womack and D. T. Jones write, “Although we gave a boost to the benchmarking industry with our previous book, *The Machine That Changed the World*, which described the most comprehensive benchmarking ever attempted in a gigantic
global industry, we now feel that benchmarking is a waste of time for managers that understand lean thinking.”

For Chrysler, benchmarking still has value. They are relatively inexperienced at international operations. The Mercosul projects in Argentina and Brazil mark the first time that they have launched such aggressive development of greenfield sites. Benchmarking information was used to set targets for a plant concept and to communicate those findings to upper management for project approval. The key criteria for comparison were the total plant area and the investment, normalized for the production rate. The results of the benchmarking indicated that the Brazil concept was comparable to competitor’s facilities. The benchmarking data can be found in Figure 3.4

**Figure 3.4: Site Characteristics Benchmarking Data between Chrysler and Two Competitors**

<table>
<thead>
<tr>
<th></th>
<th>Competitor #1</th>
<th>Competitor #2</th>
<th>Chrysler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs per Hour (jph)</td>
<td>5</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Annual Capacity</td>
<td>10,000</td>
<td>32,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Total Plant Area, sqft</td>
<td>171,000</td>
<td>304,000</td>
<td>235,000</td>
</tr>
<tr>
<td>AREA/JPH, thousand sqft/jph</td>
<td>34</td>
<td>38</td>
<td>24</td>
</tr>
<tr>
<td>Investment (plant, facilities, tooling only - 96 econ), $M</td>
<td>$61</td>
<td>NA</td>
<td>$70</td>
</tr>
<tr>
<td>INVESTMENT/JPH, $M/jph</td>
<td>$12</td>
<td>NA</td>
<td>$7</td>
</tr>
<tr>
<td>Work Pattern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kt Size</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Land (acres)</td>
<td>18</td>
<td>NA</td>
<td>150</td>
</tr>
<tr>
<td>Body Shop, sqft</td>
<td>44,850</td>
<td>42,550</td>
<td>46,000</td>
</tr>
<tr>
<td>Paint, sqft</td>
<td>37,200</td>
<td>73,600</td>
<td>67,850</td>
</tr>
<tr>
<td>Trim, sqft</td>
<td>17,825</td>
<td>39,100</td>
<td>18,975</td>
</tr>
<tr>
<td>Chassis, sqft</td>
<td>17,825</td>
<td>20,700</td>
<td>18,975</td>
</tr>
<tr>
<td>Final, sqft</td>
<td>21,850</td>
<td>27,600</td>
<td>32,200</td>
</tr>
<tr>
<td>Certification Line, sqft</td>
<td>0</td>
<td>0</td>
<td>5,750</td>
</tr>
<tr>
<td>Material Supply, sqft</td>
<td>31,050</td>
<td>100,050</td>
<td>44,850</td>
</tr>
<tr>
<td>TOTAL PLANT AREA, sqft</td>
<td>171,000</td>
<td>304,000</td>
<td>235,000</td>
</tr>
</tbody>
</table>

*Data is disguised*

### 3.4. Phase III: Finalize Site Selection Decision Analysis

The goal of the final phase of site selection is to reach consensus and conclusion on a real-estate property. The decision process requires a site selection team to perform the following action items: determine decision criteria, identify possible sites, gather information, perform decision analysis, and reach a decision conclusion. There are
feedback loops between each stage so that decisions can be revised as more information becomes available. The remainder of this section will examine these steps in detail.

Figure 3.5: Site Selection Decision Methodology

The following are action sequences in the site selection methodology:

1. **Choose Site Selection Team**: In order to obtain a composite picture of the site, team members should be selected from a broad cross-functional pool. The groups represented may include construction, engineering, environmental, finance, government affairs, information systems, international operations, legal, logistics, manufacturing, material handling, marketing, new business development, operations, platform management product planning, public relations, purchasing, quality, real estate, sales, strategy, and tax affairs.

2. **Determine Decision Criteria**: For us to know which site we want to pick, we need to determine the definition of a good site. The site selection team needs to agree on a list of decision criteria that will impact their selection. The chase for low cost labor used to be a major impetus for leaving domestic locations and expanding internationally. We have since seen that there are limitations to this strategy. Industries flocked to Korea in the 70’s to take advantage of low-cost labor. A decade after the initial rush, labor wages increased dramatically as the country gained economic prosperity and unions increased control. Many industries left in search of even cheaper labor.

An automotive plant represents an enormous capital investment and is much harder to relocate. It is not enough for a company to limit its financial analysis to labor costs. They must understand the more complex far-reaching issues of people, systems, and procedures. We call these issues the “fundamental economics” of a project. These
criteria are not easily quantifiable but are more likely to provide long-term competitive advantages. When formulating a site location strategy, companies should therefore emphasize the qualitative factors required to ensure that it supports the business strategy.\textsuperscript{44}

The decision criteria should capture the fundamental economic of the situation. We define fundamental economics as the basic quantitative and qualitative variables that characterize the site. Our goal is to optimize the fundamental economics on four dimensions: product cost structure, infrastructure, human resources, and manufacturing. The details are described in the following:

*Product Cost Structure:* These criteria affect the operating cost and the investment cost of building a new manufacturing plant. As cost-based elements, they are easier to quantify. Factors may include:

- logistics costs
- transportation costs
- energy costs
- inventory carrying cost
- tax costs
- government incentives
- labor costs
- work in process
- work in transit

*Infrastructure:* This area focuses on logistics. Factors may include:

- road access
- communication access
- port access
- government access
- commerce center access
- financial center access
- buyer access
- supplier access
- vendor support

*Human Resources:* The knowledge and skill resident in the labor pool should be a major driver of the location decision. It can affect the ability of firms to implement skill-based process technologies, or it can limit the effectiveness of quality programs.\textsuperscript{45} Factors may include:

- work ethic
- quality of life
- skill of workers
- living conditions
- skilled professional pool
- labor climate
- union strength

*Manufacturing:* The feasibility of constructing and maintaining a plant must also be considered. Factors may include:
land/property  environmental  zoning
location       utilities access  topography
road access    materials availability  construction labor

In addition to the fundamental economics, financial incentives offered by the government can have substantial impact on a company’s ability to compete. Thus, incentive packages should be given consideration in the site selection decision. Figure 3.6 illustrates the significant financial incentives offered to Japanese transplants by American states. The political and legal issues regarding the validity and stability of these incentives must be brought to the attention of the site selection team. In the event that incentive plans are challenged, contingency plans must be outlined. There is always the possibility that the incentives do not materialize. In which case, the company is left with a decision that must be fundamentally justifiable. In the end, the fundamental economics of the site need to make sense before a company can lure extra incentives.

![Graph showing escalating state incentives](image)

*Figure 3.6: Escalating State Financial Incentives for foreign transplant manufacturing plants in the US*
3. **Identify Possible Sites:** Available real estate properties need to be identified. This process is usually accomplished with the assistance of third party experts, such as marketing and research consulting firms or real estate agencies.

4. **Gather Information:** Once possible sites have been identified in Step 3, information should be obtained for each site. The site selection team is looking for data relevant to the decision criteria developed in Step 2. The method for information gathering may include negotiations with the federal and state governments, interviews with industry analysts familiar with the market, research into the working conditions, consultation with legal counsel, and financial analysis. The site selection team at Chrysler used all of these tools to gain a deeper understanding of the possible sites.

5. **Perform decision analysis:** A decision matrix, like that shown in Figure 3.7, can assist in the analysis of the fundamental economics. Figure 3.7 gives the case for two sites considered by Chrysler Corporation. Preliminary information and negotiations with the states had already narrowed the selection field to two top choices. The decision criteria, as determined in Step 2, were listed in the first column. The possible sites, as determined from Step 3, were listed in the first row. The data found in Step 4 was then quantified. We call this the economic rating. The economic rating of each decision criteria was inserted into the appropriate matrix cell.

A numerical analysis was performed to rate the two sites. First, weights were attached to the decision criteria according to the relative impact that each criterion had on the final outcome. Weightings were determined by consensus from the site selection team. For each criterion, the economic rating was multiplied by the corresponding weight. The weighted ratings were summated to yield the total fundamental economic rating of each site.

The political and legal aspects of government incentive plans can be listed separately. Risk analyses and contingency plans need to be developed for each issue. The analysis should include probabilities and cost scenarios of the different plans.
### Site Location Analysis - Fundamental Economic Factors

<table>
<thead>
<tr>
<th>Fundamental Economic Factors</th>
<th>State A</th>
<th>State B</th>
<th>State B - State A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Operating Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logistic (20M/yr for both)</td>
<td>40%</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Labor Costs ($10 vs $7.5/hour)</td>
<td>40%</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Energy ($40 vs $33 Mwh)</td>
<td>10%</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Inventory Carrying Cost diff (1 week)</td>
<td>10%</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>8.6</td>
<td>9.8</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>B. Logistics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of Road Access</td>
<td>20%</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Congestion/Expediitius Access</td>
<td>20%</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Quality/Proximity Sea Port/airport</td>
<td>30%</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Proximity to Suppliers/Dealers</td>
<td>30%</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>7.4</td>
<td>6.8</td>
<td>(0.6)</td>
</tr>
<tr>
<td><strong>C. Human Resources</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor climate/militant unions</td>
<td>20%</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Work Ethic Education</td>
<td>20%</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Expat living Conditions</td>
<td>20%</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Skilled Professional Pool</td>
<td>20%</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Quality of Life</td>
<td>20%</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>7.2</td>
<td>9.2</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>D. Manufacturing Site</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topography/Soil Qty</td>
<td>25%</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Access</td>
<td>25%</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Utilities/Marketing</td>
<td>25%</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Corporate Pres &amp; All Other</td>
<td>25%</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>8.8</td>
<td>9.0</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>E. Other</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility to State Gov't</td>
<td>50%</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Timing to Close Transaction</td>
<td>20%</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Proximity to Commercial/Financial Ctr.</td>
<td>20%</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>5.6</td>
<td>7.3</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>Total Fundamental Economic Factors</strong></td>
<td>7.7</td>
<td>8.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

6. **Reach a Final Decision:** From the analysis performed in Step 5, a decision should become evident. If the site selection team was involved during the entire process, then it should be easier to build consensus. Consensus is not a trivial issue as there are many interests represented on the site selection team that may be at cross purposes with each other. The goal of working through the methodology was to allow the team to focus on relevant decision criteria in order to make a system-
optimizing decision. Based on the political, legal, and fundamental economic analyses, Chrysler made a final decision to select Site B. They were able to achieve consensus and ownership from the team.

3.5. Conclusion

In this chapter, we have examined the site selection process starting from the decision to expand globally to the decision to choose a specific property. In the first phase, an overall site selection strategy was developed that was aligned with the company’s global expansion strategy. The second phase firmed the strategy into a concept for the manufacturing plant and site. The concept drove the requirements for the site. The final phase provided a framework for the decision analysis. The fundamental economics of the site were quantified, weighted, and ranked. Based on the analysis and consensus from the team, a site was selected. By using this site selection methodology, we believe that a company can make site selection decisions that will give them sustainable long-term competitive advantages.
4. **Coordination Analysis of the Organization**

4.1. **Overview**

Chrysler has plans to double its international sales by the year 2000. In order to be competitive in the global marketplace, Chrysler’s International group is rethinking the way it does business. Given the internal and external pressures, the old business model may not be sufficient to achieve future goals. International can reach a higher level of competitiveness by increasing its coordination with domestic operations, suppliers, and within itself.

In a personal interview with Bob Lutz, the former President of Chrysler, he characterized parts of the company as disciplined with an ultimate end in stagnation or innovative with an ultimate end in chaos. He classified Chrysler’s manufacturing as “chaotic” and in need of discipline before it could consider innovation. In order to instill discipline in its international operations, Chrysler is considering a more cohesive and coordinated International organization. The international groups are currently a collection of autonomous and independent departments. Communication is not frequent between international and domestic operations and among International’s own groups.

There are several forces driving International’s desire for greater coordination. They are expanding their business scope and adding production volume. They are simultaneously building two greenfield sites and doing major expansions in Latin America and Southeast Thailand. The increased intricacies and interdependencies suggest that it is no longer feasible for one person to oversee every detail of the entire operation. Not only is International taking on more responsibility, but they are being asked to do it cheaper and faster. The added complexity, people, and products underscore the need for better coordination.

Increased coordination will allow International to better leverage its resources and core competencies. It can allow them to speed up the learning curve. The biggest impact may be experienced with launching a new product or facility. Coordination should shorten the development cycle (by reducing duplicate effort), smooth the ramp-up (by
early and effective problem solving), and decrease costs (by avoiding delays and leveraging suppliers). To build these competitive advantages, we recommend that Chrysler International increase its level of coordination.

This chapter will propose one methodology for analyzing coordination. The methodology studies the organization, establishes the current coordination, determines the desired level, and makes recommendations. We will study Intel’s Copy Exactly, an extreme example of high coordination among sites, and consider what Chrysler can learn from Intel.

4.2. **Definition of Coordination Level**

According to Michael Porter, a firm’s choice of international strategy involves a search for competitive advantages from configuration and coordination throughout the value chain. The value chain is the activities and linkages between those activities that a company performs to add value to a product or service that it is selling. From an operations point of view, we define configuration issues to include site selection strategies and decisions. We define coordination issues to include the networking of international plants and the transferring of process technology and production expertise among plants. We discussed configuration issues in Chapter 3: Methodology for International Site Selection. In this chapter, we will further examine coordination of the organization.

4.3. **Methodology for Coordination Analysis**

We have developed a methodology for coordination analysis that allows a company to understand their current level of coordination and achieve their desired target levels (see Figure 4.1). The first phase in the process of analyzing coordination is to understand a company’s organizational structure. This information will influence their ability to coordinate activities. The next phase is to understand the current degree of coordination. The third phase is to analyze and determine the desired level of coordination. The degree of coordination versus configuration can be plotted on a modified version of Michael Porter’s strategy quadrant. The company must then
determine which strategy it wishes to achieve and determine the direction of change. The impact of the desired change must be analyzed. In the final phase, recommendations can be made to achieve that change. We have used the case of Chrysler Corporation to illustrate this methodology.

Figure 4.1: Methodology for Coordination Analysis

4.4. Case Study: Coordination Analysis of Chrysler Corporation

4.4.1. Phase I: Plot the Organizational Structure

The first step in the coordination analysis is to plot the current organizational structure. Chrysler’s International group consists of two departments, International Manufacturing Operations (IMO) group and International Operations (IO) group. IMO was responsible for manufacturing engineering at international production facilities. IO was responsible for all other international functions, including operations, business development, finance, and sales. For purposes of this discussion, we will focus our attention on the manufacturing engineering function and the operations function.

It is important to note that not all of the international plants were wholly-owned. Chrysler is a majority joint venture partner at the Austrian minivan plant. They are a minority joint venture partner in China and Egypt. They license out assembly in Austria (Grand Cherokee), Thailand, Indonesia, and Malaysia. Licensed assemblers are independent companies that produce Chrysler vehicles according to build specifications, quality standards, cost, and delivery schedules set forth by Chrysler. Chrysler has a limited amount of control in joint venture and licensed assembler relationships. International may have greater difficulty increasing coordination with these groups.

International was relatively new and had been operating with an entrepreneurial spirit to do whatever it took to get the job done. The structure of the organization is
outlined in Figure 4.2. The location, structure, and responsibilities of the organizations are listed. The paths of coordination and communication are also illustrated.

**Manufacturing Engineering Group**

- CM #1
- CM #2
- Fxnl Eng
- Fxnl Eng
- Suppliers
- Domestic Plants

**Operations Group**

- Operation #1
- Operation #2

Design and Build Manufacturing Facilities
US Headquarters
Geographical (country managers = CM) and Functional (eg. process eng, facilities eng)

**Responsibilities**
- Day-to-Day Operations
- International Plants

**Location**
- Traditional Plant Hierarchy (depends on plant)

**Organization**

*Figure 4.2: Current Organizational Structure of Chrysler's International Group*

Chrysler International consists of two major groups: manufacturing engineering and operations. Manufacturing engineering's country managers (CM) and functional engineers (fxnl eng) are co-located at the US headquarters. Plant operations are distributed around the world. The arrows depict the lines of communication between the groups.

4.4.2. **Phase II: Understand the Current Level of Coordination**

There was currently a lower level of coordination in international operations. Each plant operated separately, causing inconsistency in the mode of operation between plants. For example, the plant in Austria had world-class quality but had high operating and capital expenses. The licensed assembler in Thailand had insight into Honda and Volvo operations, but the information was not being fully communicated or utilized by Chrysler. The plant in Venezuela was struggling with its new paint system and had a bumpy launch for their small car product. The China plant had quality practices that were inconsistent with Chrysler standards. In short, the plants were not coordinated which made it difficult from them to learn from each other and achieve quantum improvements.
The coordination between various groups is characterized in Figure 4.3. Each row describes the relationship between Group #1 and Group #2. The Type column refers to the dominant relationship orientation. According to Edgar Schein, a *task-based orientation* is a “doing” orientation that focuses on the task, on efficiency, and on discovery. A *relationship-based orientation* focuses on the building of useful relationships, on enhancing one’s position of influence through actively building political alliances and on developing personal charisma.  

In Figure 4.3, frequency was used to characterize how often the groups communicate. There was infrequent communication between international and domestic operations. International plants often produced at 1/20th the production speed of domestic plants. International had to develop production methods for low-volume assembly largely through independent efforts. Domestic plants frequently had little incentive to produce parts or subassemblies for international supply, especially on high demand products. Interaction occurred mainly during major product changes. Coordination between Operations groups at the international plants was also relatively infrequent. Communication was made difficult by language, time zone, cultural, and distance barriers. Interaction occurred mainly when there was a major product or process change that involved multiple plants.

*Figure 4.3: Current Coordination and Relationship Structure between Group #1 and Group #2*

<table>
<thead>
<tr>
<th>Group #1</th>
<th>Group #2</th>
<th>Type</th>
<th>Frequency</th>
<th>Facilitator/Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country Manager</td>
<td>Country Manager</td>
<td>Relationship</td>
<td>Frequent</td>
<td>Location</td>
</tr>
<tr>
<td>Functional Manager</td>
<td>Functional Manager</td>
<td>Relationship</td>
<td>Frequent</td>
<td>Location</td>
</tr>
<tr>
<td>Country Manager</td>
<td>Functional Manager</td>
<td>Task and Relationship</td>
<td>Frequent</td>
<td>Dependent on Location and Task</td>
</tr>
<tr>
<td>Country Manager</td>
<td>Supplier</td>
<td>Task</td>
<td>Moderate</td>
<td>Dependent on Supply Needs</td>
</tr>
<tr>
<td>Country Manager</td>
<td>Domestic Plant Operations</td>
<td>Task</td>
<td>Infrequent</td>
<td>Dependent on Major Product Change</td>
</tr>
<tr>
<td>Country Manager</td>
<td>International Plant Operations</td>
<td>Task and Relationship</td>
<td>Moderate</td>
<td>Dependent on Product or Facility Change</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------</td>
<td>-----------------------</td>
<td>----------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>International Plant Operations</td>
<td>International Plant Operations</td>
<td>Task</td>
<td>Infrequent</td>
<td>Dependent on Major Product or Process Change</td>
</tr>
</tbody>
</table>

### 4.4.3. Phase III: Analyze and Determine the Desired Level of Coordination

The goal of Chrysler Corporation was to increase coordination among its activities. There was recently an increase in international investment that forced International onto the upper management "radar screen." There has been substantial cost pressure placed on International to minimize the capital investment while launching three new greenfield production plants and revamping several existing plants in Latin America and Southeast Asia. The tight schedule and high complexity of these projects were a challenge to the group. The environment was requiring greater coordination between the groups on multiple levels.

The function of the Manufacturing Engineering group was to design the facilities, define the production processes, manage the tooling and equipment from design to build to install, and audit the product quality. The current situation of the Manufacturing Engineering group was moderate coordination and centralized configuration (see Figure 4.5). The group was following an export strategy where facility designs were developed at a central office in the US and sent to plants around the world. This group wanted to further increase coordination in order to detect problems before they occurred, improve negotiations and relations with suppliers, minimize schedule delays, and decrease cost over-runs when launching or upgrading a manufacturing site. With greater coordination, they could migrate into the global strategy quadrant. Global strategy implies a concentration of many activities in a central headquarters location and tight coordination of other activities that must inherently be performed near the buyer. In this case, the "buyer" is the international plant and associated activities would include the facility construction, equipment installation, and pilot production.
International plants were scattered around the world. Each plant had limited communication with other international plants mainly due to distance, logistics, and lack of incentive, and organizational structure. The Operations groups had country-centered strategies where they were focused on production specific to their plant (see Figure 4.4). They were interested in increasing the level of coordination so that they could learn from each other, avoid the same mistakes, perform joint problem solving, and launch new products faster and more smoothly. With greater coordination, they would migrate to the decentralized network strategy quadrant. This strategy implies a high level of foreign investment with extensive coordination within the network.

4.4.4. Potential Impact of Change in Degree of Coordination

Before a company should modify its coordination strategy, it needs to understand the impact that a change in coordination level will have on its activities. There will be benefits and costs associated with a change the coordination structure. The advantages must outweigh the disadvantages and plans must be developed to deal with downside issues. The advantages and disadvantages of increased coordination include:
Figure 4.6: Advantages and Disadvantages to Increased Coordination

<table>
<thead>
<tr>
<th>Advantages of Increased Coordination</th>
<th>Disadvantages of Increased Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>• shared knowledge and learning</td>
<td>• standardization has potential to stifle</td>
</tr>
<tr>
<td></td>
<td>innovation</td>
</tr>
<tr>
<td>• combined problem solving</td>
<td>• requires common communication</td>
</tr>
<tr>
<td></td>
<td>infrastructure, logistics, and reporting</td>
</tr>
<tr>
<td></td>
<td>systems, particularly information systems</td>
</tr>
<tr>
<td>• economies of scale and faster learning curve, even if activities are separated</td>
<td>• requires a cultural shift to increased formal interaction</td>
</tr>
<tr>
<td>• anticipate problems and delays based on experiences of other programs</td>
<td>• no existing metrics or incentives to encourage coordination</td>
</tr>
<tr>
<td>• avoid duplication of efforts</td>
<td>• members may not know each other thus they must build relationships</td>
</tr>
<tr>
<td>• more consistent business approach</td>
<td>• transaction costs of coordination due to long distance, language, and cultural gaps</td>
</tr>
<tr>
<td>• greater leverage with suppliers (tooling, equipment, construction, materials, etc.)</td>
<td>• difficult to align subsidiary manager’s interests with those of the whole firm</td>
</tr>
<tr>
<td>• faster launch ramp-ups</td>
<td></td>
</tr>
<tr>
<td>• more accurate characterization of equipment if operations use common processes and suppliers</td>
<td></td>
</tr>
</tbody>
</table>

4.4.5. Phase IV: Develop Recommendations

There are many methods that could be incorporated to increase coordination. In this section, we will review possible options, including their advantages, feasibility, and associated risks. Action can be taken to standardize equipment suppliers and facility designs, develop communications infrastructures, standardize reporting systems, and organize coordinated launch teams. The following are options to increase coordination:

1. *Standardize Facility Design:* A standardized facility design can promote coordination by compelling all sites to focus and work on the same conditions. The Manufacturing Engineering group had developed a standard guideline for
paint shops and was developing one for body shops. The paint shop guideline set standards for types of systems, booth lengths, and process specifications. It was successful in reducing duplicate effort and focusing International on one mental model. A paint shop design only had to accommodate the largest vehicle intended for use. The goal of the body shop guideline was to set standards for volume, process, facility, automation, operator training, and equipment. The challenge of the body shop guideline was to accommodate the inherent differences in product (different body shops for pick-up trucks versus compact cars), volumes (differences in layouts and automation), legacy facilities (different layouts), culture (different work standards), and political environment (different safety, environmental, and local content requirements).

With all of these differences, it may not be feasible to design a one-size-fits-all body shop. The risk is that if the guideline is too loose, then it is not a standard. If it is too rigid, then it is not applicable for all situations and team members may balk at being held to its conditions. There is also the risk that the guideline becomes obsolete with technology changes. To get around these difficulties, we developed a body shop guideline that was methodology-driven. We could not simply unroll a generic layout. Therefore, the goal was to develop the methods, decision rules, and metrics for optimizing the body shop. Excerpts from the body shop guideline are presented in subsequent chapters.

2. **Reduce Number of Capital Equipment Suppliers:** The Manufacturing Engineering group was responsible for purchasing tooling, equipment, and construction services. If country managers standardized on fewer suppliers, they may achieve the following advantages:

- Greater market power leverage. Possible volume discounts.
- Opportunity to build long-term relationships and shared learning.
- Combined understanding and characterization of equipment.
• Faster launch ramp-up on equipment if installation, tryout, certification, and characterization of equipment can be better integrated.

However, there are disadvantages to selecting a single supplier:

• It may be difficult to select one supplier without forcing "regression to the mean." A tooling supplier that could design for the working environment and production speed in one plant may not be best suited to design equipment for different line speeds in another plant.

• There may be less incentive for innovation and competition among suppliers. Country managers may feel stifled if they are forced to use a single source.

• There is the possibility of being held captive by an under-performing or over-charging supplier, particularly if there are high switching costs.

• There is the potential to overwhelm and overload a single supplier. Smaller suppliers may be ineligible if they do not have enough resources to supply all Chrysler international plants. Local content requirements may necessitate that equipment be supplied in-country where some vendors may not have facilities.

In light of the success of Japanese keiretsus, Chrysler has been focusing on better relationships with their suppliers. There is a trend towards fewer suppliers, longer-term relationships, metrics and incentives for supplier cost reductions, and negotiated contracts rather than competitive bids. Many supply chain lessons learned domestically can be transferred to international operations. It is essential that a suitable supplier be chosen as the standard. A supplier needs to have the resources and expertise to satisfy the spectrum of operations. The supplier also needs to be in a position to grow with increasing international needs. However, the biggest challenge is long-term development of any supplier. Vigilant management of supplier relationships is imperative.
International was in a good position to effectively increase coordination with its suppliers. For example, they had developed a solid relationship with AAPICO, a Thai vendor that specialized in tooling used for low-volume production. It is significant that AAPICO knows how to design for low-volume assembly because their scope, pricing, designs, and attention to the project are appropriate for the program. A supplier accustomed to big orders might over-design the tooling and assign a junior engineer to a low-volume project. Since AAPICO also builds tooling for Honda, Toyota, BMW, etc., they are a rich source of innovative tooling design ideas. They are familiar with Chrysler’s standard facility design since they have built body shops for Malaysia, Indonesia, and Thailand since 1993. Chrysler can attain coordination benefits by continuing and deepening its relationship with AAPICO.

3. *Develop Common Communications Infrastructures:* Chrysler International believes that it has a competitive advantage by “starting over” in today’s environment. When other automakers were creating their international empires, they were reliant on local communications, local news, and less efficient travel. Now, companies can benefit from global communications, CNN, satellites, and global air travel. Chrysler can exploit cutting-edge technology to make communications part of a winning strategy. Chrysler will need to develop a structure for communication and build relationships where none are present. To accomplish this, they need to address the following issues:

- International should consider increasing its efforts to standardize on a common computer information system (I/S). This necessitates that they allocate a budget for information systems. They can tap corporate I/S resources and personnel. Anyone should be able to plug into the Chrysler network from anywhere around the world. They also need a standard communications or email software package. Their current mode of communication with incompatible email packages and the ubiquitous yellow sticky pad is unsustainable.
International may further develop communication based on "image" data. A picture says a thousand words and the latest telecommunications technology allows companies to harness that powerful mode of communication. Photos and videotapes of international operations should be more widely available and distributed. Video conferencing can allow groups to have a more personal and image-rich form of communication. The price of these systems and technology have dropped significantly so that installation is feasible and can be cost-effective.

International should not neglect the effectiveness of face-to-face communication. While it is not feasible for every group member to visit all sites, there is benefit to meeting and building relationships with the people overseas. Group members point out that they are often told to benchmark a plant in Europe. However, only a minority of the group has visited that plant. The logistics of bringing group members to the plant on the corporate jet, especially during the weekend, could be manageable. The benefits of doing cross-site quality workshops or exchanges at that plant may outweigh the costs. The European plant is used as a frequent benchmark, however plants like Thailand also have excellent facilities, progressive practices, and a motivated workforce. Unfortunately, IMO management has had limited visits to the plant, thus decreasing its visibility, impact, and ability to transfer best practices. We recommend that International increase coordination of the Thai plant with other plants in Asia to transfer learning and ideas.

All of these communication infrastructure techniques are feasible for International if they dedicate enough resources and focus. There is the risk that they standardize on the wrong technology. This is an issue faced by all companies. It should not deter them from taking advantage of information technology. The standards must have mechanisms in place to accommodate change.
Chrysler also faces the risk of an information security breach. International may not wish to share confidential information with its suppliers, joint venture partners, or licensed assembler partners. They will need to manage and secure the amount of technology and information transfer to those groups.

4. **Develop Common Reporting Systems**: To increase coordination, International is in the process of developing common reporting systems that can be accessed and utilized by all groups. The Manufacturing Engineering group was developing a standardized form of program management reporting for activities, scheduling, problems, and budgets. Gantt chart tools should facilitate visible management and flag trouble before it occurs. The Operations groups publish a single-page newsletter that highlights the week’s events. The newsletter is efficient but it lacks substantial depth or detail. An alternative may be to set up web sites on the internet or Chrysler’s intranet. The web site could serve as a problem-solving forum where relevant information could be posted. Hypothetically, if Thailand was launching a trim/chassis/final line, they could access the web to find out what went right and what went wrong when Europe was developing theirs. These reporting systems are feasible, however, they require advocacy, training, and a budget. The open architecture of the internet would allow worldwide operations to access the system with the proper security passwords. The risks include security on the net.

5. **Organize Coordinated Launch Teams**: Higher coordination can lead to less costly and faster product and facility launches. International could organize a team with members from multiple sites that would participate in all launches. The intent is that learning accumulated in the team could be transferred to subsequent launches. If members were from multiple sites, then they could carry that learning back to their home organizations. Downsides are that the launch team would need to dedicate human resources, may have minimal responsibility for the systems after launch, and could “step on the toes” of the plants. Incentives would have to be developed to encourage cooperation. Coordinated launch teams may
not be feasible due to the personnel constraints but the spirit of tighter coordination during launch remains.

4.5. Case Study: Intel Corporation's CopyEXACTLY!™ Manufacturing Strategy

Intel Corporation’s Copy Exactly manufacturing strategy is an example of the highest degree of coordination between multiple manufacturing sites. Intel is the world’s leading manufacturer of microprocessors. They operate in an environment of high capital investment, high volume, low product variety, short product life cycles, profit margins that are high initially but decline rapidly, and complex state-of-the-art technology. Under these conditions, Intel has developed a manufacturing strategy called Copy Exactly. Copy Exactly is a methodology for rigorously replicating equipment, process variables, and selected manufacturing systems at all sites that run the same process technology.51 The philosophy behind Copy Exactly is that identical systems with identical inputs will produce identical outputs.52

4.5.1. How does Copy Exactly Work?

Copy Exactly allows all manufacturing fabrication plants (fabs) to operate identically as a single “virtual fab” entity. Thus, the actions of one fab are leveraged over all the fabs. It requires very disciplined alignment of processes, equipment, and systems across multiple sites. The development and launch of a product using Copy Exactly utilizes the following procedure:

1. Product and process technology are developed at a development fab.

2. Technology is transferred from the development fabs to the manufacturing fabs by exactly replicating processes and equipment.

3. Continuous improvement activities for facilities, process, automation, and operations must be approved and proliferated across all sites in the virtual factory. For example, before a change can be implemented across all sites, two iterations of white papers supporting the proposed change must be delivered and approved by three cross-site
management review committees (joint engineering management, joint engineering team, and change control board).

4.5.2. **Impact of Copy Exactly**

Copy Exactly’s greatest benefit may be faster yield ramp-up. Given that the bulk of profits are generated at the beginning of the product life cycle, fast ramp-up is crucial to success. The greatest cost may be a decrease in flexibility and creativity. Proponents counter that there is time built into the schedule to allow for experimentation and that operators actually have more ownership and incentive to be creative because their ideas can be implemented on a wide scale with high visibility. Additional benefits and costs are listed below:

*Figure 4.7: Advantages and Disadvantages of Copy Exactly*

<table>
<thead>
<tr>
<th>Advantages of Copy Exactly</th>
<th>Disadvantages of Copy Exactly</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Quicker problem resolution from shared learning</td>
<td>• Slower decision making since all sites must jointly agree to make changes</td>
</tr>
<tr>
<td>• Minimized risk of achieving low start-up yields. Superior long term yields. (Yield is defined as the percentage of good dies to total die.)</td>
<td>• Potential loss of innovation if good ideas are not pursued simply because of the burdensome change process</td>
</tr>
<tr>
<td>• Matched yields across fabs</td>
<td>• All fabs make the same mistakes</td>
</tr>
<tr>
<td>• Faster transfer of new processes</td>
<td>• Cost of change approval process involving cross-site teams and approval boards</td>
</tr>
<tr>
<td>• Assurance that customers receive identical product regardless of fab</td>
<td>• Cost of cross-site auditing so unintended differences do not cause sites to diverge</td>
</tr>
<tr>
<td>• Elimination of multiple customer qualification of new fabs</td>
<td>• No opportunity to upgrade equipment during process life cycle, only at the start</td>
</tr>
</tbody>
</table>
4.5.3. Differences Between Intel Corporation and Chrysler Corporation

Certainly there are differences in the product, process, organization, and revenue generation of Intel as compared to Chrysler. The differences are cited in the table below. The differences indicate that it is not necessary for International to take such extreme measures for standardization and control. For example, Chrysler does not have to contend with the same time urgency, customer requirements, or technological complexity. Furthermore, International is not currently in a position to support such a coordination effort. It does not have the necessary organizational structure, incentive systems, or measurement systems in place.

However, there are enough similarities such that International can study and learn from Copy Exactly. We have underlined items that could be applicable to Chrysler.

<table>
<thead>
<tr>
<th>Intel Corporation - Microprocessor Fab</th>
<th>Chrysler Corporation - Body Shop</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Elephant]</td>
<td>![Car]</td>
</tr>
<tr>
<td>Microprocessors Chips</td>
<td>Cars and trucks (tons).</td>
</tr>
<tr>
<td>(sizes on the order of angstroms).</td>
<td>High product variety (7 models with hundreds of option combinations).</td>
</tr>
<tr>
<td>Low product variety (4 models).</td>
<td>Product life cycle = 1 year model change or 4-8 years for major model change.</td>
</tr>
<tr>
<td>Product life cycle = 3-4 years.</td>
<td>Mature welding process technology.</td>
</tr>
<tr>
<td>State-of-the-art wafer process technology.</td>
<td>Requires discipline to match key characteristics to dimensional quality.</td>
</tr>
<tr>
<td>Difficult to match key characteristics with yield.</td>
<td>Six geographically dispersed mfg fabs acting identically as a single virtual fab.</td>
</tr>
<tr>
<td>Ten geographically dispersed body shops acting independently.</td>
<td>Copy Exactly necessitates that fabs give up local autonomy and work together.</td>
</tr>
<tr>
<td>Frequent communication - weekly phone</td>
<td>Locally autonomous, flexible, and entrepreneurial. Separate improvements.</td>
</tr>
<tr>
<td>Infrequent communication between</td>
<td></td>
</tr>
</tbody>
</table>
meetings, quarterly face-to-face.
Identical equipment specs and suppliers.
Facilities were greenfield and have identical layout.
Workforce is highly skilled and trained.
Hierarchical organization as CE requires 17 groups in 4 levels of hierarchy.
Centralized management control.
Customers - original equipment mfg’ers.
Time is critical element of competitive advantage and profitability: development time, transfer time, ramp-up time, and time to achieve high yields.
Highest profits made in early stage of product life cycle.
Immense capital investment ($1-2 B)

operating groups.
Multiple equipment specs and suppliers.
Facilities may have legacy constraints and dissimilar layouts.
Workforce has disparate skill levels and plant-specific training programs.
Flat, decentralized, entrepreneurial.
Multiple operating types (4-wholly owned, 2-joint ventures, 4-licensed assemblers).
Customers - vehicle owner.
Lesser degree of time urgency.
Conservative approach to entering new markets with low volumes and niche products thus decreasing necessity of achieving high volumes quickly.
Shoestring capital investment budget

4.6. Conclusion

Control of a company’s coordination can produce a competitive advantage. After analyzing Chrysler’s coordination, we found that International could benefit from increasing and sustaining a higher level of coordination. To accomplish this, International must make system-wide change (see Figure 4.8). The are considering or doing the following action items: standardize facility design, promote supply chain management, commonize communications infrastructures, and form launch teams. While these actions are feasible, they will require management focus, resources (time, money, and people), and greater control systems. In the entrepreneurial environment of
International, these requirements present a significant cost. We believe that benefits from increasing the level of coordination at Chrysler outweigh the costs.

**THE SYSTEM**

- Volumes
  - Products
  - Standardized Processes
    - Standardized Facility
    - Communications Infrastructure
  - Consistent Organization Structure
  - Standardized Process to Deal with Variability
  - Standardized Method to Measure Quality
  - Consistent Incentive Systems
  - Standardized Data Collection Methods
  - Standardized Level of Automation
  - Standardized Equipment and Vendors
  - Standardized Operator Training
  - Common Reporting Systems

*Figure 4.8: Impact of Coordination on the System.*

This schematic illustrates the multiple dimensions of the system. All of these areas will need to be considered if Chrysler wants to increase its coordination level. Any changes to increase coordination must be aligned with the total system.
5. **Framework for Body Shop Design Process**

5.1. **Overview**

A well-defined design process should serve as a road map for team members to know where they have been, where they are going, and when they get there. In this section, we will present the process steps that must be undertaken to design a body shop. First, we will develop a design process framework based on a product design framework. We will then examine program management tools that will organize and track the process.

5.2. **Methodology for the Design Process**

The process for designing an automotive body shop is not unlike the process of designing an automobile. In both cases, designers begin with a blank sheet of paper to develop an object that best meets the needs of their customers. A product group designs and develops a car that will appeal to their target customers. IMO designs and develops a body shop that will optimally build those cars. Thus, concepts borrowed from product development are applied to frame the body shop design process.

According to Ulrich and Eppinger, the product development process is divided into five phases that start with a mission statement and end with production launch. The five phases are: (1) **Concept Development** where markets are defined; lead users and competitors are identified; product concepts are developed; prototypes are made; costs and feasibility are estimated; and a single concept is selected, (2) **System-Level Design** where major subsystems are defined; designs are refined; suppliers are identified; assembly schemes are defined; product families are developed; product options are planned; and service issues are identified, (3) **Detailed Design** where part geometry is defined; materials are chosen; tooling is designed; production processes are defined; quality assurances are developed; and marketing plans are drawn, (4) **Testing and Refinement** where production processes are refined; and sales plans and promotions are developed, and (5) **Production Ramp-Up** where early production output is evaluated; operations of the entire system are initiated; and early production is placed with key
customers. The final step is product launch where the product is in full production and is being sold to customers. These steps in the product development process are illustrated in Figure 5.1.

**Mission Statement**

- System-Level Design
- Detailed Design

- Product Concepts, Prototypes
- Estimate Costs & Feasibility
- Define Market, Lead Users, Competition

- Define Major Subsystems, Refine Design
- I.D. Suppliers, Make-Buy, Assm Scheme
- Develop Product Family, Options, Service

**Product Launch**

- Evaluate Early Prdn Output
- Begin Operation of Entire System
- Early Prdn w/ Key Customers

- Refine Production Process
- Develop Sales Plan, Promotion Plan

- Define Part Geometry, Choose Materials
- Design Tooling, Prdn Processes, Quality
- Develop Marketing Plan

*Figure 5.1: Generic Product Development Process as Defined by Ulrich and Eppinger*

**Mission Statement**

- System-Level Design
- Detailed Design

- Layout Concepts, Program $ Approval
- Site Selection, Stakeholders
- Market Analysis, Project Planning

**Product Launch**

- Install, Set-Up
- Pilots, Training
- Launch

- Tooling Construct, Tryout
- Certification, Document Xfer
- Ship Tooling

- Tooling Design
- Final Production Line Design

*Figure 5.2: Generic Body Shop Development Process based on Product Development Process*

Similarly to the product development process, we also divide the body shop design process into five phases (see Figure 5.2).
1. **Concept Development**: In the concept development phase, the program is identified. Stakeholders are identified as team members. The market is analyzed, the business aspects of the project are planned, and the site is selected according to the methods presented in Chapters 2 - 4. General concepts for the facility layout, process, and equipment are generated. A concept is a description of the form, function, and features of the [body shop] that is usually accompanied by a set of specifications, an analysis of competitive products, and an economic justification of the program. These findings are presented for program approval and funding. Upon approval by the program steering committee (PSC), the design process of the body shop moves forward.

2. **System-Level Design**: In the system-level design phase, the design of the body shop is begun in earnest (refer to Figure 5.3). The bill of materials, a list of the parts necessary to build a vehicle body, is developed. The bill of materials will indicate which parts will be shipped in CKD kits from the US and which parts will be sourced locally. Process engineers develop an assembly scroll which is a "recipe" that describes the assembly operations and their sequence. This information is modified for low-volume assembly from existing domestic assembly scrolls. The country managers work with the process engineers to determine the level of

![Manufacturing Strategy Diagram]

**Figure 5.3: Body Shop Design Process Flow**

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70
manpower, work assignments, and training programs. Based on the assembly scroll, the country managers also develop tooling design concepts and work with the facilities engineers to determine the tool placement on the plant floor.

3. Detailed Design: In this phase, detailed designs are developed for the tooling, fixtures, equipment, and weld guns. Specific tooling is defined and tooling suppliers are contracted. Based on findings from a weld study, weld guns are defined. Detailed designs for the tooling, equipment, and weld guns are drawn.

The importance of supplier relationships is now being recognized in IMO. Tooling suppliers are brought forward earlier in the design process. Their input is solicited to determine the optimal design given the line speed, the part shapes, the weld gun selection, and ergonomics. The tooling supplier may also work together with a firm contracted to perform a weld study. The weld study calculates the number, placement, and criticality of weld spots. It also indicates the number, style, design, configuration, and operation of the weld guns.

4. Build: The build stage includes the building and certification of tools and equipment at the vendor's site. The goods are then sent overseas to the assembly plant, installed, and certified. The trend is for a single supplier to be responsible for all aspects of the tooling including design, build, install, and certification at the plant. Unless there are local content constraints, IMO avoids having one supplier design the equipment while another supplier builds it at a different site.

5. Production Ramp-Up: In this final stage, the plant is geared up for full production. The launch team and operators build a number of pilot vehicles. Pilots are vehicles that used to prove the process, equipment, and quality. The pilots are built at a very slow rate so that production problems can be identified and fixed. On the launch date, the plant produces the first vehicles that will be sold to the public. Under the guidance of the launch team, production is ramped up to full speed. When the plant is at volume production, the plant operations group takes full responsibility for the production.
These five phases define the body shop design process. Chapters 2 - 4 presented a methodology and consideration for the first stage, concept development. Subsequent chapters will examine the remaining phases.

5.3. Program Management Tools for the Design Process

In order to organize the body shop design process, we have introduced some program management tools to the IMO department. Program management is the coordination, organization, scheduling, tracking, and allocation of responsibility for tasks needed to complete a project. The major duty of IMO country managers is program management. Their goal is to deliver a program on-time and within budget. To assist country managers with their program management duties, we have developed some computer tools, specifically a Gantt chart template using Microsoft Project™ software.

A Gantt chart is a bar chart showing tasks plotted on a timescale to indicate start and finish dates. IMO developed a standard Gantt chart template that lists, in much finer detail, all the process steps that were previously outlined in the process framework. The template includes all tasks that any IMO program might require. The country manager is required to customize the generic template to their specific program by adding or removing tasks and by specifying the appropriate start and finish dates, both target and actual. The Gantt chart template can be accessed with Microsoft Project™ software. We have included an example of a project management summary, with the body shop area exploded for illustration (see Figure 5.4).

5.3.1. Objectives of the Gantt Chart Template

The Gantt chart template serves multiple functions. It acts as a critical tasks checklist, scheduling tool, communication tool, coordination tool, planning tool, and educational tool. We have detailed the functions as follows:

1. Critical Tasks Checklist: The Gantt chart template is a comprehensive list of all critical tasks necessary to transform a greenfield site into a full-production assembly plant. Stakeholders can utilize it as a checklist to insure that they do not overlook any critical tasks or major milestones.
Figure 5.4: Example of Part of the Gantt Chart Template with Body Shop in Exploded View
(time durations have been omitted)

2. **Scheduling Tool**: The Gantt chart template is used to track the schedule and progress of all task items. Target start and finish dates are defined in the planning stages. Actual start and finish dates can be compared to the targets. By recording the percentage of work completed for each task, a country manager can identify when the schedule is slipping. If the program is behind schedule, the software will generate an
exceptions report in which the country manager can explain causes and corrective actions needed to get the program back on-schedule.

By linking tasks that are interdependent, a country manager can also identify any subsequent tasks that will be effected by a slipping task. This may serve to warn country managers of any potential problems that could result from current slippage.

3. **Communication Tool**: Country managers can use the Gantt chart template to communicate their goals, vision, requirements, and progress for a program. It is an effective communication tool for many stakeholders, including country managers, department managers, process managers, quality managers, overseas counterparts, engineering, business development, purchasing agents, program managers, and suppliers. With e-mail capabilities, progress reports can be generated and delivered to any part of the world almost instantly.

The Gantt chart template is especially useful in progress review meetings. Once the stakeholders are familiar with the standard format, they can review progress very quickly and easily. The tool is data driven so that reviews can focus on the facts and concrete plans rather than speculation.

4. **Coordination Tool**: All IMO programs require coordination of multiple stakeholders on a cross-functional team. The country manager can list a person or group that is responsible for each task. By dividing responsibility among stakeholders at the beginning of a program and committing that to the Gantt chart, we will see an increased level of coordination, accountability, and resource allocation.

5. **Planning Tool**: To develop a working Gantt chart, a country manager needs to spend time planning at the start of a program. Emphasis on the planning stage forces discipline into the system by prioritizing tasks, dividing time and resources to each task, and focusing on value-added activities.

6. **Educational Tool**: The Gantt chart template represents a collection of information residing in IMO. It can be used by new stakeholders as an educational tool to
understand the elements and flow of a program. With continuous improvements, learning will not be lost from program to program or from organizational shifts.

5.3.2. Development of the Gantt Chart Template

To develop the Gantt Chart Template, we also used ideas from product development and from total quality management (TQM). Our mission was to develop a standard format for the Gantt chart template that all the country managers would use. Prior to this standardization effort, every country manager had their own timeline or spreadsheet. The group had recently adopted Microsoft Project™ software, but every country manager had a different levels of usage. The spectrum ran from high-level usage in the Egypt project to detailed-usage in the Thai projects. A preliminary template, based on the Argentina program, was developed but it was met with resistance from the country managers. We found that we had not properly incorporated the needs of the customer. We went back to solicit the voice of the customer as illustrated in Table 5.1.

The presentation of the voice of the customer was controversial but it was invaluable in the generation of the revised Gantt chart template. The final Gantt chart template was divided into fourteen major areas. The major areas then listed the corresponding process tasks. We have illustrated the outline using the body shop section as an example. Other major areas can be broken out similarly to the body shop area. The sample categories are as follows:

- **Major Areas**: launch date (listed first to signify priority), pilots, quality, project planning, construction management, stamping, body in white, paint, trim/chassis/final, engine, training, launch, material handling, and information systems.

- **Body in White Process Steps**: vehicle processing, purchase orders, manpower, tool design, tool construct, tool tryout, document transfer, tool shipping, installation, and commissioning.

- **Body in White Tool Numbers** (part numbers for fixtures, tools, and equipment)
Table 5.1: Voice of the Customer (paraphrased)²⁶

<table>
<thead>
<tr>
<th>Preference for</th>
<th>Customer</th>
<th>Content Level</th>
<th>Specific Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier</td>
<td>High-Level</td>
<td>Unable to efficiently track even moderate content — task is too large, too detailed. Preference is to itemize by tool number. Include major tool-related items, such as Build, Installation, etc. Leave out coordination with other groups.</td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td>High-Level</td>
<td>Unsure of what the benefits of this tool are (i.e., progress tracking, conflict avoidance, roadblock resolution, assuring sufficiency of resources, accountability of others, cross-functional input). Only doing this to comply with management directive.</td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td>High-Level</td>
<td>Frustrated by software, especially linking of tasks, due to lack of training. Not enough time to get training. Not enough time to personally update project information each week.</td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td>Detailed</td>
<td>Great for complex projects. Maybe not needed to successfully manage projects of limited scope. Glad to do it to comply with management directive if chart is filtered so only applicable tasks are shown.</td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td>Detailed</td>
<td>A good tool, but too much to handle. Actual percent complete of each task is not known, so unsure if all the detail really helps. Only doing it to comply.</td>
<td></td>
</tr>
</tbody>
</table>

When country managers or suppliers go to their bi-weekly management update, they bring an updated Gantt chart to the meeting. If there are no problems, the sections are “rolled-up” so that only the major heading is visible. If an area, the body shop for example, is behind schedule, then the tasks can be “rolled-down” to reveal the steps or the specific tools that are late. The standardized form is easy to read and easy to become familiar with, thus it should facilitate communication at the bi-weekly meetings.

5.3.3. Challenges of Progress Tracking

One of the biggest barriers to affective progress tracking is that it is tedious and time-consuming. It is, however, a necessary activity. In order to overcome the down-
side, we have added automation and a more user-friendly interface. We hope that this will encourage country managers to fully utilize Microsoft Project™.

5.3.4. Conclusion

In conclusion, a well-defined process is essential to focus the team on the appropriate tasks necessary to design and build a body shop. We have created a framework to categorize the process steps. These steps have been developed in detail for the Gantt chart template. The template not only serves to organize tasks for the country managers, but also to communicate progress to the rest of the team. While progress tracking is difficult and time consuming, it is essential for the successful launch of any body shop.
6. System Level Design of the Body Shop

6.1. Overview

In Chapter 5, we introduced system-level design as the second phase in the body shop design process. In this chapter, we will examine this topic in greater detail. In system-level design we define the major subsystems of the body shop, including the assembly scheme, manpower assignments, and facility layout. Upon completion of this phase, we should have a refined concept of the how the body shop will look and operate.

6.2. Definition of the Assembly Scheme

We first define the assembly scheme, which specifies the supplied parts and the order in which they are assembled. The Level of CKD Assembly section will present how the bill of materials is determined. The Assembly Scroll section will present how the assembly order is chosen.

6.2.1. Level of CKD Assembly

The input materials to a body shop are sheet metal stampings. Stampings are sheet metal blanks formed by stamping dies into body panels at the stamping plant. A domestic plant might “buy” only stampings. These individual stampings are the lowest level of subassembly. The body shop then “makes” a body-in-white by assembling, welding, and sealing the stampings together. International plants often receive material with higher level of subassembly. A higher level of subassembly would be achieved if the plant received stampings that already had brackets, studs, or other stampings assembled. International plants must justify the level of CKD subassembly that they wish to receive. For example, the assembly plant in Toledo, Ohio may produce completed bodyside subassemblies that will be shipped in complete knockdown kits to Malaysia for further assembly.

When making the level of subassembly decision, there are several variables and corresponding interactions that affect the CKD “make-buy” decision.
The reasons why we do not simply ship the entire body-in-white (the highest level of CKD assembly) to the international plant are as follows:

- **Shipping Costs**: Weight and volume determine shipping costs. Subassemblies may not (and completed body-in-whites definitely will not) nest efficiently. If pack density is compromised then there is a penalty cost for “shipping air.” Pack density must be analyzed individually as some built-up subassemblies may be cheaper and easier to ship than the individual parts. Reoccurring shipping costs can add up quickly.

- **Local Content Requirements**: The government may mandate that a percentage of work, specific items, or a dollar value of work be produced in-country. To receive local content credit, we would need to buy local parts or assembly them locally.

- **Limited Capacity and Disruption to the Domestic Plant**: The domestic plant may not have the capacity, process in place, or labor needed to build subassemblies for international. There is a trade-off between building capacity domestically versus internationally.

There are benefits from a high level of subassembly:
• *Lower Capital Investment at the International Plant*: If high level subassemblies are bought domestically, then the international plants save on investment in fixtures and weld guns. However, we must weigh this against the feasibility and cost of racks and equipment necessary to pull subassemblies from the domestic production line. The fixed capital investment savings should also be compared to the reoccurring kit costs.

• *Better Quality from Domestic Plants*: There may be a quality difference between subassemblies built domestically versus internationally. This can work in both directions, as we have seen rejected subassemblies sent internationally by domestic plants wishing to unload their scrap.

• *Increased Labor Content In Domestic Plants*: If US demand for a particular vehicle is slow, it may be beneficial to build subassemblies domestically to better utilize plant capacity and satisfy labor union agreements.

These decision variables and interactions must be weighed to determine the appropriate level of CKD assembly. Most of the costs and benefits can be quantified into a dollar value. The quality delta is more difficult to quantify but should be considered in conjunction. The appropriate level of assembly can be partially determined by the net present value in a scenario analysis. Even if all the economic and qualitative analysis points to "buying" subassemblies, IMO still needs to negotiate with the particular domestic plant. This is often very difficult since the incentives of the two groups do not align. Our recommendation is to review transfer pricing and incentives so domestic and international plants work jointly to optimize the system as a whole.

### 6.2.2. Assembly Scroll

Once the parts in the kit are specified in the bill of material, an assembly scroll can be developed. An assembly scroll is a diagram that indicates the parts, the fixtures that hold the parts during welding, and the order of assembly. Based on observations from existing domestic operations, country managers can anticipate the bottleneck operations (double dashed lines), as seen in the following figure:
6.3. Development of Manpower Requirements

In this portion of the system-level design phase, we present the development of manpower requirements. We have developed a methodology for labor assignment. An example of a bodyside assembly will accompany the methodology for illustration. In the second part of this section, we will identify the unique manpower challenges of building a vehicle at low volumes. Training and work pacing challenges will be identified; best practices will be described; and suggestions for overcoming these hurdles will be delivered.

6.3.1. Methodology for Manpower Assignment

In this section, we present a methodology for assigning operators to the body shop. The manpower assignment interacts with all other portions of the body shop design, including fixture design, weld gun design, and facility design. Thus the process is complex and iterative. The methodology adheres to the following steps: cycle time
definition, preliminary station definition, preliminary operation definition, revised station design, and revised operation assignment. The steps are detailed as follows:

4. *Cycle Time Definition*: Based on production volumes estimated by the marketing department, we can calculate the cycle time. We define cycle time to be the time between two subsequent vehicles to roll off the line. For example, if demand is estimated at 9600 vehicles per year, then the production rate is five jobs per hour (jph), (assuming eight hours per shift, single shift, and 240 working days per year, 5 jph = 9600/240/8). If we transform the rate into time, then our cycle time is 12 minutes per station. In this early stage, it is important to account for demand growth as flexibility should be designed into the body shop now.

5. *Preliminary Station Definition*: A station is an area where workers perform a set of operations. A station might include a combination of the following:
   - a fixture that holds parts in the proper position while being welded,
   - a spot weld gun station, including a transformer, cables, and the gun itself,
   - a MIG braze weld station, where parts are joined by a seam rather than spots,
   - a sealant applicator that applies sealant to the welded joints,
   - materials presented and stored next to the line,
   - space for the operator to stand and store equipment and tools.

What constrains a station and causes the need for more than one mega-station? The number of operations in a station is constrained if:
   - the time required to perform the operations exceeds the available cycle time,
   - the tool design gets too complex to accommodate all parts and operations, or
   - the physical shape of the tool blocks access to areas on the part

We have included block diagrams of the station layout below (see Figure 6.3 - Figure 6.5). There are three diagrams that illustrate the difference between 1-4 jph, 5-9 jph, and 10-20 jph. The three diagrams can be compared to indicate how the bottleneck stations were divided into multiple stations to meet the decreasing cycle time.
Body Shop Guideline
ZJ Panel Flow Through Fixturing
1 - 4 jph

2960
Frt Floor Pan Complete

3005
Frt Floor Pan to Dash & Plenum

3267
UB Str #1
Frt RLR Rlr Pan to Rails

3269 RLR
Frt Sill & W/House

3105
Frt Sill & W/House

3262 RLR
Frt W/House

3260 RLR
Frt Str Supp to Spr Res.

3265
UB Str #2
UB Complete

3440 RLR
B/S Inner, Outer Complete

1810 - F1 Toy Tab
1810 - F2 Main Frame Roof
1810 - F3 Respot Cowl Top
1810 - F4 Respot, MIG T/Over
2964 Piercing

Figure 6.3: Block Diagram of Assembly Process Flow for 1-4 jph

Each block represents a fixture station. The fixture tool number is listed first, followed by the fixture name.

Body Shop Guideline
ZJ Panel Flow Through Fixturing
5 - 9 jph

2960
Frt Floor Pan Complete

3005
Frt Floor Pan to Dash & Plenum

3440 R-LR
B/S Inner, Outer Complete Comp Respot

3287
UB Str #1
Frt RLR Rlr Pan to Rails

3288 R-LR
UB Complete

3440 - F1 R-LR
B/S Inner, Outer Complete

1810 - F1 Toy Tab
1810 - F2 Main Frame Roof
1810 - F3 Respot Cowl Top
1810 - F4 Respot, MIG T/Over
2964 Piercing

3280 R-LR
Frt W/House

3440 R-LR
B/S Inner T/Over

Figure 6.4: Block Diagram of Assembly Process Flow for 5-9 jph

Note that the following stations were added: bodyside inner-outer complete respot station.
3. **Preliminary Operation Definition:** In this step, we define the number of operators, the operation assignments, and the order of operations for each station. We will calculate the time it takes to complete the operations. Operation time has been studied in great detail by industrial engineers in the auto industry. There are many reference guides and software packages that will calculate the time needed to perform most operations. In our example of the bodyside assembly, we will use a hypothetical time unit since our goal is to illustrate the methodology only. We have graphed the cycle times in Figure 6.6- Figure 6.8. The methodology is as follows:

a) **Estimate the number of operators needed in a station.** In the example for 1-4 jph, we estimated two operators, A (solid black line) and B (gray hatched line).

b) **List the operations that need to be performed in the proper sequence.**

According to the design requirements, a fuel filler well in the example must be installed to the left hand Rear Quarter Panel Outer (RR Qtr Outer). The fixture is designed so that the operator (1) loads the fuel filler well into the appropriate
place in the fixture, (2) loads the RR Qtr Outer on top of the first part, closes the clamps to align and secure the parts, (3) welds three spots to join the parts, (4) opens the clamps, and unloads the completed subassembly.

c) Distribute and balance the operations among the operators. In this example, Operator A starts on the Bodyside Outer Panel. Operator B starts on the Bodyside Inner Panel. When B is finished, B brings the completed Bodyside Inner and loads it into A’s fixture. For the remaining time, they work together to finish the Bodyside Inner-Outer Complete.

d) Calculate the total time needed to complete all proposed operations. The time required should be slightly less than the cycle time.

4. Revised Station Design: If the proposed operation time is much less than the cycle time, the fixture may be redesigned or the operator can perform extra duties in an adjacent station. We must still adhere to the fixture constraints listed above when redesigning the fixture. If the proposed operation time is longer than the cycle time, then we can do the following:

a) Add operators. When we increased our production rate from 1-4 jph to 5-9 jph, we added 2 more operators, Operators C and D (see Figure 6.7).

b) Add a respot station. The station can be divided into the primary station and the respot station. In the primary station, the operators weld the minimum number of spots necessary to hold the dimensional integrity of the subassembly but less than the number constrained by the cycle time. The remaining spots are welded in the respot fixture. The respot fixture no longer needs to hold the geometry of the part, so it be as simple as a stand or the top of the fixture. In our example, we separated the Bodyside Inner fixture into a primary and a respot fixture.

c) Add a second station. When we increased our production from 5-9 jph to 10-20 jph (see Figure 6.8), we moved some operations previously performed in the Bodyside Inner-Outer Complete fixture to a Bodyside Outer fixture. This extra station was added because the space limitations prevented us from adding more
operators. The cost of adding a station includes capital cost and the cost of extra non-value added work to load and unload the part in the new fixture.

5. **Revised Operation Assignment:** The operator assignments are re-calculated for the revised station design.

6. **Operator Description Sheets (ODS):** The cycle time sheets are translated into ODS sheets to describe the station operations to the operators. The ODS sheets include the parts numbers, descriptions, number of welds, weld placement, and safety welds.

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**Figure 6.6: Bodyside Inner-Outer Complete (1-4 jph) 7FTZ-3440 Cycle Time Chart**
### Bodyside Inner (5-8) 7FTZ-3430

<table>
<thead>
<tr>
<th>Operator</th>
<th>Min</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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**TOTAL 6.0**

### Bodyside Reseat Station #2 (5-9) 7FTZ-3440-F2

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**TOTAL 3.0**

### Rear Quarter Panel Outer (LH Only) 7FTZ-1156

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</thead>
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<td>C, D</td>
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</tr>
<tr>
<td>3</td>
<td>C, D</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**TOTAL 3.0**

To increase from 1-4 ph to 5-9 ph, we:
1. increase manpower
2. add Bodyside Reseat Station #2

**Process Flow:**
1a. Operators A & B weld B/S Outer Assy in 7FTZ-3440-F1
1b. Operators C & D weld B/S Inner Assy in 7FTZ-3430 fixture
2a. Move B/S Inner Assy to 7FTZ-3440-F1 fixture; A & B weld
2b. Operators C & D move to 7FTZ-3440-F2 fixture; C & D respet

---

**Figure 6.7: Bodyside Inner-Outer Complete (5-9 jph) 7FTZ-3440-F1 Cycle Time Chart**

**Note on How to Interpret the Figures:**

The three figures are cycle time charts for the assembly of the bodyside at different production rates: 1-4 jph, 5-9 jph, 10-20 jph. The first column lists the operations number. The second column lists the Operator, as designated by an alphabetic letter. The third column lists the operation description. The fourth column lists the time spent on each operation. Note that these times are not exact and should actually be calculated with industrial engineering principles. The top row marks the time spent in station. The blocks graphically represent the time spent on each operation. Arrows indicate movement of the operators or the parts. The total time spent in the station is totaled at the bottom. This total time must be less than the cycle time.
In conclusion, this methodology for manpower assignment describes how the body shop is designed and operated. It is a complex process where multiple factors need to be considered simultaneously, including cycle time, production growth, station constraints, fixture design, number of operators, order of operations, and operation time. The end result should be a system-level concept for labor assignment in the body shop.
6.3.2. Training for Long Cycle Time Systems

Long cycle times in station are typical of low-volume production plants. This creates task learning challenges, including the following:

- **Large numbers of tasks to be learned by the operator**: The optimal learning rate occurs for operations with cycle times near one minute. Yet in international, we may be asking our operator to learn 20 minutes of work over 2 stations.

- **Complexity of Tasks**: If operators do not perform the same tasks every day and we ask them to perform complex tasks, then the learning curve may be a particular challenge. In the case of absenteeism, another operator must be trained for substitution. In some plants, the same model may not be produced every day. In these cases, operators may have to re-learn tasks after resuming that model.

- **No Time Reference**: In high volume domestic plants with moving conveyor lines, the operators have better time reference to know whether they were on schedule (for example, a column in the station might signal operators that they should be finishing operation #3). Low-volume production generally incorporates a stationary line, thus masking time references.

In order to overcome these challenges, assembly plants may consider incorporating a few of the following ideas:

- “JIT training” accounted for in the launch schedule. This is because learning is best retained when it is taught close to the time that it will be applied.

- Delegations from new assembly plants sent to existing plants to train. Both Argentina and Thailand have sent teams to train at Graz, Austria to train on the Grand Cherokee.

- Training materials should be available for illustration, including parts, equipment, and vehicles. It is very difficult for the training group to teach if IMO does not provide sample parts and equipment as teaching tools.

- Graphical representation of ODS sheets posted in station where they are visible to the operator. In Graz, where some of the workforce is non-German speaking, ODS
sheets were developed using cartoon language. The display of sample parts in station may also facilitate learning.

- Job rotation to be encouraged by positive reinforcement or higher pay grades. Thailand incorporates visible management with large board displaying each operator's name and check marks for all job functions that they have successfully mastered.

- Countdown clocks installed so the operator can reference the time. A buzzer can be added to provide an audible signal for the time limit.

6.3.3. Work Pacing

Even though international labor rates may be low, we still do not wish to have excess manpower or an unbalanced line. Besides the wasted cost, there are other problems associated with poor work pacing, including:

- More Incentive to Work Ahead of Schedule: In an unbalanced line, there is more opportunity for an operator to build a bank of inventory. Inventory increases holding costs and prevents quick detection of defects. In an effort to work ahead, operators may neglect to close all clamps or weld all spots, thus creating defective parts.

- Unsynchronized Idle Time: When there is a lot of idle time in a station, operators may have more opportunity to leave the station. If this is not coordinated, then production teams cannot work in a synchronized manner or implement one-piece flow. Production rates, as well as morale, may suffer.

The following are a few methodologies to control work pacing challenges:

- Balanced Manpower Assignments: Though demand patterns may limit the total speed of the line, operators can still work at the production capacity of the fixtures. Operator teams would move with the product and work in multiple stations. In Malaysia, four operator teams are used to man 14 fixtures, as shown in Figure 6.9.
Figure 6.9: Work Teams Operate Multiple Stations in Each Quadrant

- **Quality Focus**: Focus on quality should encourage adherence to one-piece flow, and thus, synchronized work pacing. Root cause analysis methods should discover whether quality problems are caused by dimensional drift in the tooling or from improper closing of clamps and welds. Air clamps and counters on weld guns that indicate to the operator how many welds have been completed may improve quality.

- **Simflex Assignments**: Simflex assignment is a method to divide the labor in a station for maximum efficiency. One operator would be solely responsible for loading the part, while the other operator would be solely responsible for welding. This decreases the non value-added time needed to pick-up and set-down a weld gun.

### 6.4. Layout of the Facility

Based on our cycle time charts, we were able to determine the number of stations, the type of tooling, and the labor necessary. The final step was to generally arrange the tools on the plant floor. We can estimate the size of the tool based on the size of the part, domestic tooling, and past experience.

Facility layouts are illustrated for our previous example (see...
Figure 6.10 - Figure 6.12.

Figure 6.10 represents the tool and manpower arrangement at a production speed of 1-4 jph. Notice that unused space was planned in the layout. We will discuss the costs and benefits of this "white space" in Chapter 7. Figure 6.11 represents the same example but at 5-9 jph. To gain capacity, we added operators and one fixture. Figure 6.12 operates at 10-20 jph. Faster production meant that cycle times were shortened. To achieve higher production speeds, stations were added, tools were added, work was redistributed among stations, and operators were added.

Figure 6.10: Facility Layout at 1-4 jph
6.5. Conclusion

In this chapter, we developed a methodology for system-level design of the body shop. The three major areas of system design were assembly flow, manpower assignments, and facility layout. The output was a comprehensive plan for the body shop.
First, the assembly flow was determined from an analysis of the appropriate level of CKD assembly. We diagrammed the decision variables which were considered if one were to "make" internationally or "buy" domestically. The deliverables from this phase was an assembly scroll and a bill of materials.

In the second phase, we defined a methodology for assigning manpower. We used industrial engineering cycle time charts to estimate the labor requirements. We showed an example of the variation in labor requirements as production rates increased. Challenges arising from low-volume production were discussed.

In the final phase, facility layout diagrams were drawn. The layouts were a fairly accurate representation of the ultimate design of the body shop.
7. Quality and Flexibility into the Body Shop Design

7.1. Overview

This chapter will discuss quality and flexibility issues involved in the design of a body shop. In the first section, we will study quality measures by observing Chrysler's operations in Graz, Austria. In the second section, we will examine flexibility in the body shop, including volume growth flexibility, multiple model flexibility, and model changeover flexibility.

Nearly one in seven vehicles produced in Austria in 1996 were exported to the Middle East, Asia, and Brazil. One reporter writes, "As Chrysler pushes into more international markets, [Graz's] greater production flexibility (and lower automation) compared with North American factories makes it easier to tailor vehicles to different market requirements. For Chrysler, [Graz] is more than just a local assembly plant. It is a laboratory for the low-volume, complex production necessary to satisfy different consumer requirements around the world. If successful, now one would be surprised if the [Graz] formula is applied to other models."58"

7.2. Designing Quality Into the Body Shop

7.2.1. Section Overview

In the 1970's Japanese imports were able to take away large portions of market share from domestic automakers, largely due to their superior quality. Prior to the Japanese threat, the American car industry had been complacent when setting quality standards. Americans were caught off guard by rising quality expectations of increasingly demanding customers. Chrysler International does not want to repeat history. They must vigilantly guard against underestimating rising quality expectations of global customers. International espouses that all international plants must meet the Chrysler quality standard. However, in practice, we find inconsistent quality practices around the world. Chrysler needs to continue efforts to diffuse best quality practices across the international organization.
Quality issues in the body shop have far reaching implications throughout the plant and to the customer. The benchmark for quality within Chrysler International is the Steyr plant in Graz, Austria. Here they produce the Jeep Grand Cherokee. On an anecdotal level, we saw operators in the body shop really taking the time to check that every part fit in the fixture correctly before closing clamps. We saw the body side aperture team immediately convene when they saw an abnormal amount of sparks and noise from one member's weld gun. We saw operators changing and dressing their weld gun tips on a regular basis. In this section, we will investigate how quality can be achieved through training, worker involvement, statistical tools, and equipment.

7.2.2. Sources of Quality

There are four sources of quality information in the body shop:

1. daily weld integrity audits (weld checks, chisel checks) - occurs all over the body shop on a very regular basis.

2. daily dimensional quality audits (CMM checks) - occurs in the CMM room

3. daily Vehicle Quality Audits (VQA) where the vehicle is inspected for customer fit and finish requirements - occurs at the end of the final line at every day.

4. warranty information - occurs after the customer has bought the vehicle.

7.2.3. Quality Through Investment in Training

Steyr attributes their quality level in the body shop to an investment in their people and their training, and less so to an investment in the tooling. The training comes in the following forms:

- Operators have typically graduated from high-school technical trade programs.

- Prior to starting, they typically receive 2-3 weeks training for unskilled trades or 8-16 weeks training for skilled trades. They begin the job with a 2 day classroom introduction and overview of the operations.
• They can volunteer to rotate jobs (95% opt to rotate). Their rotation skills and knowledge are tracked and encouraged. They normally rotate once a week. In certain job functions, like the side aperture team, they rotate on a daily basis to balance the work load while still maintaining operator accountability for ISO9000.

7.2.4. Quality Through Worker Involvement

Steyr has a formal suggestion program called Ideas Management. Operators submit suggestions which are evaluated by management and implemented if they can produce quality improvement and cost savings. The initiating operator then receives a percentage of the first year's savings. There is little fear of introducing productivity improvements, because it is difficult to get laid-off. Chrysler pays all termination costs and gives 6 months notice. Examples of operator suggestions can be found all over the plant: semi-hard tooling in the side aperture line, barriers that prevent vehicle damage from loading the roof rack, etc.

7.2.5. Quality Through Statistical Control Tools

Steyr makes statistical process control methods an integral part of its quality effort. For every shift, at least one vehicle is audited for dimensional accuracy in the CMM room. If there is a problem, then the CMM engineer assembles a team (tooling engineers, production people, etc.) and initiates corrective action. There is control and discipline in the system because all changes must originate from the CMM room. Only the CMM team can authorize and implement changes or shim the fixtures. They can check up to 3-4 cars per shift to track the results of their changes.

7.2.6. Quality Through Equipment

7.2.6.1. Automated Clamping

Automated clamping improves productivity but it can also improve quality. Automated clamping insures that all clamps are closed sequentially before the operator can begin welding. Parts will be properly nested in their fixtures for improved
dimensional quality. This method is not effective if proper preventative maintenance is not followed.

7.2.6.2 Portable CMM Equipment

BMW is currently using a portable CMM device for its Spartanburg Z3 tooling. Fixtures were built with a round slot in the corner. The portable CMM fits into the slot. During each shift, the operator inserts the CMM device into the slot and measures the dimensional accuracy of the fixture itself. The results are compared with the specifications of the fixture. If there are problems with the dimensional fit of the parts, then the portable CMM can also be used for root cause analysis.

7.3 Designing Flexibility into the Body Shop

7.3.1 Section Overview

We can increase our competitive advantage by being flexible enough to respond to external factors with a shortened lead-time. We must anticipate changes in the following areas: customer needs and markets, environment, technology, and management strategies. "...A [flexible] company must be able to quickly secure and deploy various management resources and quickly establish a system to use them effectively." This indicates that two components need to be present: (1) a facility that is designed for flexibility and (2) procedures and leadership that are quick to react to change.

7.3.2 Types of Flexibility in the Body Shop

In this section, we will study the characteristics of a flexible body shop facility. There are three types of flexibility that we wish to investigate and optimize:

1. flexibility to respond to demand growth.
2. flexibility to build multiple models or body styles in the same body shop.
3. flexibility to changeover from model years or from pilot.
7.4. *Flexibility - Demand Growth*

7.4.1. Section Overview

The first type of flexibility is the ability to respond to demand growth. Chrysler's philosophy has been to enter new markets on a very limited scale before developing market share. Since new plants were launched at very conservative capacity levels, IMO is often faced with operations in a growth phase.

The most important factor in achieving volume growth flexibility is the ability to understand and plan for future demand patterns. It is crucial for manufacturing to work closely with sales, marketing, and business development at the onset of a program. With accurate sales projections, IMO can design a suitable body shop. For example, if the sales and marketing department indicated that our demand would grow from 12,000 to 40,000 units per year, then manufacturing would design a body shop that could accommodate growth from 6 jph, expandable to 20 jph. A body shop designed for only 6 jph would be unacceptable.

7.4.2. Methods for Increasing Production

To increase production in the body shop, we need to reduce the cycle time in each station. We could use a combination of the solutions listed below. The impact of any possible decision would be analyzed for optimal cost, quality, and time to deliver the solution. Possible alternatives included:

- *Add manpower*: additional operators can divide the work in a station.
- *Add equipment*: by adding weld guns or other equipment, operators can perform operations simultaneously.
- *Split stations*: one station can set the critical geometry of the part and an added station can pick up any respot welds. This involves the addition of fixtures and equipment.
- *Add automation*: power clamps, robots, and automated transfer system can reduce the cycle time.
7.4.3. Flexible Facility Design Elements

For volume growth flexibility, we would design the following items into the body shop at the beginning of the project:

- *Facility space*: we would plan on additional space for future fixtures, manpower, and material.
- *Infrastructure*: we would plan for adequate infrastructure (including power, building support structures, water, sewage, waste treatment, etc.) that could support extra stations, equipment, and people.
- *Total system*: it would not be enough to have a flexible body shop if the rest of the system could not support the added production. In particular, we would plan for an adequate paint shop, which is the system bottleneck in most assembly plants (see Paint Shop Guidelines).

7.4.4. Comparison of Lack of Planning vs. Built-In Flexibility

By planning for volume growth we achieve two major benefits: savings in cost and savings in production downtime. The following is a comparison of two facilities that experiences demand growth, one without flexibility and one with flexibility built-in. We have listed the process that each must go through to ramp up production. In this scenario, both body shops split up stations to reach a lower cycle time. The facility without planning experiences a much higher cost and longer changeover downtime. We have included a hypothetical cost estimation (values approximate actual costs) to illustrate the cost-benefit analysis.
<table>
<thead>
<tr>
<th>Without Built-In Flexibility</th>
<th>With Built-In Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and build additional fixtures ($21K).</td>
<td>Build additional fixtures ($20K). No extra design is necessary at this time because we already designed the additional fixture in the initial design phase.</td>
</tr>
<tr>
<td>Stop production for the entire line ($480K).</td>
<td>No disruption to production - addition can be made on weekends or off-shift ($0K).</td>
</tr>
<tr>
<td>Make room for added stations. Possibly knock down and rebuild a wall ($5K).</td>
<td>Space already available for added station ($40K per year).</td>
</tr>
<tr>
<td>Remove and re-locate existing fixtures and weld guns to make room for the new station ($1K).</td>
<td></td>
</tr>
<tr>
<td>Recalibrate all equipment after move.</td>
<td>No recalibration necessary.</td>
</tr>
<tr>
<td>Add new fixtures and weld guns.</td>
<td>Add new fixtures and weld guns.</td>
</tr>
<tr>
<td>Restart production.</td>
<td>No disruption to production.</td>
</tr>
</tbody>
</table>

In the first scenario, the cost (including opportunity cost) of increasing capacity was $507K. An additional fixture had not been designed ahead of time, so there was a $1K penalty for lack of foresight. Production had to be stopped on a high margin item ($3K per vehicle) for two shifts (8 hours per shift). If we assume that the plant was operating at 10 jph before the shutdown, then 160 vehicles were lost during the upgrade. This represented an opportunity cost of $480K ($480K = 2 shifts lost x 8 hours/shift x 10 vehicles/hour x $3K/vehicle). A wall had to be knocked-down and rebuilt to accommodate the new fixture which cost $5K. Since the added fixture was in the middle of the line, all upstream fixtures had to be moved back by 5 m, which cost $1K. In addition, there were quality problems after launch since all fixtures had to be re-calibrated.
In the second scenario where flexibility was anticipated, the capacity expansion required only $60K. The fixture still had to be built, but we had prepared for the design need, thus saving $1K. In anticipation of the expansion, we had left open a “white space” measuring 8m x 5m. It cost us $40K per year to leave that space open (assuming that space costs $1K / m² / year x 40m²). However, no fixtures had to be moved and no production was lost from the expansion.

In this example, the benefit of anticipating capacity growth was worth $447K. We believe that the opportunity cost gained and the quality problems avoided justify the cost of unused space in the body shop if we anticipate demand growth.

7.5. Flexibility - Changeover

Another type of flexibility is the ability to changeover from model years and from pilots with minimal investment cost and time. In this section, we will focus on two methods: quick-change platen gates and standardized base design.

7.5.1. Quick-Change Platen Gates

Quick-change platen gates are a methodology that Toyota uses for fast changeover. Instead of refurbishing the bulk of the fixture, gates can be unscrewed from their fixtures and new gates can be installed. This allows the majority of the fixture to be modified off-line without a disruption of production. This method does require an upfront investment in the tooling.

7.5.2. Standardized Base Design

Thailand has developed standardized hole patterns in the fixture base to which the risers are bolted and doweled in. The commonality reduces complexity. Time for development can be reduced because the base can be built and drilled before the details of the fixtures have been finished. The bottom of the risers will be common so the operator can simplify the machining operation and reduce inventory.
7.6. **Flexibility - Multiple Model**

Multiple model flexibility is the ability to build more than one product in a single body shop. In this section, we will discuss how multiple model flexibility can be accomplished with the following techniques: roll-in/roll-out fixtures, weld gun mobility, flexible assembly flow, flexible subassembly fixture layout, flexible fixture design, and flexible material management.

In high-volume plants where the investment level justifies more sophisticated technologies, we see examples such as sliding gate framers (GM Hamtramack Cadillac Seville and DeVille), Rotating Drums (Opel Antwerp Vectra and Astra), and Carriers/Traveling Jig Pallets (Toyota). At Chrysler Motors de Venezuela (CMdV), we have an existing example of multiple models in a low-volume international plant. CMdV has three separate body shops for the PL, ZJ, and XJ. The body shops do not share equipment or space. While the body shop crew works in one BIW area, the other two areas are “lights-out.”

To illustrate concepts of model flexibility, we will use an example of a very low-volume (less than 5 jph) body shop that can produce both ZJ and XJ (see attached multiple model body shop layout). By combining models in the same body shop, we can share fixtures to save fixture investment, share weld guns to save weld gun investment, and ultimately save space. This section will outline methods such as roll-in/roll-out fixtures, gun mobility, assembly flow, subassembly design, and material handling issues.

7.6.1. **Financial Implications**

In our base scenario, we would build the XJ and ZJ side-by-side on two completely separate assembly lines in the body shop. However, by incorporating the flexibility methods discussed below, we can design a more integrated solution to combining the two models.

By designing a model flexible body shop, we could realize total investment savings of $570 K. If we amortized the savings over three years of production, then we would achieve cost savings of nearly $100 per vehicle.
<table>
<thead>
<tr>
<th></th>
<th>XJ/ZJ Separate</th>
<th>XJ/ZJ Combined</th>
<th>Delta</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Weld Guns</td>
<td>70</td>
<td>48</td>
<td>(22)</td>
<td>($ 550 K)</td>
</tr>
<tr>
<td># of Fixtures (combined T/Over Respot)</td>
<td>30</td>
<td>29</td>
<td>(1)</td>
<td>($ 10 K)</td>
</tr>
<tr>
<td># of Blocks (7mx4.7m)</td>
<td>24</td>
<td>23</td>
<td>(1)</td>
<td>($ 10 K)</td>
</tr>
<tr>
<td>TOTAL COST SAVINGS</td>
<td></td>
<td></td>
<td></td>
<td>($ 570 K)</td>
</tr>
</tbody>
</table>

7.6.2. **Roll-In/Roll-Out Fixtures**

Roll-in/roll-out fixtures have been fitted with casters that allow the fixture to move. This approach has been in existence for more than 50 years. However, the fixtures themselves are now built with superior manufacturing technology. The fixtures are able to maintain dimensional accuracy even after they have been rolled around the body shop.

We have noted many benefits to using roll-in/roll-out fixtures, including:

- *floor space savings in the body shop*: this is especially important in existing body shops where space is constrained. We observed at the Honda Thailand body shop that one fixture was rolled away from the line to a satellite storage area while a second fixture, for a different model, was rolled into the vacated space.

- *fewer weld guns*: one set of weld guns was sufficient to service multiple sets of fixtures.

- *multiple model feasibility in the same body shop*: more than one model production can share the same facilitates and infrastructure. This may improve manufacturing’s ability to meet shifting customer demand patterns.
Before we can implement roll-in/roll-out, we must condition the other parts of the system. The issues of balanced work assignments and material handling will be discussed in subsequent sections.

7.6.3. Weld Gun Mobility

Weld gun mobility provides another method for sharing one set of guns, thereby reducing the total number of guns. Weld gun stations can be designed with enough freedom of motion to access weld spots on adjacent fixtures. In this example, we located the transformers of the guns in the center between the XJ fixture and the ZJ fixture. Guns were hung with rolling stations on an overhead beam. The rolling stations gave a range of motion that allowed us to weld an area on the XJ and its corresponding area on the adjacent ZJ. Long cables, properly balanced on the beam, provided added linear movement. Swing on a boom provided rotational movement.

Figure 7.2: Example of Multiple Model Flexibility Through Weld Gun Mobility
7.6.4. Flexible Assembly Flow

In this example, arrangement of the assembly flow was critical to achieve the model mix with minimal space and weld gun usage (Figure 7.3). Common fixtures were located along the top axis. Front and rear floor subassemblies for the XJ were located to the far right and fed directly to the XJ U/B Station #1 on the right. Front and rear floor subassemblies for the ZJ were located directly below the ZJ U/B Station #1 on the left.

Figure 7.3: Layout of multiple models that do not share fixtures (top) and that do share fixtures (bottom).

Note that by adding multiple model flexibility (bottom), we have reduced the number of fixtures, the number of weld guns, and the space required in the body shop.

The configuration of the toy tab station was critical to the flow of the bodyside apertures. The toy tab station was rotated 90° from the main axis of the line. This allowed the bodyside apertures to be easily brought to position in carts and loaded into the fixture. Without this rotation, then either 1) the B/S stations would have to be located on either side of the main line which could not be accommodated easily given the facility shape
constraint or 2) bodyside assemblies would have to be transported to the other side of the
line which would increase the possibility of damage if they were to bump against the
fixtures or building structures. To move from the toy tab station to the main framer, the
assembly could be rotated 90° with an overhead hoist or with a rotating table.

7.6.5. Flexible Subassembly Fixture Layout
We can take advantage of the multiple models when decreasing the number of
weld guns at the subassembly stations (see Figure 7.4). In the base case scenario, we
have four sets of guns for the right side RH XJ, left side LH XJ, RH ZJ, and LH ZJ. We
can eliminate two sets of guns by combining the right hand sides and combining the left
hand sides. Alternatively, we can eliminate two sets of guns by combining the XJ and
the ZJ. The appropriate method depends on the application. Alternative #2 may be
applicable more often since usually we will use the same type of gun for right and left.
This method was based on a proposal for Thailand.

The following is an example of two alternative station configurations. Notice that
the weld guns have mobility to access both fixtures.

Figure 7.4: Multiple Model Flexibility Through Flexible Subassembly Fixtures
<table>
<thead>
<tr>
<th>Subassembly Configuration</th>
<th>Base Case</th>
<th>Alternative #1</th>
<th>Alternative #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>XJ LH</td>
<td>RH XJ/ZJ combo</td>
<td>XJ RH/LH combo</td>
<td></td>
</tr>
<tr>
<td>XJ RH</td>
<td>LH XJ/ZJ combo</td>
<td>ZJ RH/LH combo</td>
<td></td>
</tr>
<tr>
<td>ZJ LH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZJ RH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W/G Stations</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Conditions</td>
<td>• when we need to protect for volume growth</td>
<td>• only when XJ &amp; ZJ use the same gun type</td>
<td>• only when RH &amp; LH use the same gun type (common occurrence)</td>
</tr>
<tr>
<td>Constraints</td>
<td>• higher capital investment</td>
<td>• may not have two models that use the same gun types</td>
<td>• may become the bottleneck since we need to wait for the gun to finish the LH before we can weld the RH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• may be overcome with simflex station manning (see manpower)</td>
</tr>
</tbody>
</table>

7.6.6. Flexible Fixture Design

Our multiple model flexible body shop example was able to share one fixture, the resbot turnover fixture. This was achieved through a flexible design that can grasp both the XJ or the ZJ. The resbot fixture holds the body at the front end and the back end and rotates it on a trunion. Designed for longest body (ZJ in this case) and anything shorter just requires an extension arm. This fixture design has the added benefit of making welds all over the body visible for final BIW inspection. This fixture design was used by Volvo and Chrysler in TSA Thailand.
7.6.7. **Flexible Material Management**

Material management was critical for proper implementation of a multiple model flexible body shop. Because we are building two models, we needed to have material for both the XJ and ZJ. We can account for this with two different methods:

<table>
<thead>
<tr>
<th>Description</th>
<th>Additional Space on the Line</th>
<th>Batch Build</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Increase the material storage space on the line</td>
<td>• Build only one model at a time</td>
</tr>
<tr>
<td></td>
<td>• Keep material for both models on the line</td>
<td>• Bring only material for that model to the line</td>
</tr>
<tr>
<td>Pros</td>
<td>We can build more than one model at a time</td>
<td>Less waste in inventory</td>
</tr>
<tr>
<td>Cons</td>
<td>More inventory on the line</td>
<td>Less chance for inventory damage</td>
</tr>
</tbody>
</table>

To increase quality and reduce waste, we recommend further investigation into the batch build method in a flexible body shop.

7.7. **Conclusions**

We have examined ways of dealing with quality and flexibility in the body shop. The main quality improvements stem from the people in the assembly plant rather than from the equipment itself. Operators at Steyr undergo extensive training and job rotation. They followed disciplined statistical control and root cause problem analysis. Equipment, including automatic clamping and portable CMM equipment, can also improve quality.

Flexibility should be built into the body shop design at the onset of the program. First, the body shop can be designed for capacity growth flexibility. We presented methods for increasing capacity, elements of flexible design, and an example illustrating the cost benefits. In our example, we illustrated how a flexible body shop saved almost
half a million dollars during capacity expansion. We believe that “white space” can be
justified in the body shop if opportunity costs are considered.

Second, the body shop can be designed for model changeover flexibility. Third,
we illustrated many methods for multiple model flexibility. This could be accomplished
with roll-in/roll-out fixtures, weld gun mobility, flexible assembly flow, flexible
subassembly fixture layout, flexible fixture design, and flexible material management.

We believe that quality and flexibility must be considered at the beginning of the
body shop design process.
8. Detailed Design in the Body Shop

8.1. Overview

In this chapter, we will present the final three phases of body shop design: detailed design, build, and production launch. We will develop evaluation tools for selection of an optimal body shop design. To create these tools, we have modified product development concept selection tools, including Don Clausing’s House of Quality and Pugh charts. We will use Chrysler’s body shop designs to illustrate the use of these evaluation tools.

8.2. Detailed Design

8.2.1. Main Framer Design

The main framer is the fixture where all major subassemblies are joined to produce a body-in-white. This section will examine the detailed design aspects of a main framer. There are two main types of main framers in Chrysler International plants:

- Butterfly Main Framer: gates hinge from the top
- Clamshell Main Framer: gates hinge from the bottom.

Figure 8.1: Clamshell-style Main Framer at Thailand (gates hinge from top)

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Figure 8.2: Butterfly-style Main Framer at Cordoba, Argentina (gates hinge from bottom)

In Figure 8.3, we have diagrammed the differences between a clamshell style main framer and a butterfly style main framer. Difference are highlighted with arrows in the illustration on the right.

Figure 8.3: Schematic Representation of a Clamshell-style(right) and a Butterfly-style (left) Main Framer

The following is a table comparison of the positive aspects of each type of main framer. Reference Main Framer Schematics (Figure 8.3) for a schematic representation of the pros and cons of the framer types.
8.2.2.1. Fixture Design

Fixtures should be designed to avoid operator stress and fatigue. Tool design need not be limited to the X-Y plane. Fixtures can be angled or hinged for easier operator access. Another important ergonomic consideration for the operator is visibility. The operators will have more sensory feedback and thus, higher quality, if they can see where they are to weld. An example is the box for the AN truck. If the box is positioned upside down for framing, then all spots are visible to the operator.

8.2.2.2. Weld Gun Selection

For ideal ergonomics, the weld guns should be light and easy to maneuver. We wish to avoid situations where the operator needs a very long and heavy gun to access an area. Rather than having the operator reaching blindly through a fixture, we would prefer that the part be positioned so that the gun only needs to reach through the sheet metal. We see an example at Steyr where the operator needs a 2’ long gun to reach a spot on the rear quarter outer panel. By positioning the part on its side, we could avoid reaching through the fixture and reduce the gun size.

Dual gun stations are ones in which two weld guns share one transformer and control panel. The main advantage to using a dual station is the savings accrued from eliminating transformers and control panels. The main disadvantage of using dual stations is the ergonomic impact on the operator. When the operator is using one gun, the second gun may swing behind him, thus interfering with his mobility. Dual guns are also heavier and more difficult to balance. In order to realize a savings in weld guns, an alternate solution to dual guns may be to eliminate guns all together by having multiple fixtures share one set of guns.
8.3. **Build and Production Launch**

After detailed design is completed, vendors can build the tools and equipment. Country managers visit the supplier site to try-out and buy-off on the tooling. The tooling is then boxed and transported to the assembly plant. Customs issues during the transport phase can not be ignored. The equipment is then installed, calibrated, and re-tested at the plant. Pilot vehicles are built with the tooling to insure the functionality of the entire system at the plant. These pilot vehicles are not sold to the public. Vehicle 1 launch marks the time at which the first vehicle is produced for sale. Production launch usually starts off slow and ramps up to the full production speed.

8.4. **Concept Selection Tools**

During our design phase, we generated a number of different body shop designs. The following are tools borrowed from product development research that assist the designer to select the optimal body shop layout. These tools include House of Quality and Pugh charts.

8.4.1. **House of Quality**

The House of Quality is a conceptual map that provides the means for interfunctional planning and communications. It is a basic product design tool used in quality function deployment (QFD) management at Toyota, Ford, and General Motors. We have provided a House of Quality for the Brazil body shop design (see Figure 8.5).
The left side of the house is the voice of the customer. In this case, the customer includes many groups, including business planning, IMO, and operations. The top of the house are engineering characteristics. In the center of the house, a relationship is made between the voice of the customer and the engineering characteristics. On the right of the house, we can benchmark competitor designs or we can rate our own designs. The roof represents the trade-off between specifications. For example, there is a benefit to leaving unused space in the body shop so that we can plan for expansion. However, there is an opposing cost for building unused space. We indicate that trade off with a red circle symbols in the roof.

We use the following tools to analyze the trade-offs. In the third right hand column, we rate the relative importance of each customer attribute. In the foundation, we list the current engineering measurements of our design and our benchmarks. Relative importance, technical difficulty, and relative estimated cost are also inserted to focus the trade-off issues.

From the above information, we can set our design targets. Design targets are presented at the bottom of the house. John Hauser and Don Clausing write the following, "In setting targets, it is worth noting that the team should emphasize customer-satisfaction values and not emphasize tolerances. Do not specify "between 6 and 8 foot pounds," but rather say, "7.4 foot-pounds." ... The rhetoric of tolerances encourages drift toward the least costly end of the specification limit and does not reward designs and components whose engineering values closely attain a specific customer-satisfaction target." Now that targets are established, better designs can be generated.

In the end, the House of Quality has allowed us to establish clear relations between customer satisfaction and manufacturing functions.
Figure 8.5: House of Quality - a conceptual map that provides the means for interfunctional planning and communications

8.4.2. Select a Winning Concept

To select a winning concept, we use the following methodology developed by Don Clausing. Choose criteria; form the matrix; clarify the concepts; choose the datum concept; run the matrix; evaluate the ratings; attack the negatives and enhance the positives; enter a new datum and rerun the matrix; plan further work; and iterate to arrive at a winning concept.⁶²
In the first step, the criteria based on the voice of the customer were selected. The criteria were entered into a matrix, named a Pugh chart (see Figure 8.6). A Pugh chart indicates to the team how each concept compares to the customer criteria and to each other. A datum is chosen as a baseline to which other concepts are compared. A comparative evaluation is made of each concept compared to the baseline. Evaluations are rated. However, selections are not chosen based on these quantitative findings alone. That might force us to miss some creative insights from the positive design characteristics. Instead, the team attacks the negatives and enhances the positives for the most promising concepts. New or hybrid concepts are added to the Pugh chart. The matrix is re-evaluated. This methodology is re-iterated until the team arrives at a winning concept.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Concept #1</th>
<th>Concept #2</th>
<th>Concept #3</th>
<th>Concept #4</th>
<th>Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Investment in Tooling</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Small Area of Body Shop</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Flexible Capacity</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>+1</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 8.6: Pugh Chart - a Tool Used to Rate Different Design Concepts*

### 8.5. Conclusion

In this chapter, we have concluded our design methodology with the study of detailed design, build, and production launch. We have introduced tools for design concept targeting and selection. These tools warrant further study by the IMO group. It is still too early to assess the effectiveness of these design principles and tools.
9. Conclusion

One of the goals of the Chrysler Operating System (COS) project was to standardize manufacturing processes. This thesis presented methods for standardizing the transformation of a “greenfield” site into a low-volume international automotive assembly plant. We divided the process into two sections: decision strategy and tactical implementation. The first section studied global strategies, site selection methodologies, and coordination levels in the organization. The second section proposed a methodology for designing the body shop of an assembly plant. The body shop design framework included topics of progress tracking, system level design, quality and flexible design, and detailed design.

9.1. Achievements of the Thesis

The goal of the thesis was to provide a basis of knowledge for future international automotive assembly plants. We provided strategic guidelines to frame the design process. We also provided a standard methodology for designing the body shop. It is still too early to tell whether the project has saved development time and costs. However, there are indications that Chrysler’s adoption of the Gantt chart template and flexible body shop design principles have created efficiencies. We believe that the analysis used in the selection of Chrysler’s site in Brazil will lead to long term competitive advantages.

9.2. Chapter Conclusions

The following is a summary of the conclusions reached in each chapter of the thesis

Chapter 1: introduced the thesis topic and background information.

Chapter 2: presented multiple international strategies of automotive companies. We found that there were both risks and benefits to global expansion. We saw a trend of US business entering the global marketplace. This chapter compared the international strategies of Ford, Toyota, and Chrysler. We found that Chrysler had adopted a
conservative investment strategy that was consistent with their business goals and mode of operation.

**Chapter 3:** presented an approach for international site selection. The site selection methodology was divided into three phases: the strategy phase, the plant and site concept phase, and the final decision phase. In the first phase, we found that the site selection strategy had to be aligned with the overall business and manufacturing strategy. We identified trends in regionalized trading economies, flexible manufacturing networks, competitive environments, market characteristics, political landscape, and risk management that could frame the strategy development.

In the second phase, we proposed guidelines for determining what the plant should look like and how it should be integrated into the site. The plant concept set specifications for the product, production technology, enterprise structure, scale, scope, and supply chain management. We used benchmarking techniques to compare Chrysler's Brazil plant concept with other comparable plants. We found that the concept for the Brazil was competitive in terms of normalized investment and plant area utilization.

In the final phase, we developed a framework to finalize the selection of a site. The first step was the determine the basic quantitative and qualitative variables that characterized the site. We called these the fundamental economic decision criteria. A model was developed to rate sites by their fundamental economics. The model was used on Chrysler's site location decision in Brazil. The results of the analysis favored one site. The analysis process was instrumental in focusing team consensus on the final site.

**Chapter 4:** presented an analysis of the level of coordination in the organization. The concept of coordination was defined, based on the work of Michael Porter. In order to support its international expansion goals, we recommended that Chrysler International increase the level of coordination between its suppliers, domestic plants, and among itself. We found that better coordination could be achieved through greater standardization of facility design, promotion of supply chain management, development of communications infrastructures, standardization of reporting systems, and organization
of coordinated launch teams. Chrysler’s coordination level was compared to that of Intel’s Copy Exactly strategy. We found several areas where Chrysler could learn from the achievements of Intel.

**Chapter 5:** presented a framework for the design process of a body shop. A five-phase methodology was introduced that included the topics of: concept development, system-level design, detailed design, build, and production ramp-up. A Gantt chart template was created for Chrysler. This program management tool was utilized to organize, track, and communicate progress to the manufacturing engineering team.

**Chapter 6:** presented system-level design of the body shop. The design process was divided into three major subsystems: assembly flow, manpower, and facility layout. Design criteria, methodologies, and challenges were defined for each subsystem.

**Chapter 7:** presented quality and flexibility issues involved in the design of a body shop. We identified quality practices instituted at the Chrysler plant in Austria so that they could be disseminated across the rest of the organization. Flexibility in the body shop included the study of demand growth flexibility, multiple model flexibility, and model changeover flexibility.

**Chapter 8:** presented the final three phases of body shop design: detailed design, build, and production launch. The chapter introduced concept selection tools, including House of Quality and Pugh charts, for selection of an optimal body shop design.

### 9.3. Future Research

Chrysler is facing exciting opportunities in the global marketplace. By continuing to develop its International organization, we believe that Chrysler has the potential for success in its expansion of its international operations. Chrysler International is continuing to develop body shop design standards beyond the scope of this thesis.
10. Endnotes


4. Chrysler Speech, October 10, 1996


16. J.A. Byrne, et al.


20. 1996 Toyota Motor Corporation Annual Report. 2.09 million vehicles sold overseas / 4.15 million vehicles sold total = 50%.

21. 1996 Ford Motor Company Annual Report. 2.75 million vehicles sold overseas / 5.65 million vehicles sold total = 41%.

22. 1996 Toyota Motor Corporation Annual Report. 4,800 B ¥ = $44 B, assuming 110 ¥ = $1 USD.


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