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Selecting Appropriate Product Concepts for Manufacture in Developing Countries

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SELECTING APPROPRIATE DESIGN CONCEPTS FOR MANUFACTURE IN DEVELOPING COUNTRIES

by

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ABSTRACT

SELECTING APPROPRIATE DESIGN CONCEPTS FOR

MANUFACTURE IN DEVELOPING COUNTRIES

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There is a noticeable lack of production of indigenously engineered and manufactured products in Less Developed Countries (LDC's). Few products developed in these LDC's could be viable in competitive markets or even sold as components and supplies to other manufacturers of competitive goods. Assuming that these less developed countries do not innovate and manufacture because they cannot, the next logical question to ask is why can they not?

This thesis looks at the problems of manufacture and design in LDC's from the standpoint of Product Development. It begins by looking at development theories, namely top down and bottom up and assessing the difficulties encountered with either approach. It

then looks at literature on product development, covering four areas: Appropriate Technology, Product Development Cycle, QFD, and finally Design for X. These areas are analyzed for their usefulness in solving the development problem.

The environment is considered and a linkage is developed between the Product Development Cycle and the environment. This is found to happen by way of Enterprise Needs which are needs that a product must fulfill to make it a viable option for manufacture.

Finally, a process is outlined and demonstrated to form Enterprise Needs and take them into account within a traditional concept selection process.

Environment was found to play a part in the product development cycle. By clarifying Enterprise Needs as well as Customer Needs or Functional Needs, a more balanced approach can be taken to the concept selection process choosing the best concept, not only for the customer, but for the company as well.

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CHAPTER 1 INTRODUCTION

There is a noticeable lack of production of indigenously engineered products in Less Developed Countries (LDC's). Few products developed in these LDC's could be viable in competitive markets or even sold as components and supplies to other manufacturers of competitive goods.

With little innovation and almost no manufacturing, there exists the perfect atmosphere for larger foreign companies to enter these markets. Entering these markets is particularly attractive to foreign companies because they have only recently begun to be tapped. These environments are usually rich in natural resources and provide cheap labor.

However, while this domination by foreign companies does add to the knowledge base of the LDC, which does help development to some extent, a country can become dependent upon hiring out cheap labor, selling natural resources instead of utilizing them, and using products that they can neither produce nor service. This, unfortunately, usually has the effect of making rich countries richer and keeping poorer countries from progressing.

Assuming that these less developed countries do not innovate and manufacture because they cannot, the next logical question to ask is why can they not?

It is obvious that there is no one answer to this problem. People from many professions, including sociology, education, political science, and history have developed theories on the factors that create the lack of development in these environments. More recently, the engineering field has thrown its lot in with these other fields to not only try and explain this lack of development, but also to reverse the effects.

1.1 Motivation

I had the opportunity to spend a year and a half in the Dominican Republic doing service work. I didn't realize, until that experience, that there were places in the world that didn't have access to the basics: clean drinking water, consistent electricity, and decent medical care.

After getting over my general disgust of the living conditions in which I found myself, I began looking at it from an engineering standpoint and I saw improvements that could be made. I began to wonder why someone hadn't thought about these before. But as I spent more time in the environment, I realized that they probably had--but due to other influencing factors, they couldn't do anything about it.

Since that experience, I have had the opportunity to visit other countries that likewise struggle. I have developed a deep interest in the problems plaguing these nations as well as a sense of responsibility to help improve their situation where I could.

An engineering background and this desire to improve conditions led to the realization that the two seemingly opposite fields of study (social and hard sciences) complement each other rather well in this case. By applying and teaching simple engineering and manufacturing techniques tailored to specific environments (particularly those found in LDC's), problems, social and economical, existing in those countries might be solvable, or at least alleviated somewhat. This led to the development of this thesis.

1.2 Product Development Process

The Product Development Process encompasses all the steps necessary to turn an initial idea into a final product. All companies apply either an implicit or explicit model of the product development process, and while the names of the steps may vary slightly, or the steps might be broken up differently, all processes contain basically the same stages. They are:

1. Ideas or concepts are created to satisfy some anticipated market demand
2. Specifications are developed to which the intended design should adhere.
3. Concepts are produced to satisfy these specifications from overall layout down to subsystems
4. The concepts are differentiated and one is chosen

5. Chosen concept is developed into detailed design
6. Chosen design is proven to function as intended, i.e. it meets the specifications
7. Product is prepared for manufacture and sale

These seven steps are what must happen in order to produce a product. However, since almost all design to date has occurred in well developed environments, i.e., the first world, special environmental needs have not been taken into account in the development of either the process or the products coming out of this process.

Until now, most of the criteria used to select one concept over another have been driven entirely by the customer. Few authors indicate (above a few sentences) certain needs that the company or enterprise might have. So while there has been a methodology created to take into account customer and market needs, none has been written to explicitly account for needs of the enterprise.

As a result, a designer in an LDC, walking through the product development process is at a disadvantage to choose a concept for a product that is both beneficial to the market and to the company, because resources that are readily available to those in the first world are not to those available in an LDC.

By addressing the issue of an appropriate product development process taking into account aspects of the environment where the product is to be created, products and processes can be tailored to be more easily manufactured and sold without compromising the product's ability to compete globally. This can be taken to the extreme in LDC's. By effectively classifying designs and their compatibility in certain environments, patterns associated with manufacturability can be more readily seen and addressed.

1.3 Objective

The goal of this thesis is to make an initial step in the direction of developing product and process design and development approaches for very restrictive environments (such as found in many developing countries). It is hoped that the outcome will help provide engineering designers with motivation and tools to pay more attention to the effects and influences of the conditions and industrial environment where the product they are designing is to be produced.

The specific objective of the thesis is two-fold: first is to understand the potential role of manufacturing in developing economies by reviewing the manufacturing conditions in developing countries and the traditional approaches that have been taken to produce products in those countries; second is to create an approach to selecting a design concept (from a set of existing alternative designs) that would best match the conditions and resources of an enterprise in a specific restrictive environment. The selection process will be in the context of an overall product development process. Although this is but one step in a successful product development process, it will provide important insights into the benefits of such approaches and a model for creating additional steps.

1.4 Overview

This thesis is comprised of eight chapters.

- Chapter 1 serves as the Introduction to this Thesis.
- Chapter 2 covers the background for the thesis. This will include several other schools of thought and other approaches that have previously been made to improve the lives of people in LDC's and encourage their economies.
- Chapter 3 discusses work previously done in Appropriate technology, Product Development, and Design for X.
- Chapter 4 discusses the product development process and how environment is linked to this process.
- Chapter 5 outlines the steps for developing Enterprise Needs and discusses external environmental sensitivity of these needs.
- Chapter 6 provides background for the example that will be used to demonstrate the process outlined in Chapter 5.
- Chapter 7 serves as an example of the process outlined in Chapter 5.
- Chapter 8 makes observations and recommendations about the process laid out and demonstrated in this thesis.

CHAPTER 2 BACKGROUND

This chapter is offered as background to the ever growing problem of underdevelopment in third world countries. It is based on different points of view, gathered from things I have read and classes I have taken as well as personal observations. These different points of view are important to understand the extent of the problem faced by these LDC's and the ongoing struggle to get out of the trap in which they find themselves.

2.1 Development

It is not my intent to paint a gloomy and disheartening picture of impoverishment and unhappiness that is often portrayed on the "Save the Children" commercials. I have been to these places, and while food is sometimes scarce and roofs often leak, happy children run and play much like they do in other parts of the world. Often, people in these situations have never known anything different and therefore are perfectly content with their lives and are accustomed to simply making do with what they have.

In fact, if these countries could remain in this state of greenness, never being influenced at all by the rest of the world, they might do very well forever. However, that would be impossible. Over the past 75 years, the advances made in technology, especially communications, have made the world a much smaller place. It is now not only possible to talk to someone on the other side of the globe, but it is also possible to see them real-time (or nearly so). Where the telephone once was a novelty, it is impossible to imagine life without wearing one strapped to your hip. Technology has plunged all nations into direct contact with each other. Because of television, telephone, the Internet, and travel, people have access to places like never before.

This direct contact with each other has influenced companies in the same way. Where they were once marketing to a small geographical area with similar needs, they are now marketing to the world with very diversified needs. Products from these companies are finding markets that are fascinated with the new technologies but are perhaps not well-equipped to deal with them. Exporting products and technologies such as these into LDC's stifles the development process for two reasons: (1) It does not stimulate innovation by the receiving country and (2) It introduces products that cannot be produced in the country, which encourages importing, which takes money out of the local economy, which, as history has taught us, can have devastating results.

To summarize, the development of the world has exceeded the ability of any one country to remain in a state of isolation. Because of this, LDC's must make an effort to develop in order to survive the next century.

2.1.1 Development Theories

Starting about 25 years ago, the social sciences started studying the industrial and economic development of less developed countries, why it happens the way it does, and what repercussions it has had. In the development of Third World Countries, there are basically two theories: (1) dependency, and (2) imperialism. These theories have been adopted by or scorned by almost every NGO (Non Government Organization) and aid organization in existence.

2.1.1.1 The Dependency Model

Dependency is defined as

> "a situation in which the economy of a certain group of countries is conditioned by the development and expansion of another economy, to which their own [economy] is subjected...an historical condition which shapes a certain structure of the world economy such that it favors some countries to the detriment of others, and limits the development possibilities of the [subordinate] economies..." (Dos Santos, 1968).

In other words, while no economy has ever developed without some influence from the world market, the dependency theory claims that the growth of the dependent economy is a reflex of the expansion of the dominant economies, i.e. foreign needs rather than national needs. (Bodenheimer, 1971).

Dependency does encourage development, but only to the extent that is needed to accomplish the goals of the dominant power.

2.1.1.2 Imperialism

Imperialism h as stemmed from the spread of capitalism and the need of large multinational corporations to control all aspects of the production process. It begins by using cheap labor and finding places to dump their products and progresses to long term planning of the corporation that includes indirectly controlling the decisions of governments to assure continued success. This is done with the help of government agencies working on foreign soil that influence local decisions.

This theory suggests that these corporations are often interested in a limited measure of development to provide a larger market for exports. This is often referred to as "welfare imperialism". Again, foreign needs, or the needs of these large corporations takes precedence over national needs. The development is, in short, fragmented, dependent, and ultimately deceptive. (Bodenheimer, 1971)

Although these two developmental theories are fundamentally different, they have similar results. After years of depending on the U.S. and other well-developed countries to feed them technologies, create jobs, and even influence the government, these countries find themselves immensely under-equipped to handle their own economies alone. Several have employed strategies that encourage the industrialization process, which in turn will have a positive affect on the economy. Some of these strategies are outlined in the next section.

2.2 Industrialization Strategies

There are basically two schools of thought regarding industrialization strategies. These two schools attack the problem of underdevelopment from different ends and rarely, if ever, meet in the middle. They are outlined below.

2.2.1 Top down Industrialization Strategies

The first school of thought involves a top down approach to industrialization. This group focuses mainly on government reform, depending on a trickle down effect to get money and goods into the hands of citizens. This group tends to look at things from a very logical and often economical standpoint, using models that have worked in the past as guides. This group looks at the entire country and works to improve it as a whole.

Proponents of this viewpoint believe that for a country to develop its manufacturing capabilities, it needs to go through a type of industrial revolution. Many different factors influence the length in time of such a revolution. This revolution entails a utilization of the natural resources within a country, the development of infrastructure, and the training or specialization of a work force. The current manufacturing state of a developing country is based upon the level of industrialization the country achieves. Governments directly affect the level of industrialization the country attains by their economic approaches to industrialization.

Peter Dicken, describing the mining and manufacturing activities in Southeast Asia, lists three main types of industrialization strategies governments pursue. These are:

1. The local processing of indigenous raw materials for distribution elsewhere;
2. The local manufacture of products which would typically be imported (import-substitution industrialization) and
3. The attraction of foreign firms for manufacture of products for export-oriented industrialization. (Dwyer, p. 209)

Each individual government controls the type of strategy as well as to which industry it is applied. This decision is based upon population, geographical size, and the volume of indigenous raw materials, as well as the political agenda of the governing body.

2.2.1.1 Local Processing

Extracting local raw materials, processing these materials and distributing these materials, gaining increased revenues from value added processes constitutes the local processing economic strategy. For countries with large geographical areas, plentiful resources or unique materials the local processing of such raw materials is the most viable and economical strategy. Initially, for a country to control the development of its resources, it needs foreign technologies and training.

2.2.1.2 Import-Substitution

Often, to protect domestic industries, countries utilize import substitution. This is usually implemented by way of tariffs, import-blocks in protected industries, and graduated restrictions (where raw materials are allowed, but manufactured parts are not). This strategy, if well balanced, has advantages for indigenous industries. However, if the policy is too restrictive, it could suppress future trans-national developments. Such was the case in Bangladesh, as pointed out by Salim:

> [The import-substituting] industries failed to stand on their own feet and standardize their products, and there was a tendency to overcapitalize the production process...As a result, the [manufacturing] sector remained underdeveloped, bereft of dynamism or any diversification of output, and above all, with a level of output far below its potential. (Salim, 1999)

A well regulated design of import-substitution can not only protect indigenous industries, but can also allow foreign capital and machinery free entrance into the country. This often allows countries to improve their technologies without having to "rediscover the wheel." However, Dicken notes that import-substitution has not been without price. He writes:

> Domestic production of consumer goods, such as processed food, textiles, leather goods, pharmaceuticals and chemicals, grew substantially in most of the South East Asian economies. However, although dependence on the imported consumer goods certainly declined, dependence on the import of intermediate and capital goods--and therefore, on foreign technology and capital--increased. (Dwyer, p. 210)

2.2.1.3 Export-Oriented Industrialization

By far the most extroversive economic policy, export-oriented industrialization relies heavily upon multi-national corporations. Due to its small size, limited resources, and existent infrastructure, Singapore used this strategy for industrialization. Singapore offered various governmental incentives to attract multi-national corporations. Beginning in the 1960's, the Singaporean government has used incentives to attract and keep transnational corporations, such as tax holidays, duty-free industrial sectors and ports, investment allowances, and no policies on indigenous ownership.

A couple of conclusions can be drawn from examples involving all of these strategies. First, they are all extremely dependent upon a functioning and even strong government. Without this, none of the policies work due to instabilities and sudden shifts in power and opinions. Second, no one method has proved to work in all situations. While some have been extremely successful in South East Asia, the case studies show that the same ones have failed miserably in South America.

2.2.2 Bottom Up Industrialization Strategies

In direct contrast to the top down strategy involving the government, there is another, more romantic approach. This approach has grown in recent years and is what is most promoted and catered to in the media. Bottom up approaches are embraced by NGO's (non-government organizations) and other humanitarian groups. It involves helping people in very small groups on the grassroots level (usually a village or small tribe.)

This bottom up approach is much more people oriented, looking at fulfilling basic needs as a primary goal instead of the overall economic well-being of a country. Projects taken on in this area involve digging trenches and wells to allow for irrigation and drinking water, education and literacy, and small (cottage) enterprises. This point of view believes that in order to progress as a people, basic needs must be met. Once this happens, people will have a desire to achieve more, and the economy and progression of industry will be a natural result.

2.2.2.1 Microfinance

Microfinance (also called micro-credit) started with Dr. Mohammed Yunus in 1976 with the establishment of the Grameen Bank. His vision was simple: to throw established banking norms to the wind by lending money only to poorest individuals. Small loans of a few dollars to buy tools to husk rice, to buy a cow or sewing machine or a fishing gear--stepping stone loans--have made a big difference to people's lives. (Bali, 1997) His model has been followed over the years and micro-finance schemes are now operating in many developing countries across Asia, Africa, and Latin America. Their operations emphasize "strategic lending", i.e. lending very small short term loans to very poor micro-entrepreneurs. Loan repayment is guaranteed by group members collectively and access to future credit or loans is contingent on successful repayment. Hence, peer monitoring and the prospect of subsequent larger loans act as strong incentives for repayment. (Osman, 1999)

Microcredit is a subset of the top down point of view which has become rather fashionable in recent years. It consists of lending the poor very small amounts of money needed to start small businesses. These small amounts of money (usually less than $50) are then paid back with interest and counseling and business classes are offered to participants.

According to advocates, microfinance is the key to solving three of the largest problems facing LDC's: advancing women, regenerating environmental resources, and providing sustainable livelihood for all. It is the key because it deals with the development of financial intermediation at the local level in poor and destitute areas. It addresses the institutional problems posed by scores of small and often invisible organizations that intermediate funds within isolated local financial infrastructure. It uses imperfect instruments to fund and guarantee these institutions. (Garson, 1997)

Many microcredit programs have been very successful. The payback rate is around 96% overall and it does better the lives of people who take advantage of it. Microcredit is not yet perpetual or self-sustainable, meaning that due to instabilities in the economies where it is operating and other costs, it cannot be sustained by the interest paid on the money borrowed.

2.2.2.2 Appropriate Technology

Appropriate technology is used widely among NGO's and other humanitarian organizations. Appropriate technology is basically the use of technologies that fit into the environment where they are used. Appropriate technologies are supposed to take into account social and economic views as well as functional and are viewed as a starting place to increase industrialization and development on the grassroots level. Appropriate technology is covered more in depth in Chapter 3.

2.3 Conclusion

This chapter is meant to provide some background in the area of development of the third world. It is important to understand basic developmental theories in order to add to the body of knowledge in any particular area.

As can be seen, there are several theories, each of which have worked in specific situations. Because each has had limited success, it is impossible to judge one above another in an attempt to optimize or develop one that will work in a given environment.

CHAPTER 3 LITERATURE REVIEW

Little or nothing has been written concerning altering design objectives in order to overcome environmental constraints. However, there are areas that contribute to this subject. They are:

- Appropriate Technologies
- Product and Process Design
- QFD (Quality Function Deployment)
- DFX

Because of the breadth of these subjects, they cannot be covered in depth here. However, certain aspects of interest to this thesis will be discussed in each one.

3.1 Appropriate Technologies

Appropriate technology is discussed in this literature review because it offers probably the first attempt to take environment into account in design. While this has probably been done since the beginning of systematic design, it has not been stated implicitly.

The whole idea of appropriate technology is to take the constraints presented by environment into consideration when designing the product.

Much has been written and done in the past 30 years in the area of appropriate technologies. This has been due to basically two influences. First, because of the technology drive and the increasing difference between the haves and the have-nots, especially between countries, there has been a humanitarian effort to try and narrow this gap by helping these LDC's "catch up." Second, with the expansion of the global market, larger companies are realizing their inability to meet the needs of newer markets. As a result, an R&D effort has been started that leans heavily toward appropriate technology to meet these needs.

To date, it is unclear whether Appropriate Technology (AT) is truly effective. It is fairly attractive to NGO's and other humanitarian efforts because it is new and it offers certain benefits that traditional methods do not. Academia views it as a challenge and therefore embraces it to a certain extent. There remains those, however, who do not see it as a benefit, but instead as a fad, and a fairly disruptive one at that.

This section will cover three areas. First, a case will be made in favor of appropriate technology. Second, problems associated with the idea of appropriate technology will be presented. Finally, large movements in appropriate technology will be discussed.

3.1.1 Proponents of Appropriate Technology

In doing this literature review, I came across several authors and developers who have a deep passion for Appropriate Technologies. In his book, *Design for the Real World*, Papanek makes a statement that embodies this passion. I have included it below.

> "I am not necessarily pleading for extraordinary, innovative design for radios, alarm clocks, high-intensity lamps, refrigerators, or whatever; I am just hoping for product statements aesthetically acceptable enough not to conjure up visions of a breadbox raped by a Cadillac in heat. Isn't it too bad that so little design, so few products are really relevant to the needs of mankind? Watching the children of Biafra dying in living color while sipping a frost-beaded martini can be kicks for lots of people, but only until their town starts burning down. To an engaged designer, this way of life, this lack of design, is not acceptable. (Papanek, p. 51, 1971)

In its purest form, appropriate technology is a good idea. AT reflects an approach to technological development, characterized by creative and sound engineering, that recognizes the social, environmental, political, economic, as well as technical aspects of a proposed technological solution to a problem facing society. (Lienhard, 1999)

In essence, AT embodies every issue central to good design: affordable, easy to make, easy to maintain, and at home in local cultures. (Leinhard, 1999) For this reason, engineers as well as developmentalists have jumped on the AT bandwagon, and currently several universities offer engineering degrees with an emphasis in appropriate design.

These technologies are generally on a smaller scale and very affordable. They usually involve areas that deal directly with meeting basic needs, such as waste and water systems, energy conservation, community and shelter design. Occasionally AT ventures into technology assessment and small scale production systems as well.

Beyond the designs provided by AT, there is a feeling of community and humanitarianism that surrounds it. This feeling of community along with the low cost of implementation and the perceived practicality of the end products make them highly accepted among NGO's and other humanitarian organizations.

Some quotes from AT's more staunch supporters can be found below.

- " An appropriate technology is one which, in a sustainable fashion and using locally accessible resources, meets the real and felt needs of individuals and communities without concentrating power in the hands of an elite." Bobby Lambert, RedR
- " An appropriate technology is one which is managed and maintained within the resources of a user community...implicit in this definition is the user community's capacity for dynamic development as opposed to static acceptance." WaterAid.
- " Appropriate technology is technology that most suits the local environment of a given situation, and is compatible with the available human, financial and material resources in a manner that is sustainable." AusAID
- "The most significant aspect of a new age of appropriate technology is to 'invoke', enhance, and rediscover innate, hidden or overly informal or latent local skills and potentials of productivity." Joseph Ben-Dak, Global Technology Group and Principle Advisor, Technology Transfer and Adaption, UNDP

- “Appropriate technology is more about process than about tools. Appropriateness is more likely to result when local people participate in analyzing their own problems and planning their own solutions, and then deliberately choosing technology which is relevant because it comes out of that process.” Koos Nefjes, Oxfam.

3.1.2 Opponents of Appropriate Technology

While NGO’s, humanitarian organizations and academia all applaud AT, there remain skeptics. Most are people who have first-hand experience with the implementation of AT and have seen it fail.

Appropriate technology, through the years, has developed a somewhat negative connotation: labor-intensive, very small-scale technology, deemed appropriate to the conditions prevailing in the Third World by people in the First World. In other words, technology that is not indigenous to an area is developed elsewhere, and then hopefully adapted by LDC’s with the help of people who are not familiar with conditions in those LDC’s.

This lack of understanding and the negative connotation associated with AT often causes the technology to fail, even if the technology itself lives up to expectations. For example, some Englishmen invented a new kind of cooking stove for Kenya. This stove could be made of local clay and used fuel (wood) much more economically than what had been used in the past. They went to Kenya and persuaded the natives to build 250 of them over several years. At the same time a kerosene stove made in Japan was introduced and

10,000 were sold through ordinary commercial channels. The kerosene stove was not made locally, and the fuel had to be imported. The Japanese stove prevailed. Here are some possible reasons for the greater acceptance of the Japanese kerosene stove.

- The Japanese stove was somewhat cheaper
- The Kenyans preferred buying something in a store to attending meetings
- The Japanese stove was advertised
- The appropriate technology publicity struck Kenyans wrong--they did not see themselves as different and therefore a different and what they felt was a lesser technology was unsatisfactory.
- The weakness of underdeveloped countries is mainly the organization of production and distribution. The appropriate technology approach made its demands precisely where society was the weakest. (McCarthy, 1996)

John McCarthy, of Stanford says this:

> My own opinion is that undeveloped countries are almost always better off following models that have been successful elsewhere. The reason is that undeveloped countries are usually weak in people with entrepreneurial and organizing talent. That’s why they are undeveloped. A new technology is always more difficult to introduce than a technology that has been successful elsewhere (McCarthy, 1996)

3.1.3 An Example of Appropriate Technology: The World Car

There is an industry-wide push to make a car that can not only stand up to conditions in LDC’s, but one that can be completely manufactured within the country. This includes making the design much more robust and cutting the number of components from around 5,000 to 500. (Brown, 1999) The world car movement qualifies unequivocably as an appropriate technology.

Several small manufacturers have produced cars that can be put together as kits. Most designs have taken in not only the rougher conditions of the LDC's, but also their lack of service resources, alternate uses (cars in these environments are often used to haul inordinate amounts of everything), and fuel availability.

These differences between the two environments have manifested themselves in the shape and construction of the world car. Most are made with reinforced plastic panels, both for weight and manufacturability (it cuts part count).

To meet price targets, world car makers cannot export vehicles to emerging nations. Tariffs would drive prices too high. Instead, they seek to build or license micro factories to make cars in the countries where they will be sold. Some of these micro factories could be as small as 10,000 square feet, about the size of two basketball courts, and manufacture only one car per day. (Brown, 1999)

Chrysler dedicated an entire team to the design of such a car. Their goal was to make a car that had half the variable cost of a regular compact car and was as easy to assemble as a toy. This team found it "surprisingly tough to force simplicity into [their] planning"--something that engineers were not used to, given the high-tech cars they normally design. This drove the engineers to rethink the entire car-design process from the ground up. (Ashley, 1997)

The interesting thing about this appropriate technology is something that seems to be fairly typical among those working on AT. While the concept itself might be appropriate, the process in achieving the final product is not. The design involves several ideas that could be considered inappropriate. One of the most important aspects for appropriate technology is that it involves the people who will eventually use and service the technology. In Chrysler's case, this did not happen. While they did have overall specs for their world car, it was still designed from a first world perspective. It did, however, serve as a great design experiment and did open up designers' eyes to the differences in designing in different parts of the world.

To sum up, AT has been very helpful in development because it has forced designers to look at a different set of criteria to determine the "goodness" of a design. It has promoted thinking outside of the box and encouraged innovation on a fairly simple level. However, AT almost seems to do more good for the developers than it does for the receivers of the technology. While corporations gain valuable experience in thinking outside of the box and designing for environment, their attitude in design seems to have a "big brother" sort of feel about it that does not appeal to the people for whom the technology was developed, let alone the rest of the world.

3.2 Product Development Process

The economic success of manufacturing firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low cost. Product development is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product. (Ulrich and Eppinger, 1995) In other words, the term product development encompasses all the steps necessary in order to create and distribute a product.

3.2.1 Design Methodology

There are common stages through which nearly all product development efforts must pass because certain activities need to be done. It is impossible to get from an initial idea to a final product efficiently and rigorously without going through concept development, concept selection, and manufacturing stages. The stages common to most development efforts are listed as follows:

1. Initial ideas or concepts are created to satisfy some anticipated market demand
2. Specifications are developed to which the intended design should adhere
3. Concepts are produced to satisfy these specifications from overall layout down to subsystems
4. The concepts are differentiated and one is chosen
5. Chosen concept is developed into detailed design
6. Chosen design is proven to function as intended, i.e. it meets the specifications
7. Product is prepared for manufacture and sale (Bent, 1999)

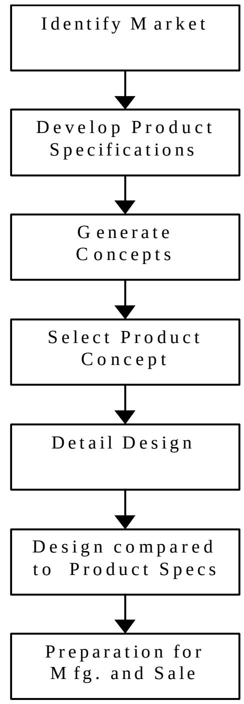

Figure 3.1 *Generic Form of the Product Development Process*

With this outlined, the next sections will introduce the processes of three authors. Rather than discuss the entire process of each author, all of which have similarities, three aspects that are of particular interest will be considered. First, the authors' views on constraints and objectives; second, the process of establishing needs and evaluation criteria; third, concept selection stage of the design process.

3.2.2 Pahl & Beitz

Pahl & Beitz's *Engineering Design* gives a very thorough look at the entire design process. They cover everything from the necessity of systematic design to the thought structures involved in problem solving. Their book is replete with flowcharts and give the impression of taking every bit of creativity out of design. Still, they approach design in a very logical manner, and as a result present some ideas that cannot be found elsewhere in literature.

Pahl & Beitz state that “the solution of technical tasks is determined by the general objectives and constraints.” (Pahl & Beitz, 1996) They recognize that the simple fulfillment of technical function alone is not the only task of designers. Other factors or objectives are definitely taken into account when products are designed and concepts are chosen, such as economic feasibility and concern with environmental and human safety.

They further mention certain constraints that are imposed by the solution of technical tasks. They state that while these constraints are often not specified explicitly, they must nevertheless be taken into account. (Pahl & Beitz, 1996 p. 45) These general or task-specific constraints can be classified under the following headings:

- Safety: also in the wider sense of reliability and availability
- Ergonomics: human-machine context, also aesthetics
- Production: production facilities and type of production
- Quality control: throughout the production process
- Assembly: during and after the production of parts
- Transport: inside and outside the factory
- Operation: intended use, handling
- Maintenance: upkeep, inspection and repair

- Recycling: reuse, reprocess, disposal, final storage
- Expenditure: costs, schedules and deadlines

Pahl & Beitz further explain that it is advisable to consider these constraints and objectives even during the conceptual phase, at least in essence. They become much more important and applicable during the detail design portion of the process and will therefore become more thorough. Pahl & Beitz' flowchart is presented below.

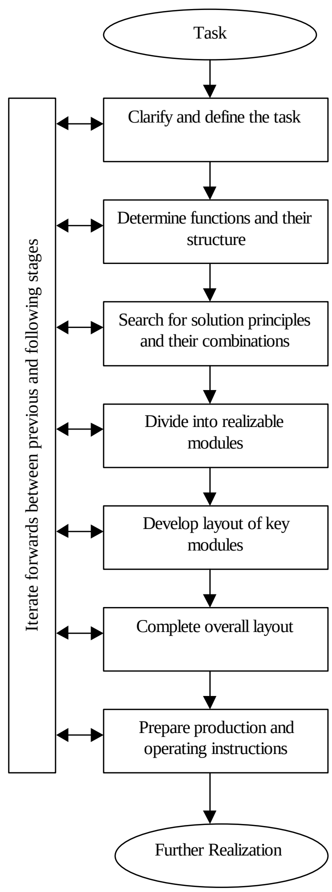

Figure 3.2 *General Approach to Design, adapted from Pahl & Beitz*

Although the same basic steps are followed in Pahl & Beitz, the flowchart has a real engineering flavor. The first thing that is very obvious by looking at this flowchart is the omission of certain aspects of design, namely customer needs and marketing concerns. Pahl & Beitz does not cover the collecting of market information or those steps which must be completed in order to determine specifications. They do, however, mention that consumer criteria are essentially contained in the first five and last four headings of the general or task-specific objectives and constraints. (Pahl & Beitz 1996, p. 178)

Once several concepts are outlined, an evaluation must take place to compare the concepts either to each other or to some ideal imaginary solution. Pahl & Beitz spends significant time on this step although it does not appear in their design flow chart. Below is a summary of this sub-process.

Identifying Evaluation Criteria. The first step in any evaluation is the drawing up of a set of objectives from which evaluation criteria can be derived. In the technical field, such objectives are mainly derived from the requirements list (the minimum that the product must have to be considered a solution; this often also includes a "wish list", (factors that are desirable but not necessary) and from general constraints which are discussed above. A set of objectives usually comprises several elements that not only introduce variety of technical, economic, and safety factors, but also differ greatly in importance. (Pahl & Beitz, p.104)

Weighting Evaluation Criteria. To establish evaluation criteria, we must first assess their relative contribution (weighting) to the overall value of the solution, so that relatively unimportant criteria can be eliminated before the evaluation proper begins. The evaluation criteria retained are given "weighting factors" which must be taken into consideration during the subsequent evaluation step. A weighting factor is a real, positive number. It indicates the relative importance of a particular evaluation criterion. In use value analysis, weightings are based on factors ranging from 0 to 1 (or from 0 to 100). The sum of the factors of all evaluation criteria must be equal to 1 (or 100) so that a percentage weighting can be attached to all the sub-objectives. (P&B, p 106)

Compiling Parameters. Parameters are then chosen for each of the criteria and their weightings. These parameters should either be quantifiable or, if that is impossible, be expressed by statements framed as concretely as possible. These function as target values during assessment.

Assessing Values. The next step is the assessment of values and hence the actual evaluation. These "values" derive from a consideration of the relative scale of the previously determined parameters, and are thus more or less subjective in character. The values are expressed by points. Use-value analysis employs a range from 0 to 4. The advantages of a small scale is that you are often dealing with inadequate information or poorly described characteristics. Rough evaluations are sufficient and may be the only meaningful approach. They involve the following assessments:

1. Far below average
2. Below average
3. Average
4. Above average
5. Far above average

These values are then multiplied by the weighting of each evaluation criteria to give a score or sub-value.

Determining Overall Value. The sub-values for every variant having been determined, the overall value must be calculated. This is done by simply adding the sub-values for each concept. This will give each concept an overall score which then allows concepts to be compared based on the numerical scores.

Pahl & Beitz do an exceptional job of discussing methodology for almost all steps in the entire product development process. While they covered functional specifications and their conversion into evaluation criteria, their discussion on customer needs and company strategy & needs is lacking.

3.2.3 Ulrich & Eppinger

Ulrich & Eppinger spend significant time on the concept development phase but as can be seen by their flowchart spend very little time on the more focused development activities that are applied later in the process. This process is introduced below.

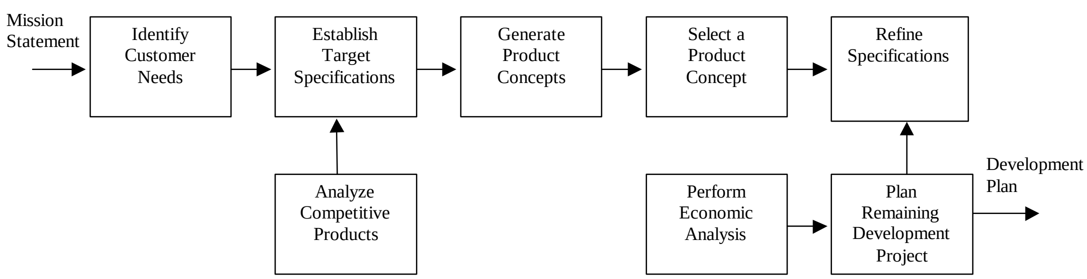

Figure 3.3 *Product Development Process according to Ulrich & Eppinger*

Unlike Pahl & Beitz, this process is very customer driven, basing all of the target specifications and most of the evaluation criteria on customer statements collected at the beginning of the process. This book dedicates an entire chapter to the methodology for comprehensively identifying a set of customer needs.

The philosophy behind this methodology is to create a high-quality information channel that runs directly between customers in the target market and the developers of the product. (Ulrich & Eppinger, 1996) This will allow developers to make educated decisions and trade-offs correctly and in favor of the customer in the chosen target market. A development team should be able to identify these customer needs without knowing if or how it will eventually address those needs. This book outlines 4 steps for obtaining a comprehensive list of customer needs.

1. *Define the scope of the effort.* This includes writing a short description of the product along with any major assumptions made. Stakeholders are identified and a short statement of the key business goals is also written.
2. *Gather raw data from customers.* Information is gathered directly from customers. Three methods that are commonly used are: interviews, focus groups, and observing the product in use.
3. *Interpret raw data in terms of customer needs.* After raw data is collected, it is necessary to interpret customer statements into what the customer actually needs. Below are several guidelines:
   - Express the need in terms of what the product has to do, not in terms of how it might do it.
   - Express the need as specifically as the raw data.
   - Use positive, not negative, phrasing
   - Express the need as an attribute of the product
   - Avoid the words must and should
4. *Organize the needs into a hierarchy.* After step three, there should be anywhere from 50 to 300 needs statements. Working with this many needs can be awkward. This step will organize needs into a hierarchy, with the primary need characterized by a set of secondary and tertiary (if necessary) needs.

After completing these steps, there should be a fairly comprehensive list of customer needs statements, which will serve as evaluation criteria later in the process.

Company goals are mentioned only briefly in this process in the mission statement step. Here, the development team is encouraged to write what they want to accomplish for the company. This, however, is not referred to at all in the development of the process.

Ulrich & Eppinger divide their concept selection stage into two steps, a concept screening and a concept scoring. During concept screening, rough initial concepts are evaluated relative to a common reference concept (a benchmark) using the screening matrix. At this preliminary stage, detailed comparisons are difficult to obtain and may be misleading so a coarse comparative rating system is used. After some alternatives are eliminated, the design team may move on to concept scoring and conduct more detailed analysis and finer quantitative evaluation of the remaining concepts using the scoring matrix as a guide. (Ulrich & Eppinger, p. 112)

Several iterations may be performed with new alternatives arising from the combination of the features of several concepts. Both screening and scoring use a six step process which goes through the concept selection activity. These steps are:

1. Prepare the selection matrix.
2. Rate the concepts
3. Rank the concepts
4. Combine and improve the concepts

5. Select one or more of the concepts

6. Reflect on the results and the process

The matrices are used as visual guides for consensus building among decision-makers. These matrices focus attention upon the customer needs and other decision criteria and on the product concepts for explicit evaluation, improvement and selection. (Ulrich & Eppinger p. 112)

Ulrich & Eppinger are very thorough in their explanation of how to design for customer needs and wants. One thing that is found lacking in this book, however, is an adequate explanation of what other factors besides customer needs drives a product and how these factors affect the concept that is chosen.

3.2.4 Magrab

Edward B. Magrab wrote a book entitled *Integrated Product and Process Design and Development: the product realization process.* The flow chart set forth by this book is shown below.

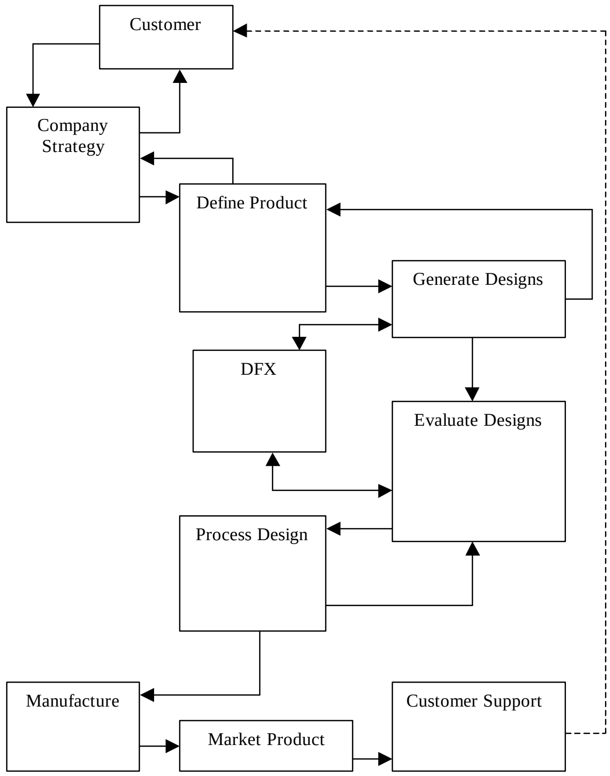

Figure 3.4 *Product Development Cycle adapted from Magrab*

A point of interest on this flow chart as compared to the others is that Magrab allows for a step known as company strategy where the others did not. This step involves substeps directly involved with the company, such as financing, sales, and marketing goals, and schedule.

Magrab does not discuss constraints, per se. He does, however, offer a list of what he calls "components of the product design specifications". A table containing these components can be found below.

Table 3.1 *Components of the Product Design Specifications, adapted from Magrab*

• Performance and features	• Environment on factory floor, packaged, stored, during transportation and use
• Target Cost	• Trademark, brand name, logo
• Benefits	• Testing
• time for product to first reach customer	• Safety
• Customers	• Documentation
• Size	• Quantity
• Shipping	• Life span (planned obsolescence
• Disposal and recycling	• Materials
• Manufacturing facilities, process and capacities: in house, in country	• Ergonomics
• Political, social and legal requirements	• Standards: US & international
• Marketing constraints	• Aesthetics (appearance)
• Weight	• Installation
• Maintenance	• Suppliers
• Competition	• Energy consumption
• Packaging	• Company constraints
• Reliability	• Life in service
• Shelf life	• Product operational costs
	• User Training
	• Patents

Magrab compiled this table from the work of several authors. The unique thing about this table is that it includes constraints and objectives. Magrab offers considerations that should be taken in to account that have not been found elsewhere. Instead of simply considering customer needs and wants, or design specifications, Magrab introduces factors such as political and social requirements, energy consumption, and in-country manufacturing capabilities. Unfortunately, while Magrab did go to the trouble of compiling these considerations, very little is said about them.

Magrab also refers to a table originally authored by J.W. Priest in his book *Engineering Design for Producibility and Reliability*. This table addresses environmental factors that should be considered in determining design specifications. This table is reproduced below.

Table 3.2 *Environmental Factors adapted from Magrab*

Natural Conditions	Induced Conditions
• Clouds and fog • Dew • Frost • Fungus • Humidity: high and low • Ice, snow, sleet and hail • Insects • Ionized gases • Lightning • Pollution: air, water • Pressure: high and low • radiation, electromagnetic • rain and salt spray • Sand and dust • Temperature: high and low • Wind	• Acceleration and deceleration • Corrosive fluids and gases • Electromagnetism • Explosion • Pressure: high and low • Radiation: electromagnetic, nuclear • Radio frequencies • Shock: mechanical, electrical • Temperature: high and low • Vibration: mechanical, acoustic

So, while Magrab does not specifically address business or environmental constraints, he does mention several things that should be considered besides simple customer needs, or engineering specifications.

Magrab also spends time on eliciting and translating customer needs into product specifications and evaluation criteria. The system he outlines closely follows the one outlined by Ulrich & Eppinger but he provides significantly less detail.

For the concept selection stage, Magrab uses a methodology called Quality Function Deployment, which will be discussed in depth in the following section.

This section has given three examples of design and development processes for new products. This is by no means a comprehensive view, but it does allow the reader to see the similarities and differences between approaches taken. These particular authors were chosen because each offers a significant part of information necessary to the completion of this thesis. Pahl & Beitz offers a look at constraints and other considerations in choosing a design that other authors do not touch on. Ulrich and Eppinger offer a very in-depth look at data collection and customer polling that makes their evaluation criteria very complete on the customer level and Magrab offers insight into designing for more than one variable, and taking into account customer, business, and manufacturing needs.

3.3 Quality Function Deployment

QFD (Quality Function Deployment) is a method for structured product planning and development that enables a development team to specify clearly the customer's wants and needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs. (Cohen, p.11)

3.3.1 House of Quality

QFD is a process that involves building matrices. The first of these is called the "House of Quality". This part of QFD is often mistaken for the whole process. It shows the customer's wants and needs along the left and the development teams technical response to meeting those wants and needs along the top. This matrix also consists of several sections joined together in various ways, each containing information related to the others. A diagram of the House of Quality is shown and explained below.

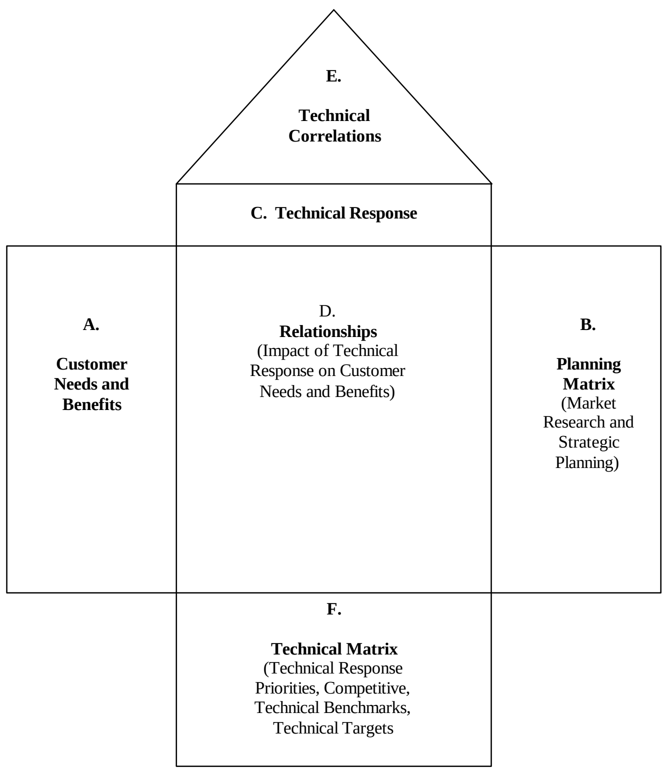

Figure 3.4 *The House of Quality, adapted from Magrab*

- **Section A**, Customer Needs and Benefits, contains a structured list of customer wants and needs. These are usually determined by market research.

- **Section B,** the Planning Matrix, contains three main types of information:
  1. Quantitative market data, indicating the relative importance of the wants and needs to the customer, and the customer's satisfaction levels with the organization's and its competition's current offerings
  2. Strategic goal setting for the new product or service
  3. Computations for rank ordering the customer wants and needs
- **Section C,** Technical Response, contains, in the organization's technical language, a high-level description of the product or service they plan to develop. Normally this technical description is generated (deployed) from the customer's wants and needs in Section A.
- **Section D**, the Relationships Matrix, contains the development team's judgements of the strength of the relationship between each element of their technical response and each customer want and need. More detail about this matrix is included in a later section entitled Prioritization Matrix.
- **Section E**, Technical Correlations, is half of a square matrix, split along its diagonal and rotated 45 degrees. Since it resembles the roof of a house, the term "House of Quality" has been applied to the entire matrix and has become standard designation for the matrix structure. Section E contains the development team's assessments of the implementation interrelationships between elements of the technical response. The correlation matrix is often the last to be filled out. This matrix is used to record the way in which factors either support or impede each other. This information helps QFD teams to identify design bottlenecks, and it helps them to identify key communication paths among designers. Another function of the Technical Correlations is to indicate which teams or individuals must communicate with each other during the development process.
- **Section F** contains three types of information:

1. The computed rank ordering of the technical responses, based on the rank ordering of customer wants and needs from Section B and the relationships in Section D
2. Comparative information on the competition's technical performance
3. Technical performance targets (Cohen, p. 12)

Beyond this structure for the House of Quality, there are several ways to arrange and construct additional matrices that help with decision-making throughout the entire development process. Most authors believe that not taking advantage of the rest of the process and additional matrices severely limits designers. They see the entire process as a way to "deploy the substitute quality characteristics identified at the design stage to the production activities, thereby establishing the necessary control points and check points prior to production start-up." (ReVelle et al p.3) Despite the added benefits, however, the fact is that most developers and designers use QFD only for the House of Quality.Organizational Tools

3.3.2 Organizational Tools

Several tools are available to organize the necessary information into a form suitable for use in the House of Quality or other matrices. These tools are very simply explained below. For a more complete explanation, there are several excellent books on the subject.

- **Affinity Diagram.** An affinity diagram is basically a way to organize customer statements or other data set. It provides a hierarchical structuring of ideas. This hierarchy is built from the bottom up and the relationships between the ideas are based on intuition.

- **Tree Diagram**. The tree diagram is also a hierarchical structure of ideas. Starts with an existing structure such as the hierarchy created by the affinity diagram. It takes the most basic or abstract concept and analyzes it for completeness and correctness. Sub-concepts are added to make it more complete.
- **Matrix Diagram.** A matrix shows interactions between two groups of things. Matrices are used widely in design because they provide an easy and quick way to analyze data. One can tell at a glance whether one concept or idea is affected by another.
- **Prioritization Matrix.** This is an extension of the Matrix Diagram and probably the most prominent part of QFD. This can be seen clearly in the House of Quality diagram above, especially in Sections D and E. This matrix allows the judgement of the relative importance of columns of entries. This is done by entering either numbers (usually 9, 3, or 1) or different symbols into the cells. Traditional QFD practice from Japan uses the symbols

  ✍ , **?** , ?

  and a blank cell to indicate “strong relationship,” “moderate relationship,” “slight or possible relationship,” and “no relationship” respectively. (Cohen, p.61) By assigning different values or levels of importance to the symbols, it is easy to see not only if there is a relationship between two factors, but also how strong that relationship is.

QFD is discussed in this thesis because it offers a fairly complete view on ranking concepts and determining correlations between technical functions. QFD is used widely, and to some extent, the ideas presented by product development authors are adaptations of

QFD. Discussing QFD provides a strong foundation for development of future chapters in this thesis.

3.4 Design For ‘X’

DFX can be defined as a knowledge-based approach that attempts to design products that maximize all desirable characteristics--such as high-quality, reliability, serviceability, safety, user friendliness, environmental friendliness, and short time to market--in a product design while, at the same time, minimizing lifetime costs, including manufacturing costs. (Bralla, p. 23) The X in DFX can have two meanings: X = all the desirable factors that a product should have; and X = excellence and completeness of design.

This subject is covered in this literature review because it takes a more open view of design and tries to find all factors that make a design good, not simply customer needs or manufacturability.

We can say that a limited series of design objectives--function, features, and appearance--even when manufacturability is added, is not enough to provide the best, most competitive design, nor the one that is most economical and beneficial to society over the long run. The designer must design for all worthwhile objectives. DXF is the knowledge-based approach that is intended to provide the designer with a means to achieve all these and other desirable objectives. (Bralla, p. 23)

3.4.1 Basic Principles

As Einstein said, "The best design is the simplest one that works." The simplest design; that is, the one with the fewest number of parts, the most straightforward arrangement, the fewest number of adjustments, the fewest number of interconnections and interdependencies, and the maximum use of modules is the one that is most reliable, least costly, easiest to service and usually the quickest one to market. (Bralla, p. 11)

James G. Bralla, in his book *Design for Excellence,* lists several basic principles that DFM (Design for Manufacturing)/DFX have in common. These are listed below:

- Function and performance
- Safety
- Long-term quality
- Manufacturability
- Environmental friendliness
- Serviceability
- User friendliness
- Appearance
- Features
- Short time to market

Thus, total design entails keeping all of the above principles in mind during all aspects of the product development process. Because it is impossible to choose a design that would involve the very best design for each of the above areas, DFX becomes a complex optimization problem, where the factors are implicitly rated for importance and trade-offs take place.

This idea of optimization is one that should be considered carefully in the work we are undertaking. The ideas of trade-offs is important as we begin to consider not only customer needs and manufacturing requirements, but also enterprise needs and environmental constraints.

3.5 Conclusion

In short, much can be learned from exploring the literature above. While at first blush it appears that none of the subjects discussed above directly relate to environment in the design process, all have added in some way to the overall picture.

The section on Appropriate Technology outlines some challenges and needs of design and production, albeit usually perceived *by* the First World *for* the Third World. Presenting it here makes two points: first, and probably most important, while the problem and most definitely the solution is still nebulous and ill-defined, the developmentalist and the design community have recognized that environment does indeed play a role in how a product is developed and manufactured; secondly, Appropriate Technology supplies us with the first actual examples of designers accounting for environment.

Sections discussing Product and Process design also add to the overall goal of this thesis. Many have written on the design process and how to best bring a product to the market. Three were explored here. All three varied in details, but a well-establish and fairly generic product development process can be seen in all three works. Also, while most authors did not explicitly state the need to design for aspects or characteristics of the environment, they did provide parameters or considerations that dealt with environment, whether they be ergonomics or weather.

Discussion of Quality Function Deployment provided a look at a quite structured and well-accepted process for product development as well as techniques for organization of information. QFD also addressed correlation, or interaction between needs and technical responses.

Finally, Design for ‘X’ was addressed to provide yet another look at a method for emphasizing certain needs in design and optimizing factors to create the best overall design for a specific X.

It is hoped that the exploration of these 4 areas will lead to a more robust process when accounting for environment within the design process.

CHAPTER 4

ENVIRONMENT AND THE DESIGN PROCESS

To this point, this thesis has discussed work that has been done by other researchers in the area of design. The four areas discussed in Chapter 3 were to aid in setting the stage for what is a logical and necessary step in design for environment, especially when the environment is radically different than what has been designed for in the past.

The premise of this thesis is that different designs are better for different settings based on their characteristics. This is particularly important when considering certain limitations imposed by the environment where the design and manufacture of the product is taking place. If the needs of the company are clearly worded and take the environment into account, they can be used in conjunction with Customer Needs to determine a design that is much better suited for development in that particular environment than others considered.

In the first portion of this chapter, environment will be discussed. The rest of this chapter will set the stage for taking the environment into account in the design selection process. This will be done by, first, discussing what is meant by the word *environment*. This will allow a a logical connection to be made between environment and the Product Development Process, the second step in the process; finally, Enterprise Needs will clearly be defined and their origin will be established.

4.1 Environment

Environments vary significantly across the globe, and it is difficult to even find common factors at times. Classifying and comparing those factors is even more challenging. To classify them, all environments need to have similar factors affecting the product development atmosphere. To compare them, all of those factors would have to be quantifiable (which they are not) and then one would have to judge what "good" is in relation to the factor. This would be no problem with respect to some factors, such as infrastructure, etc. but trying to determine if one culture contributes more to a healthy product development atmosphere than another is not only impossible but would also be highly biased and narrow-minded.

4.1.1 Differing Environments

It is important to reiterate here that there are differences in environments. These differences vary in magnitude and nature. Two companies located in the same city and on the same street and developing the same type of product could have two very different environments. This difference could be due to many things, such as equipment, knowledge, work force, etc. If two enterprises so alike have differences in environment, imagine the differences in environment of two completely different enterprises. This can be taken to the extreme by comparing a large corporation in a well developed country with a smaller, locally owned company in a less-developed country.

Chapter 2 gave several viewpoints on development. As mentioned there, most of the research and development done on the Product Development Process has been done in well-developed countries. Although not intentionally, this has established certain goals that have become universally accepted by the world. These goals have spawned other systems and ways of doing things that, while they may function very well in the developed countries, struggle in other parts of the world.

Differences between environments will be found in every situation. In most cases these differences are minimal and can be accounted for easily. In others, where the design environment is radically different, this task is a bit more difficult. These differences in environments will ultimately have an impact on the design and product that a company decides to produce. The linkage between the environment and the Product Development Process is outlined in the 4.2.

4.1.2 Defining Environment for this Thesis

For the purpose of this thesis the environment will be described as physical characteristics that the company does not have control over. This includes things such as the electrical grid, the economy, the cost of capital, etc. While it is understood that all of these can be overcome with money, for the purpose of this thesis it will be assumed that these are to be taken into account when defining Enterprise Needs and subsequently choosing a design (we will design *around* instead of finding a way to correct the percieved problem).

4.2 Environment in the Product Development Process

In order to determine exactly where environmental factors should be considered within the Product Development Process, we return to the generic form of this process introduced in Chapter 3. This process is shown to the right as Figure 4.1. As we discussed earlier, this process contains steps necessary for a product to move from an initial idea to a final product on store shelves.

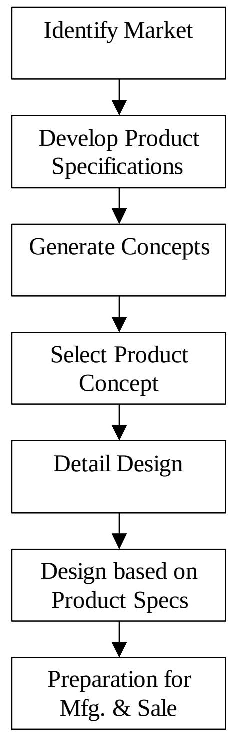

Figure 4.1 *Generic Form of the Product Development Process*

While all are important, and while all are affected on some level by a designing environment (e.g. past experiences with technologies, familiarity with similar products, etc.), one step is particularly subjective to environment. This step is the Product Concept Selection.

4.2.1 Concept and Product Selection

The generic Product Development Process shown above introduces the necessary steps to get product to market, but has very little detail. This section will talk about the importance of the concept selection. This step is a process within itself. This process is shown in Figure 4.2

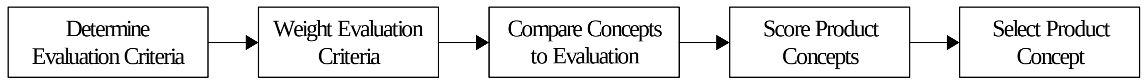

Figure 4.2 *Generic Concept Selection Process*

Most developers and companies rely on the same simple steps with a few deviations to choose a product concept. The steps are outlined briefly below:

- *Determine Evaluation Criteria*. Decide what is important in a design and determine the criteria for which concepts will be judged.
- *Weight Evaluation Criteria*. Clearly, all criteria do not have the same importance. Decide which are more important and weight them accordingly.
- *Compare Concepts to Evaluation Criteria*. This is usually done using a matrix (or House of Quality) because it allows decision-makers a visual representation of all concepts at once. Scores are given to each concept for each Evaluation Criterion.
- *Score Product Concepts*. Assuming a matrix is used, this can be done by adding the columns for each concept. Weightings for each Evaluation Criterion are multiplied by the score received for each concept and they are totaled at the bottom.
- *Select Product Concept*. If the other steps are done properly and without bias, the concept with the highest score is a candidate for the best concept for a given set of Evaluation Criteria.

Of the steps in this process, one concerns us most for this thesis. Namely, Determine Evaluation Criteria. This step will be considered more in depth in the following section.

4.2.2 Determine Evaluation Criteria

Determining Evaluation Criteria is a vital step in selecting a product concept to develop further. In this step, decision makers are allowed to determine what criteria will be used to choose a final concept. Full consideration of all inputs and parties necessary for the production and sale of this product is essential.

From the sources cited in Chapter 3, it is apparent that several factors affect evaluation criteria. These can be divided into three basic groups. These groups and their interactions are shown in Figure 4.3 and discussed below.

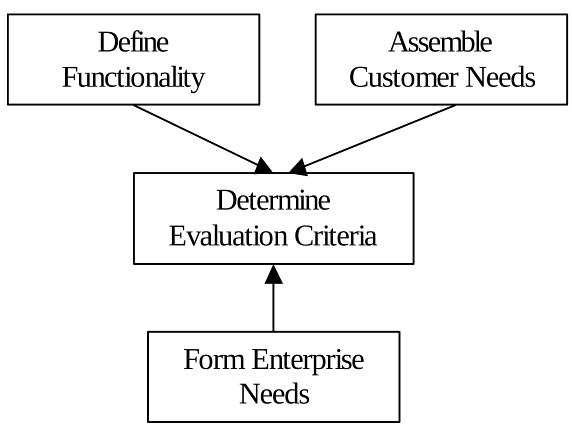

Figure 4.3 *Components of Evaluation Criteria*

- *Functionality*. Functionality includes all characteristics of the product that make it what it is. These are early stabs at engineering specifications and ar often too obvious to be stated. These are not Customer Needs nor are they Enterprise Needs. In the case of snowshoes, a customer will never say that she wants a pair of snowshoes that will distibute weight and keep her above the snow, but she will expect this from any snowshoe. She will also not say that the snowshoes must somehow be fastend to her foot, but to design a snowshoe that cannot be fastend to her foot would be absurd.
- *Customer Needs*. Customer Needs are usually determined by extensive market research. This includes identifying which market the product is being designed for and finding out which characteristics are desirable in a snowshoe. Again, we take the snowshoe example. A customer might say that appearance is very important to him and he wants his snow shoes to be bright colors. He might also say that they should not be heavy or they should be easy to navigate.
- *Enterprise Needs***.** An Enterprise Need is a need that a product must fulfill in order to make it viable for the Enterprise to produce it. For example, if the company producing snowshoes has a limitation on labor, an Enterprise Need might be a requirement for the chosen concept to be produced with highly automated equipment. Enterprise Needs are discussed more fully in the following section.

By developing each of the three categories above, a list of valid and useful Evaluation Criteria can be obtained that will help in the selection of the best design, not only for the customer, but for the company as well.

4.3 Enterprise Needs

As stated above, an Enterprise Need is a need that a product design must fulfill in order to make it viable for the Enterprise to produce it. Enterprise Needs is the category where criteria specific to an enterprise are taken into account. While this subject is hardly touched upon in design and development literature, a few authors do recognize the need for other decision-making criteria that reflect basic business needs and goals. These authors usually describe these goals in monetary terms, such as Return on Investment and Break Even Points.

In the past, Enterprise Needs have not been carefully monitored in the Design Selection portion of the Product Development Process. They are recognized by every designer on some level, but while most companies and designers go through the process of explicitly stating Customer Needs and Functionality requirements, Enterprise Needs are more implicit. Designers are aware of the needs of an enterprise yet these needs are seldom written down or referred to in any sort of formal way.

However, they do have an impact on the decisions that are made within the company. More specifically, these Enterprise Needs have an impact on the decision to produce one design or concept over another. By introducing Enterprise Needs earlier into the Product Development Cycle, a broader and more accurate picture can be obtained by decision makers, which will ultimately result in better decisions for the enterprise.

A good example of this would be up front capital, or the amount of immediate capital needed to produce a particular design. If capital is readily available and inexpensive, a design requiring costly machinery but little assembly might be very attractive to the enterprise. If, on the other hand, capital is not easily attained and is very expensive, a design requiring more assembly and handwork and less money up front may be the more appealing concept.

Up front capital needed is probably never introduced into a design selection matrix. However, designers have an idea of the cost of each, especially in comparison to each other. This implicit knowledge will eventually lead to the choosing of a design that fits the business goals even though the matrix used to select the concept may rate another design higher. So, while capital does not have a *direct* effect on the choice of concept, it does have an *indirect* effect.

4.3.1 Origin of Enterprise Needs

Since Enterprise Needs are seldom explicitly stated, little data is currently available that explains their origin. Figure 4.4 shows a logical process of how Enterprise Needs are attained. A more in depth discussion is given below.

It is logical that an Enterprise Need is based on one of two things: either a restriction or a motivation.

A restriction is exactly as it sounds: a constraint somehow placed upon an enterprise. These can be due to many factors, although most have to do with resource availabil-

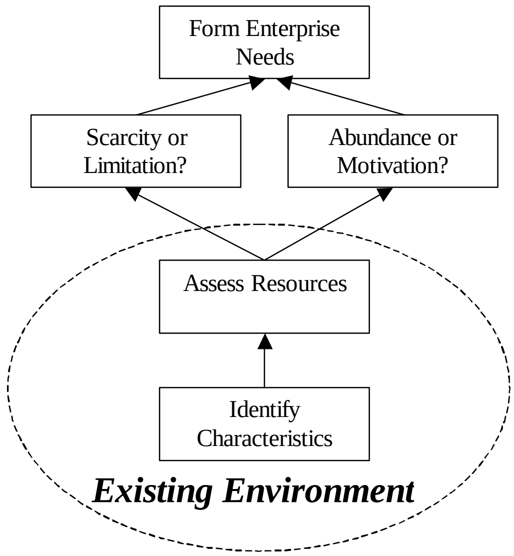

Figure 4.4 *Origin of Enterprise Needs*

ity. For example, if a company has a restriction on the amount of capital available to them, the limitation creates a "need" for the company to develop a product that uses little initial capital.

Likewise, another factor that directly affects Enterprise Needs is a motivation. This can be expressed in terms of an abundance as well. If an enterprise has an abundance of a certain resource, it would be more inclined to choose a concept that heavily utilizes that resource. This abundance makes the use of the resource a need. For example, "Our enterprise *needs* to make use of the three warehouses of suction cups we currently have in inventory."

As shown in Figure 4.4, restrictions and motivations are directly related to the resources available. If there is an abundance of a particular resource, the enterprise may choose to recognize the need to use this resource. If there is a limitation to a particular resource, the enterprise may likewise be compelled to avoid the use of (or find a way around) this resource. Therefore, in order for a resource to even be of concern to an enterprise, there must either be an abundance or a limitation on that resource. Otherwise, it does not come into play.

Without either a motivation or a restriction, there is no reason to deviate from what is currently being produced. These environmental factors will create for the saavy enterprise points of entry into the market--provide them with an “edge”.

Finally, whether a resource is a motivation or a restriction is determined by the environment. This environment can be described as the physical, economical, and social conditions where the product is being designed and produced. This will be discussed further in following chapters.

Figure 4.3 shows the components that make up a set of Evaluation Criteria. If a product is being designed for the global market, Functionality and Customer Needs are not going to change. No matter what the needs of the company, the characteristics of the product that make it function as expected and the needs of the customer will hardly vary at all. However, by taking into account Enterprise Needs (which in turn take into account designing environment) designs and can be chosen that can be more appropriate than others while still fulfilling Customer Needs and Functionality.

Establishing a complete set of Enterprise Needs is key to the success of a project, especially where several restrictions are imposed by the environment. By understanding the origin of Enterprise Needs, the established set will be much more complete and valid. Chapter 5 will address further methods for determining this set.

4.4 Final Linkage

With the origin of Enterprise Needs established, a connection can finally be made between the environment where design is taking place and the actual design process. The entire flow chart is shown opposite in Figure 4.5.

It is interesting to note that while the linkage has been shown between designing environment and the Product Development Process, this does little more than illustrate the theory that environment does have an effect on the process. As designers, we are allowed (and perhaps have the obligation) to determine the extent of the resources available within that environment. Increases in breadth and depth of resources are due to changes within the environment, and while developmental activists and governments have the obligation to work to improve the environment, designers, and this thesis specifically, simply have the obligation to choose the best design for manufacture within the environment.

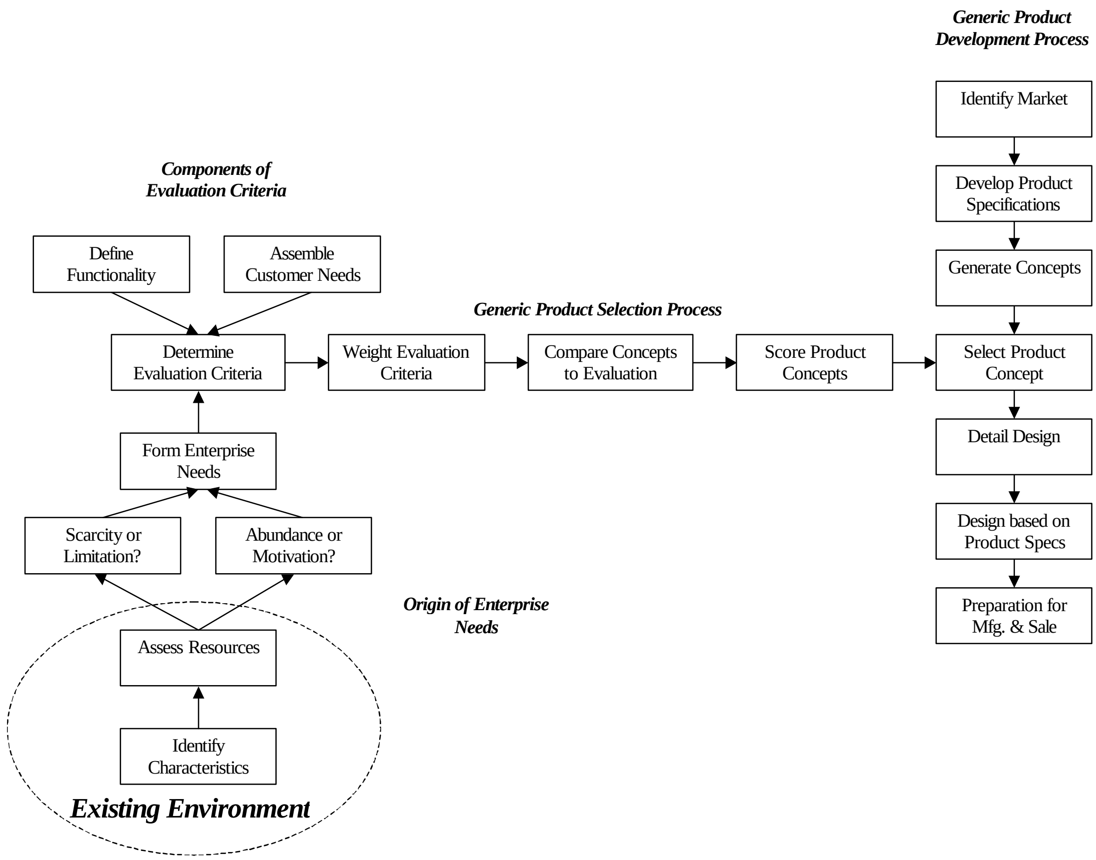

Figure 4.5 *Linkage of Existing Environment with the Product Development Process*

CHAPTER 5 CREATING ENTERPRISE NEEDS

The flowchart that was outlined in Chapter 4 that links the environment to the actual concept selection process is important for two reasons. First, it suggests something that perhaps designers already know but that is often not stated explicitly: the environment in which design and manufacture takes place will have an impact on the concept chosen for production. This is particularly true in less-developed environments. Since less development has taken place in these environments, some characteristics of said environment can have serious effects upon an Enterprise. Second, this logical linking of the environment to the concept selection process will create a framework for designers & manufacturers to account for environmental constraints from the beginning of the process to the end.

This accounting is done via a process that transforms environmental characteristics into Enterprise Needs. These can in turn be taken into account during concept selection. This chapter will outline the development of Enterprise Needs and their use in the concept selection process.

5.1 Creation of Enterprise Needs

The Origin of Enterprise Needs from Chapter 4 (Figure 4.4) is reproduced below. This flow chart ties the environment to the product development process through Enterprise Needs. By climbing up this flowchart, steps naturally fall out that will lead to the creation of Enterprise Needs. These steps are listed below.

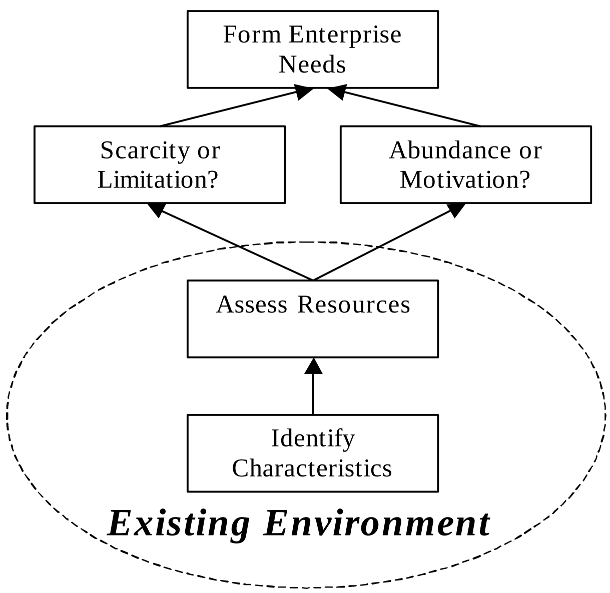

Figure 5.1 *Origin of Enterprise Needs*

1. *Identify characteristics that describe the environment*
2. *Assess the resources & create resource statements*
3. *Evaluate resource statements as either a limitation or a motivation*
4. *Form Enterprise Needs based on evaluation*

The following sections outline these four steps.

5.1.1 Identify Characteristics of the Environment

Earlier in this thesis environment was defined as the characteristics around which the Enterprise would design and manufacture. This definition is important because it allows the Enterprise to define the system in which it exists. Identifying these characteristics allows hard points to be set--aspects that will not change in order to design and manufacture within an environment, but that should still be taken into account when selecting a design concept. Therefore, the first step in developing Enterprise Needs is defining the environment or identifying the characteristics that define the environment.

Two types of environments are outlined below.

5.1.1.1 External Environment

To identify these characteristics, first consider what the Enterprise cannot change. Enterprises are greatly affected by exterior factors over which they have no control or factors that would take large capital outlays to minimize.

Unfortunately, there is not a one-size-fits-all group of characteristics that should be evaluated for all environments. It will be important to the Enterprise to carefully consider the environment in which it resides and to choose characteristics that it assesses will have an overall effect on the production of any product.

The following is a list of environmental characteristics that has been compiled from several sources (no one author utilized a group of characteristics but several considered one or two that should be taken into account when designing) and from observations made during trips to LDC's. It should not be considered complete, by any means, but offers an example of the kinds of things that can be considered characteristics.

- ***Infrastructure.*** Infrastructure is the reliability of systems such as water delivery, electricity, etc.
- ***Economy***. Economy is defined as the system or range of economic activity within a country, region, or community.
- ***Supplier Pool.*** Depth and breadth of raw materials, components, and service suppliers that are available to the enterprise within a given environment.
- ***Technology.*** The amount of manufacturing equipment and people to service that equipment is available and accessible.
- ***Natural Resources.*** Every environment has materials or factors indigenous to the region.
- ***Transportation.*** Transportation refers to the ability to move product to market and supplies within the environment.
- ***Workforce.*** Workforce is described as the availability of workers within the environment. It also describes the characteristics of the workforce.

5.1.1.2 Internal Environment

After considering the things that cannot change, the Enterprise should also consider things that it is not willing to change. Internal Environment is something that is set by the Enterprise itself and can be considered the Enterprise's strategy. Examples of strategies or internal environmental characteristics that the Enterprise may want to maintain include such things as unwillingness to import goods, or the use of existing inventory.

Although identifying environment interior to the Enterprise can prove to be useful, large amounts of cash can overcome most of the constraints that can be found internal to an Enterprise. While this is not always the recommended way (which is why it is mentioned here), the following sections of this chapter and the examples presented in this thesis will focus primarily on external characteristics to emphasize designing *around* the environment instead of over it.

5.1.2 Assess Resources & Write Resource Statements

Once the characteristics that will be used to evaluate the environment are identified, the next step is to assess each characteristic with respect to the environment where the design and the manufacture is taking place. The table below shows the list of generic characteristics discussed in 5.1.1 and some questions that can help to determine the related resources available in the environment.

Table 5.1 *Resource Evaluation Questions*

Characteristics	Resource Determination Questions
Infrastructure	• Is the water reliable? • Is there a good and reliable
Economy	• Is the economy stable? • Is it easy to borrow capital? • What is the inflation rate? • What is the borrowing interest rate?
Supplier Pool	• Are there other manufacturers within the environment that can easily supply the Enterprise with needed goods? • Are there core competencies within the region?
Technology	• How easy is it to obtain the latest technologies? • Can they be serviced within the environment?
Natural Resources	• What are the natural resources in the environment? • Do the resources need refinement and if so, is that done within the environment? • Can these natural resources be used to benefit your business?
Transportation	• Is shipping within the environment reliable? • Is the transportation grid adequate for your needs? • Do routes exist to get supplies into the plant and product to the market?
Workforce	• What is the current workforce like? • Are there workers available within the given environment? • Do they possess skills necessary to support your environment?

This list should be considered a thought-starter for the process of considering the resources available (or not available as the case may be) for the Enterprise's environment. The questions that an Enterprise should ask itself should not be based on an idealistic view of what a perfect designing and manufacturing environment should be, but rather a look how things happen within the environment and how the enterprise is able to react to the characteristics based on its knowledge of the environment. For example, if everyone within the environment is still communicating via Pony Express and everyone with whom the Enterprise will transact business has stables, horses, and riders, evaluating internet usage appears pointless. In short, the Enterprise should evaluate its systems in the environment and how well it is able to transact business with respect to those systems.

When considering each characteristic, resource statements are formed to adequately describe the major points of each characteristic. For example: imagine that an environment has a transportation system with few paved and maintained roads because of terrain but that extensively utilizes waterways and air transport to move goods from one location to another. The resource statements an Enterprise may create could be:

- Minimal & poorly maintained highway system.
- Extensive airstrips and airports
- Well-developed & broad use of waterways to transport goods

Resources statements should be short, concise, and descriptive statements about the environment related to a particular characteristic. The Enterprise should use as many as it feels necessary to give an accurate picture of the environment for that particular characteristic.

Resource statements should also be unambiguous. Since they will later be evaluated as either a limitation or a restriction, only one answer should be correct when the question is asked: “is this resource statement a limitation or a motivation to the Enterprise? If this small test results in more than one answer, the resource statement should be reworded.

5.1.3 Evaluate Resources as Limitations or Motivations

After exploring each of these characteristics with respect to the environment, the next step is to determine whether each created resource statement can be considered a motivation or a limitation. This serves two purposes. First, it provides the Enterprise the opportunity to very clearly see what the effects f a particular resource are. Secondly, it will help later in the formation of Enterprise Needs.

The definitions of limitation and motivation that were discussed in Chapter 4 are reviewed below.

- ***Limitation***: a constraint somehow placed upon an Enterprise. In terms of physical resources, it can also be called a scarcity. There can be a scarcity of workers or a scarcity of copper. However the term limitation refers to anything that the Enterprise feels discourages manufacture.
- ***Motivation***: a wealth of a resource within a given environment. This can also be termed an *abundance* when referring to physical resources. Motivation implies anything that the Enterprise feels urges it toward manufacture.

Assume that an Enterprise has listed “unreliable electricity” under the characteristic Infrastructure. Since reliable electricity is necessary to run quite a few processes within a manufacturing enterprise, this resource statement can be seen by the Enterprise as a limitation.

Again, labeling something as either a motivation or a limitation should not be based on what the Enterprise sees as the ideal situation. Instead, it should be based on its interaction with its own environment.

By assessing each resource or characteristic as either a limitation or motivation, the Enterprise can focus the Enterprise Needs it will create on minimizing the limitations and leveraging the motivations in the environment. This step allows the Enterprise to look at the environmental characteristics that affect it and determine whether the particular characteristics are a help or a hindrance within its particular environment.

5.1.4 Form Enterprise Needs

The final step in forming Enterprise Needs is the actual forming of the need. In order to do this in an organized manner, the use of a matrix is helpful. This matrix is called an Enterprise Needs Creation Matrix and an example matrix is shown below.

Table 5.2 *Enterprise Needs Creation Matrix*

Characteristics	Resource Evaluation	Limitation/ Motivation	Enterprise Needs
Infrastructure			
Economy			
Supplier Pool			
Technology			
Natural Resources			
Transportation			
Workforce			

The left hand column contains the characteristics that define the environment in with the Enterprise resides. The second column contains the resource statements that are used to describe the characteristic within the given environment. The third column indicates whether each resource statement is deemed a limitation or a motivation. The final column is the listing of Enterprise Needs--needs that will be taken into consideration when choosing a design concept.

Enterprise Needs are not created in the same fashion as Customer Needs (as set forth by Ulrich & Eppinger). While Customer Needs can vary in subject and focus, Enterprise Needs are limited to minimizing the effects of the limitations within the environment and maximizing the motivations.

The first three steps of the Creating Enterprise Needs process are: first, identify the characteristics used to evaluate the environment; second, assess the resources in the environment under the characteristics chosen; and third, evaluate each of those resources tied to the characteristics as either a limitation or a motivation.

The final step is to actually write the Enterprise Needs. Enterprise Needs are formed by taking the Resource statements found in the second column and the assessment of either a limitation or motivation found in the third column, and rewording them to form a need. These needs will be placed in the last column of the matrix.

For instance, under Infrastructure, one of the resource statements could be "unreliable electrical grid". Assume that according to column 3, this is seen by the Enterprise as a negative aspect of the environment, or a limitation to the way the Enterprise can do business. Enterprise Needs for the characteristic Infrastructure will include a Need minimizing the use of electricity in the processes used to form the product. The Enterprise Need may read: "Uses processes that minimize the need for electricity". The same sort of Enterprise

Need may be formed for the following resource statement, “Sporadic water delivery”. The Need may read: “Uses processes that minimize dependence on constant water delivery.”

Here is another example: Suppose an Enterprise resides within an environment where there are three observations can be made about the labor force:

- The majority of the workforce is comprised of skilled workers
- Manual labor is expensive
- The unemployment rate is low.

Examples of Enterprise Needs based on these three observations could be

- Utilize skills available from current workforce
- Minimize manual labor.

The wording of Enterprise Needs, while not absolutely critical, can have an effect on the Concept Selection Matrix. Because these Needs will be intermixed with Customer Needs during the evaluation of concepts, they should be similar to Customer Needs in form and length. A few guidelines are listed below:

1. *Write Enterprise Needs in terms of what the product is to accomplish.* While it may at first seem strange to form Enterprise Needs in this way, ultimately, the concepts will be chosen based on how well they are able to fulfill the needs set forth by the Enterprise, both Customer and Enterprise Needs. By writing the needs in terms of what the product will do (or how it will be created), the concept chosen will reflect the fulfillment of the needs.
2. *Write positive Enterprise Needs Statements.* When forming Enterprise Needs, write the statement positively instead of negatively.

Examples are shown below:

Guideline	Right	Wrong
Write Enterprise Needs in terms of what the design is to accomplish	Design minimizes need for constant electricity in manufacture.	Company must use less electricity in manufacture.
Write positive statements	Design maximizes use of manual labor during manufacturing.	Design doesn't use skilled labor in manufacture

Figure 5.2 *Guidelines for Writing Enterprise Needs*

It is important to note that not every resource statement and evaluation of limitation or motivation has a corresponding Enterprise Needs. At times, although a resource statement can be listed as either a motivation or a limitation, no absolute affect will be felt by the Enterprise itself. A culmination of the needs found under a particular characteristic can also result in one Enterprise Need. In the example above, although there are three resource statements for the characteristic Workforce, the affects of those resources were combined to result in two Enterprise Needs, "Utilize skills available from current workforce." and "Minimize manual labor"

In writing the Enterprise Needs, the Enterprise may feel that a few of the resources statements and evaluations appear negligible or unimportant. For example: if a resource statement reads, "Reliable electricity" the evaluation of that resource statement would be as a motivation. But simply because an environment or an Enterprise has constant electricity doesn't necessarily warrant the need of the Enterprise to maximize the use of electricity in the development of the product. However, do not hesitate to write an Enterprise Need to that effect. The importance of this need will be considered as the Enterprise Needs are weighted for evaluation in the concept selection process.

5.2 Concept Selection Process

The entire point of creating Enterprise Needs is to use them to choose a product among a group of products that will be most suitable for a given environment. Most product development processes set forth by literature utilize a concept selection matrix. This section will discuss how a concept selection matrix will be formed and how Enterprise Needs are used within that matrix.

The steps for the concept selection process are as follows:

1. *Establish relative importance of the needs*
2. *Prepare the concept selection matrix*
3. *Rate & Rank the concepts*
4. *Select one or more of the concepts*

5.2.1 Establish Relative Importance of the Needs

Once an Enterprise has formed a viable list of Enterprise Needs, they must be prepared for use in the concept selection process. The first step in this process is to establish the relative importance of the created Enterprise Needs.This relative importance will provide the Enterprise with a clearer view of what their most important priorities are with respect to its environment.

No one but the Enterprise itself can establish its priorities. The following is a process for obtaining relative importance of needs.

5.2.1.1 Arrange the Needs in Order of Importance to the Enterprise

At this point, the Enterprise should arrange their list of Enterprise Needs in order from most important to least important. Unfortunately, this is not an exact science. It is necessary for the Enterprise to use their own judgment in this process. However, if there is a question about which of two needs is more important, the Enterprise should ask itself which of the two, if not met, will cost it the most money.

This should be done for all evaluation criteria that will be entered into the matrix. However, it should be done *separately* for each subset. Enterprise Needs should be ranked within the subset of enterprise needs, Customer Needs should be ranked within the subset of customer needs, etc. This is to avoid confusion in the next step, as explained in section 5.2.1.2.

At this point, the Enterprise should also take a look at the evaluation criteria and take a first cut at deleting those criteria that the Enterprise does not feel should be taken into account. For instance, evaluating whether or not fish is used in a design is probably not useful. Delete criteria that are superfluous and have little to do with the product being evaluated.

5.2.1.2 Determine the Overall Importance of Evaluation Criteria Components.

At this point, the Enterprise will need to determine exactly what components make up the Evaluation Criteria. In Chapter 4, three types of Evaluation Criteria were established, namely, Customer Needs, Functionality Specifications, and Enterprise Needs. If more than one of these components will be used to evaluate the concepts, overall importance of each must be established.

If, for example, an Enterprise finds itself in quite a restrictive environment, Enterprise Needs may have a higher importance, and therefore a higher weighting than Customer Needs. If the market is highly competitive for the chosen product, Customer Needs may be weighted more heavily. If an Enterprise has determined that each of the components is equally important, each will receive 33% of the total score. Whatever the decision on the part of the Enterprise, the total weighting should add up to 100%.

Assigning weightings in this manner avoids imbalance in the process. If no weightings were assigned per the criteria categories, it would be easy to stack the score simply by adding more of one type of evaluation criteria.

5.2.1.3 Assign a weighting to each Need, important needs receiving higher weightings.

With the relative importance of the criteria subsets is established, the Enterprise will assign a weighting to each individual Need based on its importance within its criteria subset. For example, Assume an Enterprise assigns 20% of the total score to Customer Needs, 30% to Enterprise Needs and the remaining 50% to functionality. This would mean that the total of the individual weightings assigned to Enterprise Needs would be 30%.

Once weightings for each of the needs is obtained, they are ready to be entered into a concept selection matrix.

5.2.2 Prepare the Concept Selection Matrix

A concept selection matrix is a matrix that allows an overall view of the products to be compared. They vary in complexity from a simple matrix to evaluate the concepts with respect to customer needs to a complete use of QFD and House of Quality that take into account not only customer needs and technical specifications, but also interactions between those specifications.

For this process, we will use a fairly simple concept selection matrix. An example is shown below in Table 5.5.

Table 5.3 *Example Concept Selection Matrix*

	Evaluation Criteria	Weighting	Concept #1		Concept #2		Concept #3		Concept #4		Concept #5	
1												
2												
3												
4												
5												
6												
7												
8												
	Total											

The organization of this matrix is as follows:

- Concepts are listed along the top of the matrix. Descriptive names should be used to distinguish the concepts.
- Needs are listed down the left side of the matrix. This incorporates needs from all evaluation criteria subsets: Enterprise Needs, Customer Needs, and Functionality Requirements.
- Weightings are listed in the second column as percentages. These are listed here for ease of computation once all concepts have been rated.
- The next columns are divided in two--two columns for each concept. The first column is where the rating of the concept is placed. The second column is where the weighted score is placed. This score is computed by multiplying the weighting by the rating in the first of the concept columns.

Once this matrix filled in with the concepts, the evaluation criteria, and their weightings, the Enterprise is ready to rate the chosen concepts.

5.2.3 Rate & Rank the Concepts

Concepts are rated using a two-step process.

First, concepts receive a score from 1 to 5 on how well the concept fulfills the criterion, 5 being the best. If the criterion is not met at all by the concept, the score is 1. After all concepts receive scores for all criteria, each rating or score is multiplied by the weighting assigned to the need found in the weighting column. This will give a weighted score for each criterion for each concept. Once this is complete, the weighted score column for each concept is totalled.

Once total scores are obtained, the concepts are ranked. This is done by putting the concepts in order by their total scores. The concept with the highest score is 1, the concept with the next highest score is 2, and so on until all concepts receive a rank.

5.2.4 Choose One or More Concepts

After ranking all concepts within the matrix, the Enterprise will have a good idea of which of the proposed concepts best meet the evaluation criteria. Ideally, the concept with the highest scores are the ones that the Enterprise will want to study further.

5.3 Conclusion

This chapter has provided an outline of *how* Enterprise Needs are gleaned from the environment. By assessing the characteristics that define the environment, listing them as either a limitation or a motivation, and then forming positive Enterprise Needs based on that assessment, the Enterprise can include the effects of the environment in the design process, specifically concept selection.

The concept selection process is important in that it provides structure to an otherwise nebulous choice as to what an Enterprise should pursue. By adding the Enterprise Needs into this type of a matrix, a more rounded view is obtained from the process.

The entire process will be demonstrated in Chapter 7 by walking a similar company in three different environments through the Enterprise Needs creation process.

CHAPTER 6 EXAMPLE PRODUCT CONCEPTS & ENVIRONMENTS

Chapter 6 will set the stage by giving background for the product used in the example, product concepts that will be chosen from, and basic descriptions of the environments that will be used to walk through the process of developing Enterprise Needs that was set forth in Chapter 5. The objectives of this chapter are:

1. *Define the product that will be used in the process & describe the proposed product concepts that will be evaluated.*
2. *Briefly provide background for the environments that will be used.*

6.1 Product Description

The product chosen to be used in the exercise of developing Enterprise Needs is snowshoes. The differences in both design and concept of snowshoes, while still providing the same basic function, makes them a reasonable choice for this study. The motivations and limitations available in a given area will drive Enterprise Needs which will in turn drive the choice of one design over another based on the environment while the basic function of the product does not change.

The differences in the snowshoes, assuming that we hold performance constant, is the manner in which the snowshoes are manufactured. The following section will show the 5 designs chosen for evaluation in terms of their compatibility with the design and manufacturing environment. A short description of each concept and the processes used for manufacture are outlined in the following sections.

6.1.1 Design Concept #1: Leather & Wood

Design #1 is made of wood and leather. Wood was soaked and carefully bent into the proper shape for the frame. Two wooden cross bars act to stabilize the fram and allow a pivot point for the foot for easier maneuverability. The weavings and leather attachments were also probably likewise created by hand.

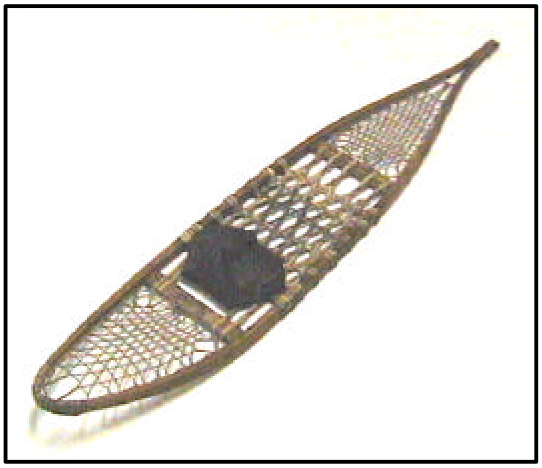

Figure 6.1 *Traditional Snowshow: Leather & Wood*

6.1.2 Design Concept #2: Injection Molded 1 piece

Concept #2 is an example of a one-piece injection molded was injection-molded using a simple mold and plastic. It consists of a plastic base (the actual snow-shoe) and a nylon strapping that serves to keep the snowshoe on the foot of the user.

Figure 6.2 *Injection Molded 1-piece*

6.1.3 Design Concept #3: Aluminum Tubing & Plastic Webbing

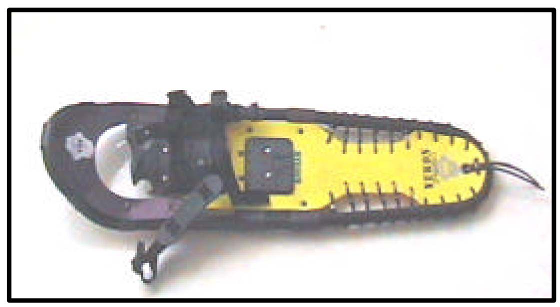

Figure 6.3 *Aluminum Tubing & Plastic Webbing*

Concept #3 (Yellow) appears to be a mix of concepts 1 and 3. Metal tubing makes up the frame of the base--most likely bent into the proper shape using a metal bending machine. The base has been cut from two pieces of thick plastic sheeting and has been attached to the aluminum frame using two methods: around the front half of the snowshoe (the weight-bearing portion) the plastic sheeting has been attached using plastic loops and rivets. The back part of the base is attached to the aluminum tubing using a plastic webbing material. A metal crossbar subassembly consisting of the claw, a metal cross bar with metal loops at each end, the platform for the foot, and the and the webbing needed to attach the snowshoe. This subassembly has been attached to the metal frame using two plastic loops threaded through the metal cross bar & riveted back on itself.

6.1.4 Design Concept #4: Injection Molded w/ Aluminum Tubing

Concept #4 represents an injection molded base with an aluminum frame. The frame has been formed by bending the aluminum frame into shape using a bender. This was then inserted, along with a metal cross bar and a pivoting claw, into a mold for an injection molding machine which created the plastic base of the snowshoe. A plastic platform & claw covering have been riveted onto the claw & crossbar to create the footrest. Nylon webbing and closures keep the foot attached firmly to the plastic footrest.

Figure 6.4 *Injection Molded with Aluminum Tubing*

6.1.5 Design Concept #5: Collapsible Snowshoes

Snowshoe #5 is the most complex design shown. It is made up of two main sub-assemblies and requires user assembly to function properly.

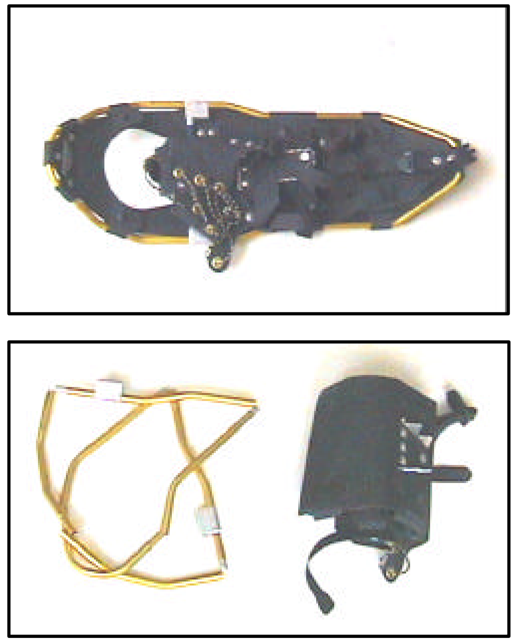

Figure 6.5 *Collapsible Snowshoes*

The first subassembly consists of fitted aluminum tubing held in place by a piece of elastic cord that has been threaded through each tube. These tubes have been bent to the appropriate shape and cut into lengths that allow the snowshoe to be dissembled & folded into a carrying pack. The tubing subassembly also contains two metal “pockets” that allow the base to be assembled to the frame.

The second subassembly makes up the base. It consists of a very heavy piece of cloth cut into the appropriate shape and size to fit the frame. To the center of this base, a metal claw and pivoting foot platform have been attached using heavy rivets. The front portion of this assembly contains a bent piece of metal that fits into the rest of the frame to complete the perimeter. The base is attached to the frame using eight heavy-duty one-way navy snaps and sliding the crossbar into the fittings attached to the frame. Several processes were used in the assembly of this snowshoe; at first blush, a metal bender, welder, riveter, laser cutter along with handwork.

6.2 Environment Descriptions

The environments introduced in this section will be used in subsequent chapters to compare and contrast the development of Enterprise Needs and how they differ based on environmental factors. They are outlined very briefly below. due to organized unions.

6.2.1 Site #1

Site #1 represents a third world environment. This is an environment where no industrial revolution has taken place. There are large barriers to manufacture ranging from poor electricity to intraversible roads. Communications and technology are mediocre at best.

- ***Infrastructure.*** There is no constant and reliable electricity at Site #1. It does go out for hours at a time, sometimes days. Water delivery is also sporadic and not purified.
- ***Economy.*** As mentioned above, Site #1 is largely a hand-to-mouth society. The borrowing interest rate is high and so is inflation, making borrowing capital difficult. The instability of the government has made it difficult to encourage small business growth.
- ***Supplier Pool.*** Few suppliers exist within this environment that supply goods to other companies. The majority of businesses produce end items for public consumption within the immediate environment. There are very few manufacturers.
- ***Technology.*** Because of the poor economy, technologies used within other environments are not easily bought or adopted at Site #1. Lack of education and lack of infrastructure make it difficult to utilize new technologies developed in other environments.

- ***Natural Resources.*** Site #1 is rich in many natural resources including copper, zinc, forrest, and hemp.
- ***Transportation.*** The transportation infrastructure is poor. Few established roads While shipping companies exist, they are very expensive and unreliable.
- ***Workforce.*** Labor is inexpensive and the labor pool is large. Unemployment is high. Lack of education and industry have not encouraged skilled workers.

6.2.2 Site #2

Site #2 represents an environment that has gone through an industrial revolution and has some familiarity with product development. Site #2 has the ability to buy technology and has a fairly easy time adopting it given that the capital is available for such actions.

- ***Infrastructure.*** Adequate water and electricity are available at Site Two.
- ***Economy.*** The economy at Site #2 is stable, due mostly to government intervention. While things such as utilities and mass transportation are federalized, the government encourages growth in the manufacturing sector by offering incentives. Capital is reasonable but not cheap and inflation has a higher than average growth rate.
- ***Supplier Pool.*** Since the government is encouraging manufacture, the small indigenous supplier pool continues to grow. Products offered by these suppliers are more expensive to produce and usually of a lesser quality than those found elsewhere on the world market. However, quality and price continue to improve as experience in manufacture increases.
- ***Technology.*** A large majority of the manufacture at Site #2 is still highly manual. While automated manufacture and robotics are available, they are expen-

sive to obtain and even more expensive to maintain given the origin of this machinery is not indigenous.

- ***Natural Resources.*** Site #2 has many natural resources including rubber, sugar cane, and aluminum.
- ***Transportation.*** The transportation grid at Site #2 is still developing. Although there are roads connecting the major cities, trucking companies are sparse and are often delayed due to the lack of direct routes. Little is shipped on an antiquated railway system.
- ***Workforce.*** Because of the efforts of the government, a greater emphasis is being placed on education. This, coupled with the influx of small businesses in the past decade have led to a pool of skilled workers. While this is true, labor is still fairly cheap.

6.2.3 Site #3

Site #3 represents a well-developed environment, familiar with product development. This environment is also where much innovation takes place. This type of environment is often called a First World Environment.

- ***Infrastructure.*** Adequate and reliable water and electricity are available to Site #3 at all times.
- ***Economy.*** The economy at Site #3 is very good. Inflation is low, the cost of borrowing capital is low, and there is a growth rate in the manufacturing sector.
- ***Supplier Pool.*** Supplier pool is well developed because competition drives prices down and innovation up. Most manufacturing needs can be taken care of in-country and full service supplier help is available to cut down on internal engineering costs.

- ***Technology.*** Manufacturing equipment and people to service that equipment is available and accessible. Because of the innovation taking place in this environment, it is easy to get the latest and greatest manufacturing equipment & technology.
- ***Natural Resources.*** Natural resources available at Site #3 include large quantities of iron ore, oil, forest (wood) and wheat.
- ***Transportation.*** Shipping and transportation are well-established industries and reasonable in price. Roads and highways are in great shape as well as air transport and waterways.
- ***Workforce.*** Workforce in general is skilled. Unemployment rate is low and manual labor is generally quite expensive

6.3 Summary

The purpose of this chapter is to carefully explain the concepts that will be evaluated in Chapter 7. It also provides a picture of the environments that will be used to demonstrate Enterprise Needs creation and evaluate those needs within a Concept Selection Matrix. It was supplied in this chapter to allow easy access during discussion of the example without having to provide extensive background in the midst of attempting to demonstrate a process.

CHAPTER 7

TEST CASE: SITE #1 ENTERPRISE NEEDS FORMATION & CONCEPT SELECTION PROCESS

Chapter 5 defined a method for creating Enterprise Needs. Chapter 7 will present this example by taking the chosen product (snowshoes) and the defined environments (labeled sites in Chapter 6) and walking through the Enterprise Needs Creation Process. The objectives for this Chapter are the following:

1. *Demonstrate Enterprise Need Creation process using one of the Sites introduced in Chapter 6.*
2. *Utilize Enterprise Needs in the concept selection process*

7.1 Enterprise Needs Creation Process

The Enterprise Needs Creation process was introduced in Chapter 5. The purpose of this chapter, and particularly this section, is to take the steps outlined and apply them to specific environments or sites, which were described in some detail in Chapter 6. This will be accomplished by walking through the process using one of the sites. The process will then be repeated for the other two sites and the results will be compared and contrasted in the next section.

As outlined in Chapter 5, there are basically 4 steps to creating Enterprise Needs. These are reviewed below:

1. *Identify characteristics of environment*
2. *Assess the resources in the designing environment*
3. *Evaluate resources as either a limitation or a motivation*
4. *Form Enterprise Needs based on assessment*

The following three sections will walk through the process of creating Enterprise Needs based on Site #1.

7.1.1 Identify the Characteristics of the Environment

As described in Chapter 5, the first step in creating Enterprise Needs is to identify the characteristics that will be used to describe the environment. In this case, the environments have been evaluated based on the observations of the Enterprise and the following characteristics have been chosen to describe the resources of the environment: infrastructure, economy, supplier pool, technology, natural resources, transportation and workforce.

The process will be followed using an Enterprise Needs Matrix. The characteristics chosen have been entered into the first column of the matrix, shown in Table 7.1.

Table 7.1 *Enterprise Needs Matrix: Characteristics*

Characteristic	Resource Statements	Motivation/ Limitation	Enterprise Needs
Communication	•		
Infrastructure	•		
Economy	•		
Supplier Pool	•		
Technology	•		
Natural Resources	•		
Transportation	•		
Workforce	•		

7.1.2 Assess Resources in the Design Environment

The next step is to analyze the environments based on the characteristics chosen to define them. In the case of Site #1, we take a look at the characteristics. The information provided in Chapter 6 on the environments or Sites will serve as our "observations" of the Enterprise. Based on this information, Site #1's infrastructure cannot boast of any reliable or constant electricity. It goes away for hours at a time, and sometimes days. Water delivery is also sporadic and not purified. Resource statements for infrastructure could be: No constant electricity; Sporadic water delivery; Unpurified water; these would be added under infrastructure to the Enterprise Needs Matrix.

For economy, based on the information provided in Chapter 6, the resource statements may be: High borrowing interest rate, High inflation rate, Negative growth rate in manufacturing sector, And so on and so forth, until all of the characteristics and their resources have been evaluated and entered into the matrix. A matrix with the completed resource evaluation column for Site #1 is shown as Table 7.2.

Table 7.2 *Enterprise Needs Matrix: Resource Statements*

Characteristic	Resource Statements	Motivation/ Limitation	Enterprise Needs
Communication	• Limited internet access & use • Good landline telephones		
Infrastructure	• Unreliable electrical grid • Sporadic water delivery • Unpurified water		
Economy	• High inflation rate • High borrowing interest rate • Few small businesses		
Supplier Pool	• Little indigenous mfg of supplies • Mfg. fairly new to area. • Low # of Mfg. suppliers in env. • High costs for value-added supplies		
Technology	• Low adaptation of technologies • Low rate of innovation		
Natural Resources	• Copper • Zinc • Forrest • Cattle		
Transportation	• Poor road conditions • Few shipping companies • Good but not prolific railway system		
Workforce	• High unemployment rate • Large supply of unskilled labor • Small number of skilled laborers • Manual labor generally inexpensive		

7.1.3 Motivation/Limitation

Once clear and concise resource statements are formed and entered into the matrix, each is assessed as either a motivation or a limitation. This should be a fairly quick and painless process if the statements formed to describe the environment were correctly formed. As mentioned in previous chapters, if a resource statement is deemed a motivation, it encourages production; if it is deemed a limitation, it limits production. The Enterprise Needs Matrix for Site #1 is shown in Table 7.3 on the following page with the Motivation/Limitation column filled in.

If there can be more than once ansswer to the question of whether a resource statment indicates a motivaiton or a limitation, the Enterprise should take another shot at forming the resource statements. Each statement should only be able to be answered in one way.

Table 7.3 *Enterprise Needs Matrix: Motivation/Limitation Column*

Characteristic	Resource Statements	Motivation/ Limitation	Enterprise Needs
Communication	• Limited internet access & use	Limitation	
	• Good landline telephones	Motivation	
Infrastructure	• Unreliable electrical grid	Limitation	
	• Sporadic water delivery	Limitation	
	• Unpurified water	Limitation	
Economy	• High inflation rate	Limitation	
	• High borrowing interest rate	Limitation	
	• Few small businesses	Limitation	
Supplier Pool	• Little indigenous mfg of supplies	Limitation	
	• Mfg. fairly new to area.	Limitation	
	• Low # of Mfg. suppliers in env.	Limitation	
	• High costs for value-added supplies	Limitation	
Technology	• Low adaptation of technologies	Limitation	
	• Low rate of innovation	Limitation	
Natural Resources	• Copper	Motivation	
	• Zinc	Motivation	
	• Forrest	Motivation	
	• Cattle	Motivation	
Transportation	• Poor road conditions	Limitation	
	• Few shipping companies	Limitation	
	• Good but not prolific railway system	Limitation	
Workforce	• High unemployment rate	Motivation	
	• Large supply of unskilled labor	Motivation	
	• Small number of skilled laborers	Limitation	
	• Manual labor generally inexpensive	Motivation	

7.1.4 Forming Enterprise Needs

The final step in preparing Enterprise Needs is the actual forming of Enterprise Needs statements from the information in the other columns of the Enterprise Needs Matrix.

This is continued for each resource statement and its corresponding assessment until a list of Enterprise Needs is formed in the right column of the Enterprise Needs Matrix. A complete list for Site #1 is shown below.

Table 7.4 *Enterprise Needs Matrix: Enterprise Needs Column*

Characteristic	Resource Evaluation	Motivation/ Limitation	Enterprise Needs
Infrastructure	• Unreliable electrical grid • Sporadic water delivery • Unpurified water	Limitation Limitation Limitation	• Uses processes that minimize the need for electricity • Uses processes that minimize dependence on constant water delivery. • Water purification irrelevant to design
Economy	• High inflation rate • High borrowing interest rate • Few small businesses	Limitation Limitation Limitation	• Design minimizes up front capital
Supplier Pool	• Little indigenous mfg of supplies • Mfg. fairly new to area. • Low # of Mfg. suppliers in env. • High costs for value-added supplies	Limitation Limitation Limitation Limitation	• Design minimizes the need for value-added goods upstream
Technology	• Low adaptation of technologies • Low rate of innovation	Limitation Limitation	• Design uses indigenous or familiar technologies
Natural Resources	• Copper • Zinc • Forrest • Cattle	Motivation Motivation Motivation Motivation	• Design can utilize copper in design • Design can utilize zinc in design • Design can utilize wood in design • Design can utilize Cow by-products in design.
Transportation	• Poor road conditions • Few shipping companies • Good but not prolific railway system	Limitation Limitation Limitation	• Minimizes supplies shipped into the plant • Minimizes weight and bulk of product shipped to market
Workforce	• High unemployment rate • Large supply of unskilled labor • Small number of skilled laborers • Manual labor generally inexpensive	Motivation Motivation Limitation Motivation	• Design maximizes need for manual labor • Design minimizes need for skilled labor

Once this matrix is complete, the Enterprise Needs can be extracted and used with other evaluation criteria in the concept selection process.

7.2 Concept Selection Process

Chapter defined the concept selection process as follows:

1. *Establish relative importance of the needs*
2. *Prepare the concept selection matrix*
3. *Rate & Rank the concepts*
4. *Select one or more of the concepts*

This section will use the above steps to evaluate the Enterprise Needs created in section 7.3.

7.2.1 Establish Relative Importance of Needs within Subsets

Relative importance of the Needs is established with the following process:

1. *Arrange the Needs in Order of Importance to the Enterprise.*
2. *Determine the Overall Importance of Evaluation Criteria Components*
3. *Assign a weighting to each Need*

These will be followed with data from Site #1.

7.2.1.1 Arrange the Needs in Order of Importance to the Enterprise.

From the Enterprise Needs Matrix for Site #1, there are 15 Enterprise Needs for the seven chosen characteristics, as listed below:

Table 7.5 *Site #1 Enterprise Needs*

Characteristic	Enterprise Needs
Infrastructure	• Uses processes that minimize the need for electricity • Uses processes that minimize dependence on constant water delivery. • Water purification irrelevant to design
Economy	• Design minimizes up front capital
Supplier Pool	• Design minimizes value-added goods upstream
Technology	• Design uses indigenous or familiar technologies
Natural Resources	• Design can utilize copper in design • Design can utilize zinc in design • Design can utilize wood in design • Design can utilize Cow by-products in design.
Transportation	• Minimizes supplies shipped into the plant • Minimizes weight and bulk of product shipped to market
Workforce	• Design maximizes need for manual labor • Design minimizes need for skilled labor

In order of importance to the Enterprise, the Needs are as follows:

Table 7.6 *Relative Importance of Enterprise Needs*

	Enterprise Needs
1	Minimizes the use of up front capital
2	Design maximizes use of manual labor
3	Uses processes that minimize the need for electricity
4	Design uses indigenous or familiar technologies
5	Design minimizes value-added goods upstream
6	Design minimizes need for skilled labor
7	Design can utilize wood
8	Design can utilize cow by-products
9	Design minimizes supplies shipped into the plant
10	Design minimizes weight and bulk of product shipped to market
11	Design uses processes that minimize dependence on constant water delivery
12	Design can utilize copper
13	Design can utilize zinc
14	Water purification irrelevant to design

From this list, the Enterprise has determined that it does not want to consider lines 11-14 in the above list. Therefore, these are deleted from the criteria.

The Enterprise also considers Customer Needs and Functional Specifications. It has determined the following lists for those, respectively.

Table 7.7 *Relative Importance of Functional Needs*

	Functional Needs
1	Must keep User above the Snow
2	Allows foot to pivot for easy walking

Table 7.8 *Relative Importance of Customer Needs*

	Customer Needs
1	Lightweight
2	Convenient to Store
3	Durable
4	Provides good traction
5	Does not slip off foot

7.2.1.2 Determine the Overall Importance of Evaluation Criteria Components

The Enterprise has determined the following breakdown for importance in Evaluation Criteria Components:

Table 7.9 *Site #1 Evaluation Criteria Subset Weightings*

Evaluation Criteria Component	Weighting
Enterprise Needs	50%
Functional Needs	20%
Customer Needs	30%

Enterprise Needs has been deemed the most important of the three subsets of evaluation criteria, and will therefore receive half of the total weighting. Functional Needs will receive 20% of the total, and Customer Needs will make up the difference at 30%.

7.2.1.3 Assign a weighting to each individual Need.

With the relative importance of the criteria subsets is established, the Enterprise will assign a weighting to each individual Need based on its importance within its criteria subset. This is shown in the following table.

Table 7.10 *Evaluation Criteria Weightings*

	Evaluation Criteria	Weightings
1	Minimizes use of upfront capital	12%
2	Maximizes use of manual labor	8%
3	Minimizes need for constant electricity	7%
4	Maximizes use of indigenous or familiar technologies	5%
5	Minimizes value-added goods upstream	5%
6	Minimizes need for skilled labor	3%
7	Utilizes wood in design	3%
8	Utilizes cow byproducts in design	3%
9	Minimizes supplies shipped into the plant	2%
10	Minimizes weight and bulk of product	2%
11	Keeps user above the snow	12%
12	Allows pivot of foot when walking	8%
13	Lightweight	8%
14	Convenient to store	7%
15	Durable	5%
16	Provides good traction	5%
17	Does not slip off foot	5%
	Total	100%

In the above table, Enterprise Needs are represented with lines 1-10 and add to 50% of the total. Functional Needs are represented by lines 11-12 and add to 20% of the total. Finally, Customer Needs are represented by lines 13-17 and add to 30% of the total.

Once weightings for each of the needs is obtained, they are ready to be entered into a concept selection matrix.

7.2.2 Prepare the Concept Selection Matrix

Below is shown the concept selection matrix for Site #1 given the above evaluation criteria and weightings.

Table 7.11 *Site #1 Concept Selection Matrix*

	Evaluation Criteria	Weightings	*Traditional*		*1 pc. Injection Molded*		*Tube frame, plastic weaved*		*Tube Frame, Injection Molded*		*Collapsible*	
1	Minimizes use of upfront capital	12%										
2	Maximizes use of manual labor	8%										
3	Minimizes need for constant electricity	7%										
4	Maximizes use of indigenous or familiar technologies	5%										
5	Minimizes value-added goods upstream	5%										
6	Minimizes need for skilled labor	3%										
7	Utilizes wood in design	3%										
8	Utilizes cow byproducts in design	3%										
9	Minimizes supplies shipped into the plant	2%										
10	Minimizes weight and bulk of product	2%										
11	Keeps user above the snow	12%										
12	Allows pivot of foot when walking	8%										
13	Lightweight	8%										
14	Convenient to store	7%										
15	Durable	5%										
16	Provides good traction	5%										
17	Does not slip off foot	5%										
	Total	100%										

As shown above, all evaluation criteria from the three criteria subsets have been entered into the column on the left. The five snowshoe concepts discussed in Chapter 6 can be found in the top row. The weightings created in the previous step are entered into the weightings column next to their respective criterion.

With the concept selection matrix filled in with the necessary preliminary data, the concepts are prepared for evaluation.

7.2.3 Rate and Rank the Concepts

Again following the process outlined in Chapter 5, an evaluation of the snowshoe concepts was performed. Using a scale of 0 to 3, 3 being the best fit, the concepts were rated based on the evaluation criteria. Once these ratings were obtained, each rating was multiplied by its respective weighting to get a final weighted score. These scores were then totaled for each of the concepts. The completed matrix is shown below.

Table 7.12 *Site #1: Completed Concept Selection Matrix*

	Enterprise Needs	Weightings	*Traditional*		*1 pc. Injection Molded*		*Tube frame, plastic weaved*		*Tube Frame, Injection Molded*		*Collapsible*	
1	Minimizes use of upfront capital	12%	3	0.36	1	0.12	1	0.12	1	0.12	2	0.24
2	Maximizes use of manual labor	8%	3	0.24	1	0.08	2	0.16	1	0.08	2	0.16
3	Minimizes need for constant electricity	7%	3	0.21	1	0.07	2	0.14	1	0.07	2	0.14
4	Maximizes use of indigenous or familiar technologies	5%	3	0.15	1	0.05	2	0.1	1	0.05	2	0.1
5	Minimizes value-added goods upstream	5%	2	0.1	2	0.1	2	0.1	1	0.05	1	0.05
6	Minimizes need for skilled labor	3%	2	0.06	3	0.09	1	0.03	1	0.03	1	0.03
7	Utilizes wood in design	3%	3	0.09	0	0	0	0	0	0	0	0
8	Utilizes cow byproducts in design	3%	3	0.09	1	0.03	1	0.03	1	0.03	1	0.03
9	Minimizes supplies shipped into the plant	2%	2	0.04	1	0.02	1	0.02	1	0.02	1	0.02
10	Minimizes weight and bulk of product	2%	1	0.02	3	0.06	1	0.02	1	0.02	2	0.04
11	Keeps user above the snow	12%	3	0.36	1	0.12	3	0.36	3	0.36	3	0.36
12	Allows pivot of foot when walking	8%	2	0.16	0	0	3	0.24	3	0.24	3	0.24
13	Lightweight	8%	1	0.08	3	0.24	2	0.16	2	0.16	2	0.16
14	Convenient to store	7%	1	0.07	3	0.21	2	0.14	2	0.14	3	0.21
15	Durable	5%	2	0.1	1	0.05	3	0.15	3	0.15	2	0.1
16	Provides good traction	5%	2	0.1	2	0.1	3	0.15	3	0.15	3	0.15
17	Does not slip off foot	5%	2	0.1	1	0.05	3	0.15	3	0.15	2	0.1
	Total	100%		**2.33**		**1.39**		**2.07**		**1.82**		**2.13**

According to this matrix, taking into account Customer Needs, Enterprise Needs, and Functional Needs as Evaluation Criteria, the Traditional Concepts receives the highest score. The ranking of the concepts and their respective scores are found below in Table 7.12.

Table 7.13 *Concept Rankings, Site #1*

Concept	Score	Rank
Traditional	**2.33**	**1**
Collapsible	**2.13**	**2**
Tube Frame, Plastic Weave	**2.07**	**3**
Tube Frame, Injection Molded	**1.82**	**4**
1-Piece Injection Molded	**1.39**	**5**

7.2.4 Choose One or More Concepts

From the scores and rankings above, this Enterprise should consider looking further into the traditional and the collapsible snowshoe concepts.

7.3 Site Comparisons & Insights

For the purpose of comparison, the process above was repeated for the other two environments (Sites #2 & #3) described in Chapter 6.

This thesis focuses mainly on accounting for the Environment in the Product Development Process, which is done by way of Enterprise Needs. Functional and Customer Needs were added to Site #1 to demonstrate the process. For this section, however, we will assume that these needs are held constant across environments and can therefore be neglected.

This section will compare the results of the concept selection process across environments to demonstrate the role environment plays.

7.3.1 Enterprise Needs Weighting Comparison

First, the Enterprise Needs Weightings generated for Sites #1, 2, and 3 are compared and contrasted. They are reproduced below in Tables 7.14, 7.15, and 7.16 for ease of assessment.

Table 7.14 *Site #2 Enterprise Needs*

	Enterprise Needs
1	Design maximizes indigenous technologies
2	Design utilizes regional core competency in textiles
3	Design minimizes up front capital
4	Design maximizes the use of manual labor
5	Design utilizes rubber
6	Design utilizes silver
7	Design utilizes sugar cane
8	Design is not bulky & is easily shipped
9	Design minimizes reliance on refined natural resources

Table 7.15 *Site #3 Enterprise Needs*

	Enterprise Needs
1	Design minimizes use of manual labor in manufacture
2	Design can utilize aluminum
3	Design can utilize latest technology
4	Design utilizes skilled labor in environment
5	Design utilizes supplies manufactured within current environment
6	Design utilizes up front capital
7	Design is light and non bulky for shipping
8	Design can utilize iron ore
9	Design can utilize wood

Table 7.16 *Site #1 Enterprise Needs*

	Enterprise Needs
1	Minimizes the use of up front capital
2	Design maximizes use of manual labor
3	Uses processes that minimize the need for constant electricity
4	Design uses indigenous or familiar technologies
5	Design minimizes value-added goods upstream
6	Design minimizes need for skilled labor
7	Design can utilize wood
8	Design can utilize cow by-products
9	Design minimizes supplies shipped into the plant
10	Design minimizes weight and bulk of product shipped to market
11	Design uses processes that minimize dependence on constant water delivery
12	Design can utilize copper

By comparing these three tables a few points can be made:

Different needs were created for the different environments. Even though all three used the same characteristics to describe their environments, the resource statements (see Appendix A & B for Site #1 & 2 resource statements) and consequently the Enterprise Needs vary.

The importance of the Need will vary based on the Environment. While Sites #1 and #2 both listed the Need to minimize up front capital, Site #1 prioritized it as their #1 Need and thus assigned it the highest rating. Site #2, on the other hand, while understanding this Need to be important, listed it as #3 in their hierarchy and assigned it a lower rating. This ultimately affected the outcome of the Concept Selection Matrix. The same thing happened with electricity. While Site #1 listed it as important to avoid electricity in manufacuring processes, Sites #2 and #3 both listed them as such low priorities that they didn't even receive a weighting, thus excluding it from the Concept Selection Matrix.

Finally, wording of the Need, while subtle, can change the way that the Need is evaluated within the matrix. All Sites used up front capital as a descriptor of their environment. Since Sites #1 & #3 have different levels of difficulty obtaining capital, the wording of the needs varies slightly. For example, Site #1 clearly states that it wants to *minimize* the use of capital. Site #3 states a need that allows it to *utilize* up front capital. It is interesting to note that the Enterprise Needs toward the beginning of the hierarchy use words like *minimize* and *maximize* and toward the bottom of the hierarchy, the word *utilize* is more often used.

7.3.2 Concept Selection Matrix Comparison

Concept Selection Matrices were also generated for Sites #2 & #3. This section compares their results. For ease, the results of the Concept Scoring Matrices have been summarized into the following table. For the complete matrices for Sites #1 and #2, see Appendices A and B respectively.

Table 7.17 *Enterprise Needs Concept Selection Comparison*

	Traditional	*1 pc. Injection Molded*	*Tube frame, plastic weaved*	*Tube Frame, Injection Molded*	*Collapsible*
Site #1	**2.75**	**1.2**	**1.5**	**0.95**	**1.7**
Site #2	**1.7**	**1.15**	**1.15**	**0.75**	**1.7**
Site #3	**0.94**	**2.1**	**1.91**	**2.68**	**1.88**

The following conclusions can be drawn from the chart above.

Based on the Needs and their weightings, the concepts scored as indicated above. The overall best concept for Site #1 (as indicated earlier in this chapter) is the traditional concept using wood and leather. For Site #2, the matrix indicates that two concepts scored the same: The traditional concept and the collapsible concept. For Site #3, The fourth concept using injection molding with a bent aluminum frame.

The table above shows intuitively what is expected. Site #1, a developing environment, shows a traditional snowshoe as the most suitable concept. This is what can be seen in developing countries--strong use of manual labor, not much large and expensive equipment. Site #3 also shows what is expected. Site #3 is a prosperous and well developed environment. Manual labor is expensive; up front capital is not hard to get. Therefore, a concept that uses automated machinery is the most suitable for this environment.

7.4 Conclusions

Some interesting points can be drawn from above. First and foremost, the process of creating Enterprise Needs is feasible. Entering those needs into a concept selection matrix is also feasible. Through this process, a product concept can be chosen that is most compatible to be manufactured within a given environment.

A couple of observations: first, Enterprise Needs are most easily written for environments that boast dramatic characteristics. It was much easier to write Enterprise Needs for Site #1 where there were very definite hard points that needed to be worked around. As a contrast, it was challenging to write Enterprise Needs for Site #3, where many of the resource statements did not lead to maximizing or minimizing any limitation or motivation.

Second, for Site #1, the spread between the concept scoring the highest and the concept scoring the lowest was quite large. It was not quite so large for the other two Sites, although Site #3 had the second highest score. More research would have to be done to determine the exact cause, however, at first blush it appears that Enterprises in Environments with definite and immovable hard rocks will result in more definite results.

CHAPTER 8 CONCLUSION

The goal of this thesis was to make an initial step in the direction of developing product and process design and development approaches for very restrictive environments (such as found in many developing countries). It is hoped that the outcomes of this thesis will help provide engineering designers with motivation and tools to pay more attention to the effects and influences of the conditions and industrial environment where the product they are designing is to be produced.

8.1 Existing Theories and Literature

One of the objectives of this thesis was to better understand, from existing literature and personal observations, the role of design and manufacturing in developing economies and the traditional approaches that have been taken to produce goods within those environments. From the basic top-down and bottom-up approaches looked at in Chapter 2 of this thesis it is obvious that neither approach has been successful. Top down approaches rely too heavily on stable governments in a part of the world where stability is difficult to find. Bottom up approaches address the needs of the individual for a time but do not encourage trade outside the immediate environment and therefore do not foster long-term growth.

Also, from the literature, it is clear that the product development community does not take environment into account--that most assume a well-developed environment because that is where most innovation takes place. This is valid; it also contributes to the problem at hand. As demonstrated by those who have attempted Appropriate Technologies, using a product development process that does not account for very real and immovable constraints inhibits small enterprises within LDC's from correctly assessing what the hard rocks are. For small manufacturers in this type of environment, Customer Needs are not the only evaluation criteria that must be assessed in order to develop a viable product.

In short, a chasm exists between the developmentalists and their ultimate goal for economic and technological growth in Latin America. That chasm can be bridged by the product development community.

8.2 Enterprise Needs Development

The other objective of this thesis was to create an approach to selecting a design concept (from a set of existing alternative designs) that would best match the conditions and resources of an enterprise in a specific restrictive environment.

Since environment is known to play a part in what eventually gets produced by a company it made sense that it could somehow be linked into and accounted for within the product development cycle. Enter Enterprise Needs. Through Enterprise Needs, the constraints placed upon the Enterprise by the Environment can be accounted for. What's more, the creation of Enterprise Needs offer the Enterprise the opportunity to fully assess the environment for limitations *and* motivations, thereby allowing it to minimize the former while maximizing the latter.

8.2.1 Linking Environment to Product Development Process

In the literature review and from observation, this linking of the environment to the development process is a new concept. It has not been addressed in the literature before, yet it is an important first step in accounting for the environment. Once this step was accomplished, the process for developing Enterprise Needs naturally fell out of the flowchart linking the environment to the product development process.

Allowing the creation of Enterprise Needs serves the bigger purpose of the thesis: to address particular concerns that Enterprises within LDC's have. By specifically accounting for constraints and environmental characteristics that can either help or hinder the design & manufacturing process, Enterprise Needs allow the Enterprise to solidify what it has control over, what it can change, and what it is willing to change, while still offering options for design given its hardpoints.

8.2.2 Concept Selection Process

This thesis also presented--through the linkage of environment to product development and through the creation of Enterprise Needs that account for that environment--a way to select (from an existing set of design concepts) a concept most suited to its environment without disregarding customer needs or functional specifications.

This was the last step in the process of not only accounting for the environment, which in and of itself is not too useful, but also solidifying the idea with a concrete example of how it may be useful in the real world.

8.3 Challenges and Opportunities

As with any new idea, certain challenges face the developed process. These challenges also represent opportunities for improvement.

8.3.1 Enterprise Needs Creation

The actual creation and wording of the Enterprise Needs statements proved to be quite challenging. Since the object of the process is to ultimately minimize the limitations and maximize the motivations, wording became difficult when resource statements were not extreme. For example, in some environments it was important to minimize the use of electricity in the manufacturing process. This was easily worded as "minimize use of electricity in manufacturing processes." in other environments, there was ample electricity and this was indicated in the resource statements. Wording a need associated with that set of resource statements is tricky. The enterprise does not necessarily want to maximize the use of electricity although electricity is a motivation or in abundance. It does not want to minimize electricity either, which leaves the wording and the importance of the Need a little bit nebulous. In the end, it was phrased as "Design utilizes processes that use electricity" and was assigned a very low weighting to minimize its effect on the entire process.

To improve the process, more clarification could be given on creating and wording Enterprise Needs to avoid ambiguity.

8.3.2 Interactions

Interactions between Enterprise Needs are also not taken into account in the process outlined for this thesis. For example: a company's desire to maximize the use of manual labor can be related to the company's desire not to use up front capital. Machines can be bought and utilized to minimize man hours and man hours can be maximized to avoid buying machines. There is a correlation and an interaction here that is not addressed with the current process.

Future work in this area may want to address this problem. This could be done by investigating the use of QFD and the system outlined there for acknowledging and accounting for interactions.

8.4 Conclusion

Since beginning this thesis, I have been in the workforce for three years. The idealistic way I began has been tarnished slightly as I have had the chance to work for a multinational company in less developed environments. I better understand the challenges facing manufacturing than I did when I started. I have more sympathy for the small manufacturer in those environments as well as large manufacturers trying to design for their environment.

Although my idealistic view has tarnished somewhat, I still believe that there has got to be a place where engineering and design meets up with do-gooders and development. That is what this thesis was about: to define the problems facing Less Developed Countries and why they may be facing them; to outline what has been done in the area of helping these problems get solved; and finally, to propose a solution to one of the problems as a first step.

Environment can and does have an effect on the Product Development Cycle. This can be overcome by consciously accounting for factors in the environment that either prohibit or encourage manufacturing.

From the viewpoint of a large manufacturer in another environment designing for that environment, it is important to tap the resources specific to that environment, including the indigenous talent and knowledge.

From the viewpoint of the small, local manufacturer, clearly thinking about and giving voice to Enterprise Needs and then designing toward those Needs can lead to an advantage within the market.

APPENDIX A:
Enterprise Needs Formation Tables for Site #2

Table A.1: *Completed Site #2 Enterprise Needs Matrix*

Characteristic	Resource Statements	Motivation/ Limitation	Enterprise Needs
Infrastructure	• Reliable electricity • Reliable water delivery	Motivation Motivation	• Design utilizes manufacturing processes dependent upon electricity • Design utilizes manufacturing processes dependent upon water delivery
Economy	• Mid to high rate of inflation • Stable economy • High cost of captial	Limitation Motivation Limitation	• Design minimizes upfront capital costs
Supplier Pool	• Developing Mfg. Sector • Little refining of natural resources • Region has core competency in textiles	Motivation Limitation Motivation	• Design minimizes reliance on refined natural resources • Design utilizes core competency in textiles
Technology	• Innovative society • Little adaption of outside technologies	Motivation Limitation	• Design maximizes use of indigenous technologies
Natural Resources	• Rubber • Silver • Sugar Cane	Motivation Motivation Motivation	• Design can utilize rubber • Design can utilize silver • Design can utilize sugar cane
Transportation	• Developing highway system • Few shipping companies	Motivation Limitation	• Design is not bulky & is easily shipped
Workforce	• Medium rate of skilled labor • Manual Labor reasonably priced • Low unemployment rate	Motivation Motivation Limitation	• Design utilizes skilled labor currently within the environment. • Design maximizes the use of manual labor

Table A.2: *Heirarchy of Site #2 Enterprise Needs*

	Enterprise Needs
1	Design maximizes indigenous technologies
2	Design utilizes regional core competency in textiles
3	Design minimizes upfront capital
4	Design maximizes the use of manual labor
5	Design can utilize rubber
6	Design can utilize silver
7	Design can utilizes sugar cane
8	Design is not bulky & is easily shipped
9	Design minimizes reliance on refined natural resources
10	Design utilizes skilled labor currently within the environment
11	Design utilizes manufacturing processes dependent upon electricity
12	Design utilizes manufacturing processes dependent upon water delivery

Table A.3: *Site #2 Concept Selection Matrix: Enterprise Needs*

	Enterprise Needs	Weightings	*Traditional*		*1 pc. Injection Molded*		*Tube frame, plastic weaved*		*Tube Frame, Injection Molded*		*Collapsible*	
1	Maximizes indigenous technologies	15%	3	0.45	1	0.15	1	0.15	1	0.15	1	0.15
2	Utilizes regional core competency in textiles	15%	1	0.15	1	0.15	1	0.15	1	0.15	3	0.45
3	Minimizes upfront capital	15%	3	0.45	1	0.15	1	0.15	1	0.15	2	0.3
4	Maximizes use of manual labor	10%	3	0.3	1	0.1	2	0.2	1	0.1	3	0.3
5	Design utilizes rubber	10%	0	0	3	0.3	3	0.3	0	0	2	0.2
6	Design utilizes silver	10%	0	0	0	0	0	0	0	0	0	0
7	Design utilizes sugar cane	10%	0	0	0	0	0	0	0	0	0	0
8	Minimizes use of new, outside technologies	5%	3	0.15	1	0.05	1	0.05	1	0.05	1	0.05
9	Design is not bulky & is easily shipped	5%	1	0.05	3	0.15	1	0.05	1	0.05	3	0.15
10	Design minimizes reliance on refined natural resources	5%	3	0.15	2	0.1	2	0.1	2	0.1	2	0.1
	Total	100%		**1.7**		**1.15**		**1.15**		**0.75**		**1.7**

APPENDIX B:

Enterprise Needs Tables for Site #3

Table B.1: *Completed Site #3 Enterprise Needs Matrix*

Characteristic	Resource Statements	Motivation/ Limitation	Enterprise Needs
Infrastructure	• Reliable Electrical grid • Reliable water delivery • Clean water (reword)	Motivation Motivation Motivation	• Design utilizes manufacturing processes dependent on electricity. • Design utlilzes manufacturing processes dependent on reliable water.
Economy	• Low inflation rate • Low cost for borrowing capital • High growth rate in mfg. sector	Motivation Motivation Motivation	• Design utlilizes upfront capital.
Supplier Pool	• Developed, specialized mfg. sector	Motivation	• Design utilizes supplies manufactured within current environment.
Technology	• Advanced machinery and equipment available. • Innovative environment	Motivation Motivation	• Design utilizes latest technology
Natural Resources	• Iron Ore • Forrest • Aluminum	Motivation Motivation Motivation	• Design utilizes iron ore • Design utilizes wood • Design utilizes Aluminum
Transportation	• Extensive & maintained roadway system • Waterways and Docks • Extensive railway system	Motivation Motivation Motivation	• Design is light & non-bulky
Workforce	• High percentage of skilled workers • Cost of manual labor high • Low unemployment rate	Motivation Limitation Limitation	• Design minimizes use of manual labor in manufacture • Design utilizes skilled labor in environment

Table B.2: *Heirarchy of Site #3 Enterprise Needs*

	Heirarchy of Enterprise Needs
1	Design minimizes use of manual labor in manufacture
2	Design can utilize aluminum
3	Design can utilize latest technology
4	Design utilizes skilled labor in environment
5	Design utilizes supplies manufactured within current environment
6	Design utilizes upfront capital
7	Design is light and nonbulky for shipping
8	Design can utilize iron ore
9	Design can utilize wood
10	Design utilizes manufacturing processes dependent upon electricity
11	Design utilizes manufacturing processes dependennt on reliable water delivery

Table B.3: *Site #3 Concept Selection Matrix: Enterprise Needs*

	Enterprise Needs	Weightings	*Traditional*		*1 pc. Injection Molded*		*Tube frame, plastic weaved*		*Tube Frame, Injection Molded*		*Collapsible*	
1	Design minimizes use of manual labor in Mfg.	40%	0	0	3	1.2	2	0.8	3	1.2	1	0.4
2	Design utilizes aluminum	15%	3	0.45	0	0	2	0.3	3	0.45	3	0.45
3	Design uses region's core competency in mfg.	15%	1	0.15	2	0.3	2	0.3	3	0.45	3	0.45
4	Design uses skilled labor in environment	10%	1	0.1	2	0.2	2	0.2	2	0.2	2	0.2
5	Utilizes supplies manufactured within the environment	5%	1	0.05	2	0.1	2	0.1	3	0.15	2	0.1
6	Design utilizes upfront capital	5%	1	0.05	3	0.15	2	0.1	3	0.15	2	0.1
7	Design is light & non bulky for shipping	5%	1	0.05	3	0.15	1	0.05	1	0.05	3	0.15
8	Design utilizes iron ore	3%	1	0.03	0	0	2	0.06	1	0.03	1	0.03
9	Design utilizes wood	2%	3	0.06	0	0	0	0	0	0	0	0
	Total	100%		**0.94**		**2.1**		**1.91**		**2.68**		**1.88**

LIST OF REFERENCES

Bali, Mohammed, *Microcredit Lending: the Great Escape from Poverty*. Maroodi Jeex, Somaliland Alternative Newsletter. Issue number 6, September/November 1997.

Bent, David S., *Characterizing Learning Prototype Factors within the Early Stages of the Product Development Process,* Thesis, Brigham Young University, Provo, Utah, 1999

Bralla, James G. *Design for Excellence* McGraw-Hill Inc., New York City, NY 1996

Cohen, Lou, *Quality Function Deployment: how to make QFD work for you,* Addison-Wesley Publishing Company, Reading Massachusetts, 1995

Dos Santos, "Crisis de la Teoria del Desarollo y las Relaciones de Dependencia en America Latina," reprint from *Boletin de CESO,* Oct.-Nov. 1968, pp 26, 29.

Dwyer, Dennis, *South East Asian Development: Geographical Perspectives,* John Wiley & Sons, Inc., New York, 1990

Economic and Population Statistics from CIAFactbook 1999. http://www.cia.gov/cia/publications/factbook/index.html. 17 June 2000 (chapter 2)

Fairbanks, Michael; Lindsay, Stace, and Porter, Michael E., *Plowing the Sea.* Harvard Business School Press, 1997

Fann, K.T and Hodges, D.C., *Readings in U.S. Imperialism,* "Dependency & Imperialism: The Roots of Latin American Underdevelopment," pp. 155-181, by Susanne Bodenheimer, 1971.

Garson, Jose, *Microfinance and Anti-Poverty Strategies: A donor perspective.* www.undp.org/uncdf/pubs/mf/mf-contents.htm

Magrab, Edward B. *Integrated Product and Process Design and Development* CRC Press LLC, Boca Raton, Florida, 1997

McCarthy, John. *Progress and its Sustainability*. http://www-formal.stanford.edu/jmc/progress/index.html.

Osman, Khalil, *Micro-finance Institutions: Effective Weapon in the War Against Rural Poverty*. Muslimedia: January 16-31, 1999. http://www.muslimedia.com/archives/special99/micro.htm

Papanek, Victor, *Design for the Real World* Halliday Lithograph Corp., West Hanover, Massachusetts 1971

Salim, Ruhul, *Capacity Realization and Productivity Growth in a Developing Country: Has Economic Reform Had Impact?,* Ashgate Publishers, Aldershot England, 1999

Ulrich, Karl T., and Eppinger, Steven D., *Product Design and Development*, McGraw-Hill Inc., New York, NY, 1995.