

An Applied Study of the Analytic Network Process to Assess Country Conditions for Korean Steel Exports*

Keun Tae Cho** · Soon Wook Hong***

Abstract

In this study, we demonstrate how the Analytic Network Process (ANP) model which is combined with Michael Porter's diamond framework can be used for assessing conditions of selected countries: Brazil, India and China for Korean steel exports. The problem of assessing country conditions requires a model that evaluates several factors on different dimensions. Those dimensions are needed for ranking them according to their likeliness of being a target for Korean steel exports. The ANP consists of four kinds of dimensions called control hierarchy: benefits, opportunities, costs, risks, each of which represents the relationship of its own clusters and elements. To develop the clusters and elements of each dimension, Porter's diamond framework will be used. The final results show that China is the most attractive country to export steel, followed by Brazil and India. This is consistent with the information that we found with respect to the elements that were taken into consideration.

I. Introduction

The Korean iron and steel industry has been a mainstay of industrial development in Korea for decades. Iron and steel are essential for making products and machinery needed in industrial production. The Korean

automobile and shipbuilding industries, now prominent worldwide, owe much of their impressive growth and success to the successful iron and steel industry. In 1996, iron and steel production in Korea rose to 38,903 thousand tons, making the Korean iron and steel industry the sixth largest in the world. In twenty-two year, the production has in-

* This research is partially supported by Korea Research Foundation.

** Katz Graduate School of Business, University of Pittsburgh

*** Department of Industrial Engineering, Youngdong University, Chungbuk, Korea

creased thirty-fold with considerable improvement in productivity [5].

However, the industry is currently at a turning point. In 1995, steel consumption per capita was estimated at 799 kg which suggests that the industry will soon mature, because experience in advanced countries shows that this index generally levels off at about 800 kg or below [12]. It may encourage the industry to place more emphasis on export market rather than domestic market. Therefore, our concerns are to identify which country is more important as an export market in order for leading us to a right decision ultimately.

This problem with interactive criteria and alternatives can be viewed as a multiple criteria decision making (MCDM) problem within the context of the long range and strategic process of the industry. The Analytic Network Process (ANP), one of MCDM methods recently developed by T. Saaty [9], deals with the dependency and feedback that the problem has. That is, the power of the ANP lies on its use of ratio scales to capture all kinds of interactions and make accurate predictions, and, even further, to make better decisions. The ANP is the first mathematical theory that makes it possible for us to deal systematically with all kinds of dependence and feedback. The reason for its success is the way it elicits judgments and uses measurement to derive ratio scales. Priorities as ratio scales are a

fundamental kind of number amenable to performing the basic arithmetic operations of adding within the same scale and multiplying different scales meaningfully as required by the ANP. The ANP consists of four kinds of control hierarchies: benefits, costs, opportunities, risks, each of which represents the relationship of its own clusters and elements.

The goal of this paper is to apply the ANP model which is combined with the Porter's diamond framework to assess country conditions for Korean steel exports. In this study, Brazil, India and China are considered as three foreign markets, because they have greater potential in steel demand than other countries that we trade. In order to rank them according to their likeliness of being a target for Korean steel exports, some clusters and elements are required in the ANP model as evaluation criteria. To logically develop these clusters and elements systematically, Porter's diamond framework should be utilized to address a nation's competitive advantage. For the purpose, several clusters and elements will be considered with regard to the industry and market characteristics from each of those countries in this study.

II. Industrial Analysis

The iron and steel industry, for the purp-

ose of this study, is defined as those significant producers of finished, semi-finished, and specialty steels. In 1996, the Korean iron and steel industry consists of 31 companies including one integrated mill. This section of the paper concentrates on the structure of the Korean steel industry.

A. Microeconomics Characteristics of the Industry

To set the stage for further industry analysis, the microeconomics factors facing the players must be considered. The following description corresponds to the two principal classifications of producers, integrated operations and minimills.

Integrated steel makers, the mammoth producers that come to mind when one thinks of traditional steel mills, produce steel from scratch in sprawling mills that are from two to seven miles long and typically supply flatrolled carbon sheet, strip, and plate products. They use a step by step manufacturing process that was developed in nineteenth century and has not changed very much since then. The minimum efficient scale of a modern integrated plant ranges from six to eight millions of tons of raw steel capacity. These producers are characterized by high fixed costs profile and therefore little flexibility. These high costs originate with high initial investment in physical plant and large non-discretionary capital expenditures to several labor con-

tracts. Flexibility also suffers because the re-orientation of production facilities takes time and capital that are not always readily available, and because the strict terms of union-negotiated labor contracts make layoffs during periods of steel consumption downturns very difficult. Wage protections and variety of social contracts also restrict the flexibility of Korean steel makers.

Minimills are relatively small, nonintegrated companies typically with a raw steel capacity of 0.5 to 1.5 millions tons. Unlike their older and larger counterparts, minimills do not produce steel from scratch. Instead they produce steel products by melting ferrous scrap in electric arc furnaces. With the newer technologies, minimills enjoy significant cost savings. Relying on scrap as their chief raw materials rather than producing steel from iron, coal, and lime, minimills benefits from lower materials expense. Further cost benefits can be attributed to the use of non-union labor, thereby freeing the operation from union-mandated work rules and wage restrictions. Unlike the union-manned integrated steel mills, minimills base employee compensation on production and profit levels. As a result of this more accommodating relationship with labor, minimills possess greater production flexibility than integrated companies.

B. Factors Driving the Industry

The main drivers in the industry are the

changes in overall demand for steel, the various regulatory schemes faced by producers, the demand for substitute materials, and changes in technology. The demand for steel is shaped primarily by the automobile industry, the construction industry, and other heavy industries. For example, a recent upturn in all of these markets has greatly improved sales and profitability of a big domestic producer, POSCO (Pohang Iron & Steel Co., Ltd.).

The next major driver of change in the industry is government regulation. The refined environmental law poses significant longterm obstacles for Korean steel makers. Coking emissions represent the most significant aspect of the law. For example, POSCO will increase their reliance on outside vendors to satisfy their coking needs. The Korean Iron and Steel Institute (KISI) reports that approximately 13 percent of the industry's capital outlays has been budgeted for environmental cleanup and improvement [5].

Demand for steel is also impacted by the demand for steel substitutes, predominantly aluminum and plastic. The demand for substitutes is driven primarily by the automobile industry. Plastics represent a significant costs savings over steel, due to greater malleability, lower tooling costs, weight savings, and enhanced aerodynamic properties. Both plastics and aluminum are easily and readily recycled. This is of growing

importance to auto makers, since greater recyclability of automobiles is becoming a desired end-step of automobiles' product lives.

Finally, technological changes have the potential to affect the industry profoundly. For example, thin-strip casting eliminates the need to hot roll slabs, a step that is still necessary in both conventional and thin-slab casting. This technology poses a grave threat to integrated steel manufacturers over the long term because this low-cost procedure will result in many competitors entering the flat-roll sheet market, one of the few remaining competitive advantages of integrated mills.

C. Competitiveness of the Industry

As reported by the Korea Development Bank [12], Korean iron and steel products are very price competitive. For example, In 1995, Korean hot-rolled coil sold for US\$ 337 per ton, 57.2 percent of the Japanese price, and 65.1 percent of the American price. Korean cold-rolled coil sold for US\$ 510 per ton, 77.3 percent of the Japanese price, and 73.5 percent of the American price. Plate sold for US\$411 per ton, 69.8 percent of the Japanese price, and 62.2 percent of the American price. Price competitiveness can be demonstrated by doing a cost analysis. The pretax cost of Korean steel products was US\$489 per ton, 78.0 percent of the Japanese cost. The major

cause for the narrowing of the gap is labor costs that comprise 16.2 percent of total pretax costs. The labor cost per ton was 42.0 percent of the Japanese labor cost. Material costs for Korean products were stable at around 91 percent of Japanese material costs. Financial expenses are also going up, but they make up only 4.9 percent of the pretax cost. The upward trend in labor costs is inevitable for Korea. In view of this, Korean iron and steel producers are restructuring and raising technical standards. In production processes, continuous casting for semi-products accounted for 97.8 percent in 1994, while it made up 96.9 percent in Japan for the same period. Korea ranked top in the world in the use of continuous casting. Many other factors related to technological advancement in the processes are better in Korea than they are in Japan. For example, the time needed for melting in a 100-ton electric furnace, labor productivity, and the number of kwh required to produce one ton of crude steel are all more efficacious in Korea than in Japan.

III. Country Analysis: Porter's Diamond Framework

The effective geographic scope of compe-

tion in an industry can be local, regional, national, international, or global. This scope will be influenced by economic, political and strategic viewpoint. The specific economics of the industry's value chain will depend on the economies of scale, scope and learning; logistical constraints; and distinctiveness of local tastes present in the industry. Trade restrictions and highly specific product regulations tend to narrow the geographic scope of competition by limiting the ability of outside firms to compete in local markets. Institutional features, such as idiosyncratic local distribution channels, might also make it difficult for outside competitors to penetrate certain national and regional markets. Firm strategies have a substantial impact on the geographic scope of competition, as well. The geographic scope of competition in an industry does not change by itself. Firms precipitate such changes through their investments and strategic choices. Firms can often gain advantage from features of the local environment that are external to any single firm. Generally available resources do not provide a competitive advantage for any firm, whereas region- or nation-specific resource can provide advantages to firms in the region or nation with respect to outside competitors, but not with respect to each other.

We use Porter's diamond framework [7] to characterize the sources of advantage that a firm might draw from its local envi-

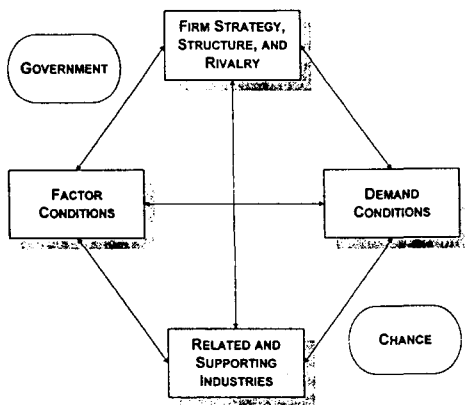
ronment. Porter developed it for assessing the influence of the nation on the international competitiveness of its firms. In the framework shown in Fig. 1, the determinants of competitiveness in a given industry are Factor Conditions, Demand Conditions, Related and Supporting Industries, and Firm Strategy, Structure and Rivalry that are found in the nation. Factor Conditions refers to the local availability of the inputs necessary to compete in an industry. Demand Conditions refers to the size, sophistication, and segment structure of local demand. Related and Supporting Industries refers to the presence of world class suppliers and firms in industries related by common technologies, distribution channels, or target markets. Firm Strategy, Structure and Rivalry comprises the conditions under which firms are created, organized, and managed, as well as the nature of local rivalry.

According to Porter, government policies and chance events are best understood by addressing their impact on the determinants. Government influences the determinants through its impact on factor costs and availability, its role as a purchaser, its impact on the goals of firms, and its impact on the nature of competition within industries. Chance events may unfreeze existing industry structure and shift advantage to new competitors by changing the relative importance of the various determinants. Nations succeed in industries where these determinants provide the incentives, pressures, and capabilities to innovate and upgrade firm capabilities. Although Porter focuses on the geographic unit of analysis, the same framework can be applied at the regional or local level.

IV. Assessment of Country Conditions

A. Brazil

Brazil is the fifth largest country in the world and has tenth largest economy. Population is about 152 million and to be growing at just under 2 percent a year. About 55 percent of the population is under 20 years of age, and less than 10 percent is over 60. The standard of living of a large proportion of the population is very low, while that of the top stratum is extremely



[Fig. 1] Porter's Diamond Framework

high. The gross domestic product (GDP) per capita in 1993 was the equivalent of about US\$3,000 per annum, and the official GDP in 1993 was US\$456 billion. The average GDP growth rate of the last three years was approximately 5.1 percent. The economy is basically one of free enterprise, but there is still considerable state and semi-state participation in various strategic sectors, such as transport and utilities.

Major manufacturing industries include petrochemicals, steel, automobiles, mining, cement, paper and allied products, and food processing. None of these industries is in decline. There is large potential for expansion in all areas, assuming the current economic difficulties can be overcome. There are still restrictions of foreign investment in some sectors. There has been no significant development or modernization of the government-controlled railroad network over the past years, therefore, road transport dominates both long distance and inter-city traffic. Nevertheless, construction of new highway has been slow in recent years. Also, most of the major federal and state highways have not been well maintained. The potential of the waterways and coastal transport has not been developed.

The government has customarily supported free enterprise and the free trade system. However, state and semi-state entities control nearly all the public utility sectors and the petroleum industry, exclud-

ing distribution, and oligopolistic situations exist in many sectors. There is considerable bureaucratic intervention. Regulations are constantly changing, and there are complex labor and tax codes. On the other hand, there is a motivated work force, and the development of labor-intensive industries and ventures directed toward exporting is encouraged.

Generally speaking, Brazil was a relatively closed economy in the 1970s and 80s. In 1993, exports and imports were about 8.7 and 5.8 percent of GDP, respectively. However, trade has taken place in the 1990s resulting in the reduction of trade barriers and various protective practices, and local manufacturers are becoming more competitive internationally. The Brazilian economy is fairly broad based, including almost every type of industry imaginable.

Brazil is a member of the Latin American Integration Association, and has agreed with Argentina, Paraguay, and Uruguay to form the Southern Cone Common Market, known as Mercosur. Under the treaty agreement, tariffs were being lowered gradually to reach zero by 1995. Also, movement of labor, goods and services will be unrestricted; capital investment encouraged; macroeconomics policies coordinated; and external policies and tariffs for nonmember countries harmonized.

For many years, Brazil's foreign trade policy has reduced imports and encouraged

exports. Therefore, certain classes of imports have been subject to high import duties and/or import quotas. However, the government is slowly diminishing trade barriers, and import duties are being reduced. Imports are authorized where local prices are significantly higher than international prices or when serious shortages arise. In addition to customs requirements, imports are also subject to the laws and regulations of other government agencies with which the custom authorities cooperate in enforcement. The foreign exporter should make certain that the Brazilian importer has provided proper information to permit the submission of necessary information concerning packaging, labeling, etc., and that arrangements have been made by the importer for entry of the merchandise into Brazil.

The minimum import duty is currently 40 percent as of the end of 1994. Exemptions from or reductions in import duties are granted from time to time to certain industries or enterprises considered of particular importance to the Brazilian economy, depending on the region where they are established, the nature of the goods, the resultant increase of the utilization of domestically produced material, etc. Duties may also be suspended on goods imported for re-export, for further processing prior to export or for use in preparing other products for export. Import duties must be paid before customs clearance is given,

unless they are transported to a bonded warehouse. Products shipped to Brazil and billed directly by the foreign supplier to its customer in Brazil are assumed to include a profit of 20 percent of the amounts billed, on which income tax is payable if the sales agent or representative domiciled in Brazil who acts as an intermediary has the authority to bind the overseas seller contractually.

B. India

India has a stable political system that is based on parliamentary democracy. Out of the total population of 844 million, the working population is estimated at 285 million. The bulk of the working population remains engaged in agriculture and allied activities at the low levels of productivity, although there has been some shift from the farm sector in recent years. There is a growing middle class, estimated at 150 to 200 million at present, whose consumption and living standards are comparable to those of the Western economies during the 1960s. Problems of unemployment are serious as regards the educated labor force, particularly graduates and diplomaholding engineers. The per capita GDP was US\$275 in 1992. India is a multilingual nation; English is widely used in commerce. The developing economy is based on agriculture but with a wide spectrum of industries. Inflation is moderate.

India is rich endowed with minerals, and

although they have only been partially exploited, they are largely reserved for the public sector. There are large deposits of coal, iron, ore, manganese, mica, bauxite, and limestone. The most important sources of commercial energy are coal, gas and oil. Coal and hydropower contribute primarily to electricity production. Crude oil production has increased considerably, but it is still insufficient to meet country's requirements, and crude oil remains the single largest item in the import bill.

The principal manufacturing industries are cotton and jute textile; iron and steel and other basic metals; electrical and other machinery; petrochemical; chemicals, including cement, fertilizers, medicines and pharmaceuticals; transport equipment; and food products. Of these, food products, textile, cement, fertilizer, paper, basic metals, transport equipment, and appliances have shown fairly consistent growth. Power, electronics, telecommunications, and food processing are some of the potential growth areas in the manufacturing sector.

Internal transport and communications are fairly well developed. The country is extensively by rail and road network, supplemented by airline routes connecting the major cities. The Indian rail road system has a route length of about 61,000 km and is the largest public sector undertaking in the country. Road transport is playing an increasing role in internal transportation and

its share in both goods and passenger traffic is expected to increase. Scheduled air services are run by three public sector corporation. Inland water transport and coastal shipping are not well developed.

India has mixed economy with the public sector traditionally dominant in infrastructure areas and in basic industries. The government has exercised considerable control over the private sector through licensing the setting up of manufacturing capacity; approval procedures for importing foreign capital, technology, capital goods, and raw material; and allocation procedures for basic raw materials. The last decade has seen considerable liberalization in government control industry. This process and deregulation of the economy have gathered momentum since 1991, when a new government began to introduce a series of economic reforms. The present trend is clearly toward a larger role for the private sector, with fresh public investments being more or less restricted to a narrow list of strategic and essential infrastructure areas. The government is also pursuing a policy of divestment of equity in public sector enterprises outside these areas and dilution of its holdings through fresh issues to the public, through privatization.

In general terms, the government's aim over decades of economic planning through successive five-year plan has been to raise the standard of living of the people through

programs that are also designed to promote equality and social justice. Foreign exchange controls have been somewhat relaxed. Although not a member of any trade bloc, India has entered into bilateral trade agreements with a number of countries and is a member of several international organizations.

Permission to import was given to items considered essential and materials for the manufacture of export goods. This restrictive treatment is undergoing significant change in accordance with the government's declared policy of reducing protection to make domestic industry internationally competitive. Duties change from the country of origin and the type of product. For example, complete exemption or rate concession is allowed for imports from some neighboring and developing countries such as Bhutan, Egypt, and Brazil. Total basic and auxiliary duties range between 0 and 110 percent. Lower duty rates are generally applicable to raw materials and intermediate goods in comparison with finished products.

There is no problem in retaining the services of an Indian employee/salesman to promote and the sale of goods and services in India, and as a liaison office may be opened for such a purpose if the individual in charge is given power of attorney. However, for income tax purpose it is important that these persons do not enter into sales contracts on behalf of the exporter, and

such agreements should be signed by the overseas directly. Appointment of a sales agent is generally permitted under Indian law.

C. China

China's population is about 1.4 billion, with an estimated growth rate of 1.2 percent. The Chinese have high energy needs but limited capital. As in other sectors of the state-owned economy, the energy sector suffers from high rates of waste, low utilization, and inefficiencies in production, transport, conversion, and consumption. Other problems include declining real prices, rising taxes and production costs, spiraling losses, high debt burden, insufficient investment, low productivity, low efficiency, poor management structure, environmental pollution, and inadequate technological development. Demand for energy has risen steadily in response to rapid expansion of the economy over the last 10 years. Domestic energy policies generally encourage investment in the exploration of China's vast and largely untapped energy resources. Energy needs are supplied mainly by coal (about 75%), oil (around 20%), hydropower, and natural gas.

While highways run about 980,000 km of roads including 162,000 km paved and inland waterways run 138,600 km including about 109,800 km navigable, Railroads run total about 54,000 km throughout the nation

as common carrier lines. Domestic and international telecommunications services are increasingly available for private use: unevenly distributed internal system serves principal cities, industrial centers, and most townships: 11 million telephones.

Major state industries are iron and steel, coal, machine building, armaments, and textiles. These industries completed a decade of "reform" (1979-89) with little substantial management reform. Although the central government depends upon income from state-owned enterprises, their productivity has been falling while costs of production and debt levels have been increasing sharply. The government recognizes the need for substantial reforms but remains reluctant to terminate state subsidies and to pursue innovative approaches to management. The Chinese have in some instances tried to substitute "advisory planning" for mandatory planning. The industrial sector needs to undergo new reform designed to resolve the chronic debt, low efficiency, and heavy losses of state-run enterprises sustained in the late 1980s. Industrial growth spurted 14 percent in 1991, but there were marked disparities in growth among different types of enterprises. State-owned industry grew only 8.4 percent, while collective and private sectors grew 18 percent and 24 percent respectively. The industrial output of foreign joint ventures, foreign contract ventures, and solely foreign-owned enter-

prises rose 56 percent.

At the beginning of 1991, factory managers were called on to cut losses and boost productivity, and enterprise managers were challenged to reduce material consumption by 3 percent, pare administrative expenses by 5 percent, and cut operational losses by half during the next year. To this end, Beijing announced 11 measures, such as lowering interest rates on state enterprise loans, forming 100 new enterprise groups to improve production coordination, and giving some of these groups and other key firms more foreign trade authority in the long term. To attract new investments to support technical upgrading and improve competitiveness, Chinese banks intend to issue more loans over the next 5 years to support these projects. In 1992, China undertook an effort to improve the efficiency and productivity of state-owned industries by increasing investment in technical transformation projects and earmarking several billion U.S. dollars to purchase production facilities constructed by foreign companies and advanced technology needed to upgrade China's heavy industries.

The current leadership has recognized that foreign trade and technology play critical roles in China's modernization, and has promulgated measures to improve the investment climate. China has experimented with decentralizing its foreign trading system and has sought to integrate itself

into the world trading system. In November 1991, China joined the Asia-Pacific Economic Cooperation group, which promotes free trade and cooperation in economic, trade, investment, and technology issues.

Nevertheless, many aspects of China's trade regime remain unclear. Western nations still express serious concerns and reservations about the eventual terms of China's accession. Its current system of market and administrative controls limits foreign access through such means as tariffs, import and export licensing, import substitution regulations, and foreign exchange restrictions. The government also restricts foreign entry into service sectors, such as insurance, banking, accounting, and legal services. In addition, arbitrary and inadequate legal and regulatory systems affect foreign investor's ability to do business in the country. Central planning, rather than market forces, are key to determining the composition of most Chinese exports and imports. Therefore, domestic prices for imported products are often subsidized. Government trade and investment decisions will be governed by the need to restructure the economy and by concerns about future political directions. According to Chinese statistics, their global trade totaled \$136 billion in 1991, an increase of 18 percent over 1990. China's trade surplus dropped from \$8.7 billion in 1990 to \$8.1 billion in 1991. The government also is working to

expand trade ties, particularly with Russia and the new Central Asian states and with India, South Korea, Vietnam, Taiwan, and other developing and newly industrialized economies in Asia, Africa, and Latin America.

Foreign investment stalled in the aftermath of Tiananmen. Recently, the Chinese have taken steps to improve the foreign investment climate. In 1990, the government eliminated time restrictions on the establishment of joint ventures, provided some assurances against nationalization, and allowed foreign partners to become the chairs of joint venture boards. In 1991, China granted more preferential tax treatment for wholly foreignowned businesses and contractual ventures and for foreign companies which invest in selected economic zones or in projects encouraged by the state, such as energy, communications, and transportation.

V. The Analytic Network Process (ANP)

The Analytic Network Process (ANP) is a new theory that extends the Analytic Hierarchy Process (AHP) to the case of dependence and feedback and generalizes on the supermatrix approach [9][10]. It allows interactions and feedback within

clusters and between clusters. Feedback can better capture the complex effects of interplay in human society. The ANP provides a thorough framework that includes clusters of elements connected in any desired way to investigate the process of deriving ratio scales priorities from the distribution of influence among elements and among clusters. The ANP is implemented in the software *ECNet* developed recently by Expert Choice Inc. [11].

The ANP is a coupling of two parts. The first consists of a control hierarchy or network of criteria and subcriteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion and a supermatrix of limiting influence is computed for each control criterion. A supermatrix is a two-dimensional matrix of elements by elements. The priority vectors from the paired comparisons are placed in the appropriate column of the supermatrix. As the supermatrix is built in this way, the sum of each column corresponds to the number of comparison sets.

Finally, each of these supermatrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria. In addition, a problem is often studied through a control hierarchy or system of benefits, a second for costs, a third for op-

portunities, and a fourth for risks. The synthesized results of the four control systems are combined by taking the quotient of the benefits times the opportunities to the costs times the risks to determine the best outcome.

Here is an outline of the steps of the ANP.

1. Determine the control hierarchies including their criteria for comparing the components of the system and their subcriteria for comparing the elements of the system. One hierarchy for benefits, a second for costs, a third for opportunities, and a fourth for risks.
2. For each control criterion or subcriterion, determine the clusters of the system with their elements.
3. Determine the approach you want to follow in the analysis of each cluster or element, being influenced by other clusters and elements, or influencing other clusters and elements with respect to a criterion. The sense of influencing or being influenced must apply to all the criteria for the four control hierarchies.
4. Perform paired comparisons on the clusters as they influence each cluster and on those that it influences, with respect to that criterion. The derived weights are used later to weight the elements of the corresponding column clusters of the supermatrix corres-

ponding to the control criterion. Assign a zero when there is no influence.

5. Perform paired comparisons on the elements within the clusters themselves according to their influence on each element in another cluster they are connected to or on elements in their own cluster. The comparisons are made with respect to a criterion or subcriterion of the control hierarchy.
6. For each control criterion, construct the supermatrix by laying out the clusters in the other they are numbered and all the elements in each cluster both vertically on the left and horizontally at the top.
7. Compute the limiting priorities by each supermatrix according to whether it is irreducible or it is reducible with one being a simple or a multiple root and whether the system is cyclic or not.
8. Synthesize the limiting priorities by weighting each limiting supermatrix by the weight of its control criterion and adding the resulting supermatrices.
9. Repeat the synthesis for each of the four control hierarchies.
10. Synthesize the results from the four control model hierarchies by multiplying the benefits by the opportunities and dividing by the costs multiplied by the risks.

When making pairwise comparisons in an

ANP model, the questions are formulated in terms of dominance or influence. Given a criterion, which element has greater influence (is more dominant) with respect to that criterion? Use one of the following two questions throughout an exercise. First Given a criterion and given an element X , which element has greater influence on X with respect to that criterion? Second, Given a criterion and given an element X , which element is influenced more by X with respect to that criterion?

When making judgments in a costs or risks network, the question must be phrased asking which element is more costly or more risky. The more costly or risky elements must end up with the largest priorities. The same is true regardless of whether the element is a criterion or an alternative.

VI. Application of the ANP Model

The problem of assessing country conditions requires a model that evaluates several factors on different dimensions. Those dimensions will be required for ranking them according to their likeliness of being a target for Korean steel exports. The selected dimensions are benefits, opportunities, costs, and risks. The decision of ranking

foreign markets is not only based on traditional dimensions (benefits and costs), but also it is based on the possible conditions of expansion (opportunities) and on the likelihood of changes of current conditions (risks). Then, we select a control model in which its basic criterion is represented in the following relation of the previous four dimensions: $(\text{Benefits} \times \text{Opportunities}) / (\text{Costs} \times \text{Risks})$.

Control Hierarchy: Two levels integrate the control hierarchy. The first is the principal goal that is measured by a ratio between the pair of benefits and opportunities and the pair of costs and risks. The second is the basic criteria based on the four criteria dimensions. The final result will rank the countries according to the most attractive combination of high benefits, good market opportunities, low operating costs, and low risks.

Networks: It is necessary to represent a more complex business reality. This reality contains the interaction among several elements that are sources of advantages or disadvantages. According to Porter's diamond framework, the principal sources are factor conditions; demand conditions; related and supporting industries; and firm strategy, structure and rivalry. These elements are represented as clusters in the different four networks.

Porter's framework includes also two more elements, which are the government

and the chance. The government element is represented by an additional cluster and the elements of chance are represented through the evaluation of risks and opportunities in the high level part of the ANP model.

Finally, the network which represents the interrelation of Porter's diamond components, includes the three countries to be evaluated: Brazil, India, and China. These are represented and grouped in the countries cluster (alternative cluster).

The standard network and description of elements are listed in the following Table I. Our four networks are constructed based on these clusters and elements, but they are adjusted to specific conditions. In the following paragraphs, these conditions are shown.

A. Benefits Network

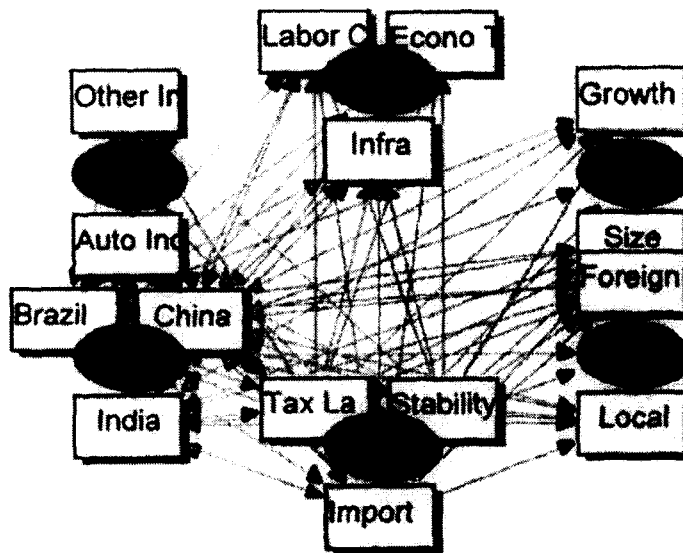
In order to assess the benefits resulting from exporting steel from South Korea to Brazil, India or China, the benefits elements in the Table I are considered to create a relationship among the three countries.

As shown in Fig. 2, the established relationships are back and force links from the countries to all of the other elements. These relationships are created in this way because all the benefits elements selected affect directly and independently each of the countries. On the other hand, each element evaluates which country is more important in terms of benefits. What is even more important thing in the network

<Table 1> Standard Network Clusters and Elements

Clusters	Elements	B	O	C	R
Factor Conditions	Raw Material			◇	
	Labor Cost			◇	
	Infrastructure	◇	◇	◇	
	Economic Trend	◇	◇		◇
	Living Standard	◇	◇		
	Financial Service		◇		
	Base for Regional Expansion		◇		
Demand Conditions	Size	◇	◇	◇	
	Growth	◇	◇	◇	
Related and Supporting Industry	Auto Industry	◇	◇	◇	
	Other Industries	◇	◇	◇	
Firm Strategy, Structure and Rivalry	Local Manufacturers	◇	◇	◇	◇
	Foreign Manufacturers	◇	◇	◇	◇
Government and Chance	Foreign Direct Investment (FDI) Regulation		◇		
	Tax Law	◇	◇	◇	◇
	Stability	◇	◇	◇	◇
	Import Regulation	◇	◇	◇	◇
Country	Brazil	◇	◇	◇	◇
	India	◇	◇	◇	◇
	China	◇	◇	◇	◇

The symbol (◇) means that each control hierarchy has the element
 B : Benefits, O : Opportunities, C : Costs, R : Risks



[Fig. 2] Benefits Network

〈Table II〉 The Final Supermatrix in Benefits Network

Clusters and Elements	Weight	Brazil	India	China
Factor Conditions:				
Labor Cost	0.5516	0.2000	0.2000	0.6000
Infrastructure	0.1279	0.5816	0.3090	0.1094
Economic Trend	0.3206	0.1061	0.1929	0.7010
Demand Conditions:				
Size	0.3252	0.2500	0.2500	0.5000
Growth	0.6741	0.1667	0.1667	0.6667
Related and Supporting Industry:				
Auto Industry	0.5102	0.6483	0.1220	0.2296
Other Industries	0.4899	0.2500	0.2500	0.5000
Firm Strategy, Structure and Rivalry:				
Local Manufacturers	0.6437	0.2377	0.1551	0.6072
Foreign Manufacturers	0.3564	0.2184	0.1515	0.6301
Government and Chance:				
Stability	0.4801	0.1283	0.2764	0.5954
Tax Law	0.2221	0.1095	0.5816	0.3090
Import Regulation	0.2988	0.1634	0.5396	0.2970
<i>Local Synthesized:</i>		0.2686	0.1955	0.5361

is to create the influences of government and chance clusters on the other clusters, because all the countries being considered in this study are developing countries with stronger government roles and powers than developed countries.

We elaborate the pairwise comparison giving more priority to those elements that provide more benefits to the steel exporter. For example, comparing infrastructure against labor cost, we select infrastructure as more important, because better infrastructure provides more benefits. Costs that could be generated in a country with no infrastructure are higher than those from a country with cheaper labor cost. Moreover, steel

exports rely more on transportation and handling infrastructure than in labor cost. The synthesized local results of benefits network are included in the Table II.

In this network, China comes up with the highest percentage with 53.61 percent. Not so far Brazil took the second place with 26.86 percent. And lastly, India results the less important in terms of benefits with 19.55 percent. Relating the results with the information we gathered, this percentages are consistent: China, even though has the less open economy regarding tax law and import regulation, has enormous steel demands and inexpensive abundant labor forces. Moreover, China is also the country

with best economic trend.

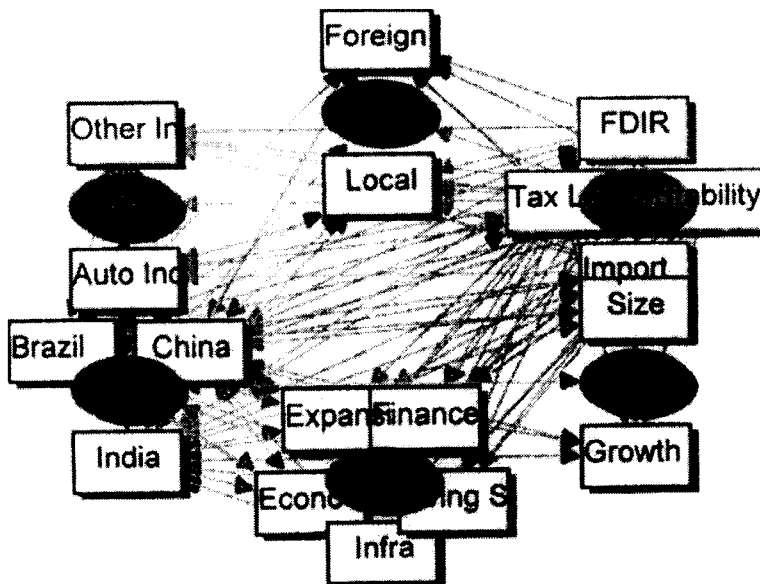
B. Opportunities Network

This network represents the complex interaction of opportunity determinants including specific elements such as: Financial Services, Living Standards, and Base for Regional Expansion. These cluster elements are not present in the other networks. The cluster elements in this network are included in Table I.

As shown in Fig. 3, the principal links or relationships are made among non-country cluster elements. Therefore, it is reflected several interactions such as the general influences of the elements in the government and chance cluster on the elements in the other clusters. For example, stability alters the potential actions of the manufactures

and the rival structure. These kinds of relationships are linked through all the models. The opportunities network is one of the most complex structures, because it should reflect a series of influences back and forth among all the determinants of the competitiveness in the future and the potential changes.

The result of this evaluation is reflected in the following Table III. It is interesting to analyze that in all the determinants (cluster elements) the relationship of the countries is the same except for infrastructure and base for a regional expansion. China in this position has the lowest score for opportunities because its factor conditions are weaker than Brazilian or Indians. Nevertheless, in the general result, China provides better conditions, government sta-



[Fig. 3] Opportunities Network

bility, and an open market opportunity. Finally, there is a greater demand with a good rate of growth.

In summary, as indicated in Table III, China yields the most opportunities score with a value of 64.26 percent, Brazil is the second with a score of 17.90 percent. Finally, India is the third country with a value of 17.83 percent. The analysis is more useful for assessing opportunities between India and Brazil. Brazil has a better position in the following elements: Base for a Regional Expansion, Financial Services, Infrastructure, Local and Foreign Manufac-

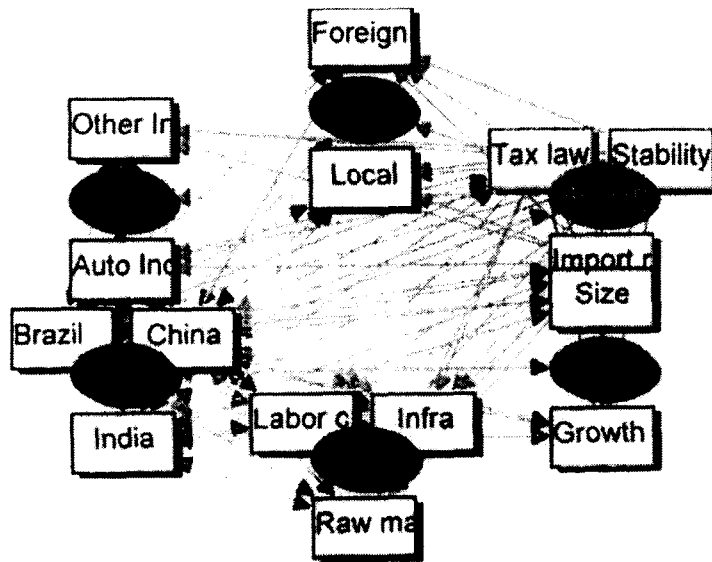
turers, the elements of Government and Chance cluster except for FDI regulation. On the other hand, India has a better position in the following ones: Demand Characteristics such as Size and Growth, and Living Standards. Both countries have similar sources of opportunities regarding economic trend.

C. Costs Network

In the costs network, the costs elements in the Table I are considered to make an assessment among the three countries. As exhibited in Fig. 4, the links are made

(table III) The Final Supermatrix in Opportunities Network

Clusters and Elements	Weight	Brazil	India	China
Factor Conditions:				
Expansion	0.1154	0.6483	0.1220	0.2296
Living Standard	0.2271	0.1056	0.1499	0.7445
Infrastructure	0.5815	0.5815	0.3090	0.1094
Economic Trend	0.3532	0.2000	0.2000	0.2000
Financial Service	0.1427	0.2297	0.1220	0.6483
Demand Conditions:				
Size	0.3136	0.1634	0.2970	0.5396
Growth	0.6865	0.0938	0.1666	0.7396
Related and Supporting Industry:				
Auto Industry	0.5833	0.0688	0.2499	0.6813
Other Industries	0.4159	0.0819	0.2363	0.6817
Firm Strategy, Structure and Rivalry:				
Local Manufacturers	0.2540	0.2426	0.0879	0.6694
Foreign Manufacturers	0.7461	0.2363	0.0819	0.6817
Government and Chance:				
Stability	0.1163	0.1666	0.0938	0.7396
Tax Law	0.1461	0.1618	0.0872	0.7510
Import Regulation	0.2276	0.1870	0.0977	0.7153
FDIR	0.5099	0.0938	0.1666	0.7396
<i>Local Synthesized</i>		0.1790	0.1783	0.6426



[Fig. 4] Costs Network

from the countries to the elements and vice versa in order to consider the mutual influence that exists between countries and elements. Links are also created between government and chance cluster elements and other clusters elements affecting costs. Those links are from Stability, Tax Law, and Import Regulation to Local and Foreign Manufacturers, etc.

The following Table IV shows the local synthesized result of costs networks. Based on the control hierarchy, China comes out as the country that carries the lowest cost, with a result of 26.65 percent, followed by Brazil with 33.52 percent and India with 39.82 percent. This is consistent with the information that we found with respect to the elements that were taken into consideration. For example, China has greater

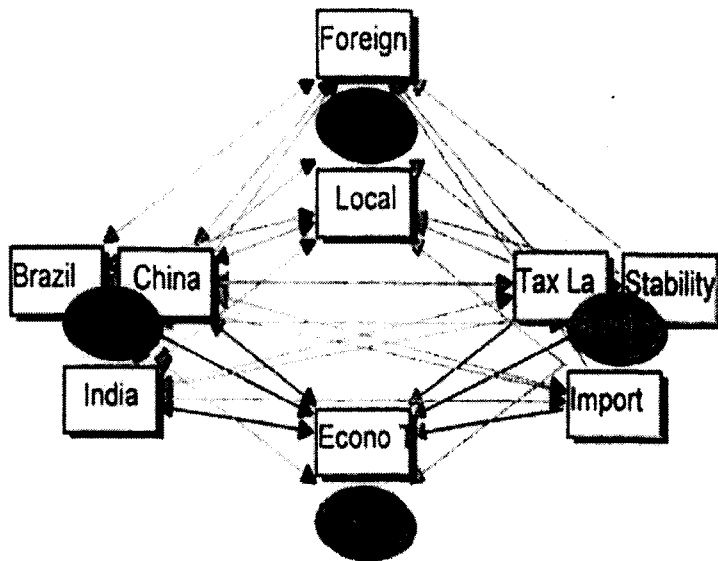
competitiveness in terms of labor cost weighted as 7.51 percent than other two countries, although China is the country with worst infrastructure (65.71%) affecting the costs for handling and transporting the steel with considerably high costs for raw material (50.00%).

D. Risks Network

With respect to risks, exporting steel from Korea to Brazil, India or China is represented by the elements shown in Table I. The other elements are not taken into account due to their inexistence or small relevance to the risks network. The links, as shown in Fig. 5, were made from the countries to the elements and vice versa in order to consider the mutual influence that exists between countries and

<Table IV> The Final Supermatrix in Costs Network

Clusters and Elements	Weight	Brazil	India	China
Factor Conditions:				
Labor Cost	0.3593	0.5917	0.3332	0.0751
Infrastructure	0.3502	0.1963	0.1466	0.6571
Raw Material	0.2906	0.2500	0.2500	0.5000
Demand Conditions:				
Size	0.4537	0.5815	0.3090	0.1094
Growth	0.5464	0.5876	0.3234	0.1094
Related and Supporting Industry:				
Auto Industry	0.4996	0.1000	0.6000	0.3000
Other Industries	0.4996	0.1000	0.6000	0.3000
Firm Strategy, Structure and Rivalry:				
Local Manufacturers	0.7210	0.3234	0.5876	0.0890
Foreign Manufacturers	0.2791	0.1666	0.0938	0.7396
Government and Chance:				
Stability	0.2537	0.6000	0.2000	0.2000
Tax Law	0.4663	0.3333	0.3333	0.3333
Import Regulation	0.2799	0.5815	0.3090	0.1094
Local Synthesized:		0.3352	0.3982	0.2665



[Fig. 5] Risks Network

〈Table V〉 The Final Supermatrix in Risks Network

Clusters and Elements	Weight	Brazil	India	China
Factor Conditions:				
Economic Trend	0.1000	0.4286	0.4286	0.1428
Firm Strategy, Structure and Rivalry:				
Local Manufacturers	0.4439	0.1000	0.3000	0.6000
Foreign Manufacturers	0.5561	0.2000	0.2000	0.6000
Government and Chance:				
Stability	0.3333	0.4286	0.4286	0.1428
Tax Law	0.3333	0.5396	0.1634	0.2970
Import Regulation	0.3333	0.5396	0.1634	0.2970
<i>Local Synthesized:</i>		<i>0.3155</i>	<i>0.3271</i>	<i>0.3574</i>

elements. The links are also created from the government and chance cluster to other clusters to reflect its influence.

Therefore, our interpretation of the results takes into account the inverse relationship that exists between the likelihood of exporting steel to those countries and the risks involved with doing so. This means that the greater the number we have as a result, the riskier the country is considered for exporting steel. We could phrase that as "since the result for a given country is X, and the result for other country is 2X, the risks for exporting to the last country will be twice as

much as the ones for the former".

As exhibited in Table V, China results as the country that carries the largest risk, with a result of 35.74 percent, being followed by India, with 32.71 percent, and Brazil, with 31.55 percent. This is highly consistent with the information that we found with respect to the elements that were taken into account for performing this analysis.

It is important to observe that China has consistently obtained the greater values under Local and Foreign Manufacturers, with the exceptions of Government and Chance as well as Economic Trend. This is

〈Table VI〉 The Final Results : BO/CR Ratio

	Brazil	India	China
Benefits	0.2686	0.1955	0.5361
Opportunities	0.1790	0.1783	0.6426
Costs	0.3352	0.3982	0.2665
Risks	0.3155	0.3271	0.3574
<i>BO/CR Ratio*</i>	<i>0.1047</i>	<i>0.0617</i>	<i>0.8336</i>

* Normalized Values

mainly because of the strong position that Brazil and India manufacturers have in their local arena.

VII. Final Results

The following Table VI contains the results for the overall Benefits, Opportunities, Costs, and Risks network. It shows that China is the most attractive country to export steel, followed by Brazil and India. The results are consistent with the output of the other networks. Clearly, China is the best in all the networks but in the Risks network. Even though China is most risky country, it gives us the best opportunities and benefits at the lowest cost. The second best country results to the Brazil. The advantages from Brazil over India were basically, much better benefits and slightly better opportunities, lower costs and risks.

VIII. Conclusion

We could use the model to determine which of the three selected countries is the best to export steel from Korea. The initial objective was to use the model for any country and we come up with the following guidelines to apply it to any selected set of

countries.

- ◆ Select the countries of interest.
- ◆ Gather data and information about the country in terms of:
 - General economic indicators including demographic and geographic
 - Government policy
 - Industrial climate
 - Import regulation and duty
 - Trade and foreign investment policy
- ◆ Analyze and classify the information
- ◆ Compare similarities and differences among the selected countries.
- ◆ Substitute those countries in our networks.
- ◆ Perform the pairwise comparisons.
- ◆ Analyze the results and check consistency with the information gathered.

We find interesting that the model is useful to come up with the best choice among countries with similar characteristics and non-evident differences. For example, it was clear that China has lower barriers of entry and lower costs than the others two. Therefore, the model is helpful to assess countries with complex and similar characteristics to judge.

Another important finding is that this model reflects the relation of how the elements affect the selected alternatives and at the same time what is more important for these alternatives among the elements. For example, in our networks, we consider

relationships in which we selected which were the most important country regarding one criterion, and on the other hand, we consider for each country which criterion was more important. Therefore, we consider the model as a consistent tool that includes all the possibilities and that can reflect problems from the real world as a mathematical abstraction.

We may use this case as a prototype for implementing Porter's diamond framework in the ANP model, which could be later used as an absolute model in order to assess competitive advantage of an industry in country or a market.

〈Acknowledgements〉

We are grateful to Professor Thomas L. Saaty who provided us with an opportunity to make researches in Multiple Criteria Decision Making, particularly in the ANP as well as the AHP, at the Joseph M. Katz Graduate School of Business, University of Pittsburgh.

REFERENCE

- [1] Abreu, M. and Verner, D., *Long-Term Brazilian Economic Growth: 1930-1994*, OECD, 1997.
- [2] Asian Development Bank, *Key Indicators of Developing Asian and Pacific Countries*, 1995.
- [3] Brandao, A.S. and Carvalho, J.L., *Trade, Exchange Rate, and Agricultural Pricing Policies in Brazil*, The World Bank, 1991.
- [4] Chai, J.C.H., *China: Transition to a Market Economy*, Oxford Univ. Press, 1997.
- [5] Korean Iron and Steel Institute, *Report on the Korean Iron and Steel Industry*, 1997 (Korean).
- [6] Nyrop, R. F., *et al.*, *A Country Study: Brazil*, 4th ed., Headquarters, Department of The Army, 1983.
- [7] Porter, M.E., *The Competitive Advantage of Nations*, The Free Press, 1990.
- [8] Reuvid, J., *Doing Business with China*, Gresham Press, 1994.
- [9] Saaty, T., *Decision Making with Dependence and Feedback: The Analytic Network Process*, RWS Publication, 1996.
- [10] Saaty, T. and Takizawa, M., "Dependence and Independence: From Linear Hierarchies to Nonlinear Networks", *European Journal of Operational Research*, Vol.26(1986), pp.229-237.
- [11] Saaty, T., *The Analytic Network Process: Guide, Manual and Examples*, Expert Choice Inc., 1996-1997.
- [12] The Korea Development Bank, *Korean Iron and Steel Industry Trends, KDB Economic & Industrial Focuses*, March, (Korean) 1996.
- [13] The National Statistical Office, *1996 Based Preliminary Report on Mining & Manufacturing Survey*, December, (Korean) 1997.

- [14] US Department of State, *1996 Country Reports on Economic Policy and Trade Practices*, January, 1997.
- [15] US Department of State, *Background notes: Brazil*, July, 1994.
- [16] US Department of State, *Background notes: China*, August, 1993.
- [17] US Department of State, *Background notes: India*, November, 1994.
- [18] Worden, R. L., et al., *A Country Study: China*, 4th ed., Headquarters, Department of The Army, 1988.