

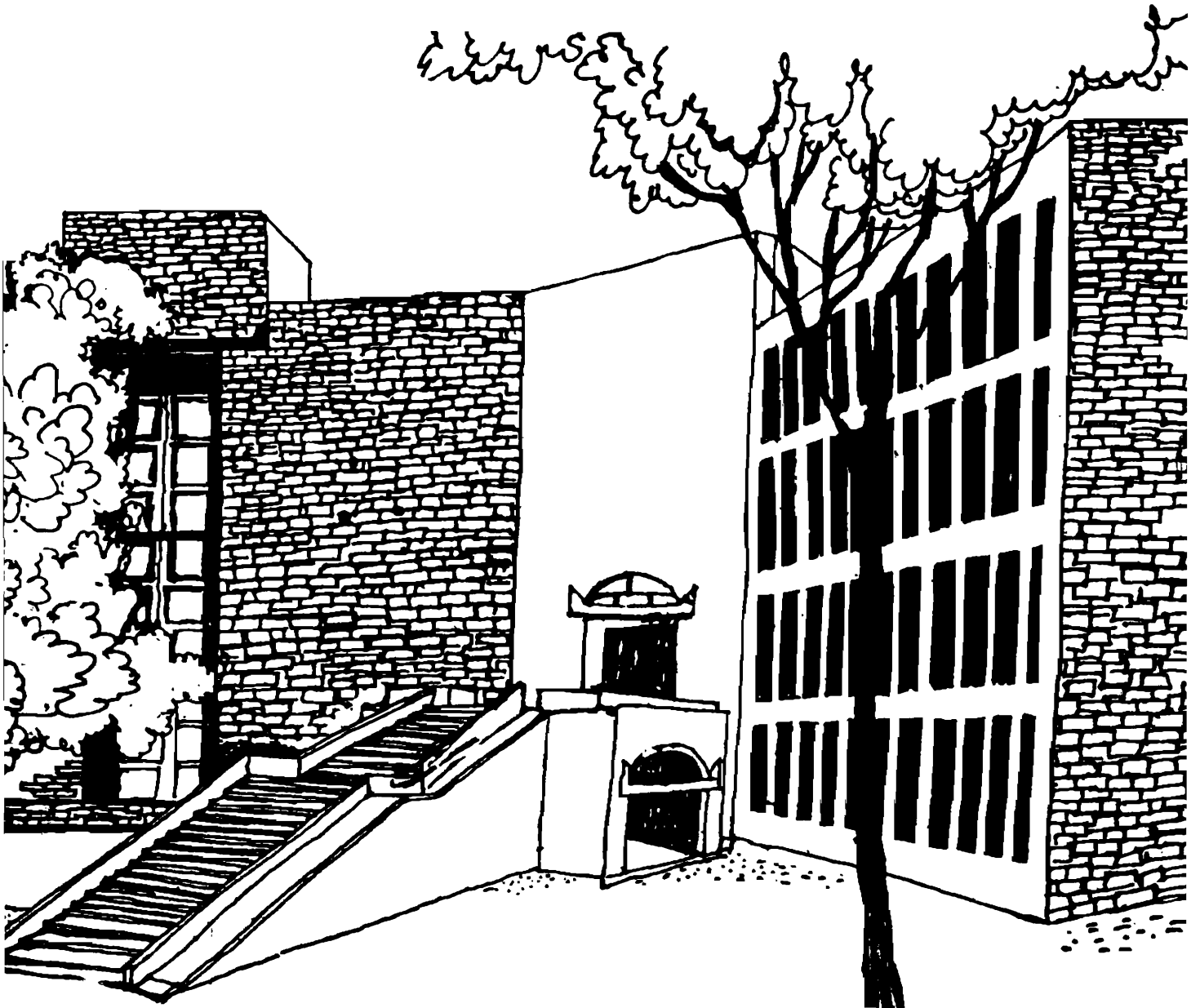


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Working Paper



OPERATIONS RESEARCH FOR DEVELOPING
COUNTRIES: A DIFFERENT VIEW

By

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Operations Research for Developing Countries: A Different View

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Abstract

In this paper, we discuss the recent success stories of operations research in developing countries. Personal experiences in developing two similar mathematical models for two steel companies (one in a developing country and another in a developed country) are discussed. Most interestingly and contrary to the common belief, the model used in the developing country was found far more successful than that used in the developed country. We conclude this paper with a list of action programs for making OR more useful in developing countries.

1. Introduction

Operations Research (OR) has been gaining increasing significance in developmental economics. It has been assumed in many studies (Rosenhead and Bornstien, 1990; Patel,1995; Gass, 1990; and Gass, 1991; Tripathy,1996) that operations research in developing countries needs to take a different approach from that in developed countries. There have been discussions on barefoot OR and poor people's OR. Poor infrastructure, non-availability of right and rich data, lack of faith in scientific decision making in government, and lack of systems approach planning in public and private sectors are assumed to be the bottlenecks of OR applications in developing countries. While several papers have been written about the failure of OR in developing countries, very few have discussed the success of OR in developing countries. The absence of success stories probably leads one to believe that either OR does not apply to a developing country or OR practice in a developing country is different from that in a developed country.

This paper is motivated by the experience of the author while developing a large-scale optimization model in a steel plant in India (Dutta et al, 1990 Dutta et al, 1994, Sinha et al, 1995,) in 1985-1991. During the same period, an initiative was taken in a US university (Fourer, 1997) to develop a similar but more sophisticated model. The author joined the US university as a doctoral student and as a part of his study (Dutta, 1996) was responsible for the development of the OR model for US steel companies. However, this model developed with the "state of the art optimization technology" was less successful than the Indian model based on "old optimization technology". As a counter-argument, this interesting experience strengthens the observation that OR in a developing country is no different from that in a developed country.

In this paper we discuss the recent success stories of OR in developing countries and try to find some generic guidelines for OR successes in developing countries. In the third section, we discuss the experience of developing a model in an American steel company. In this section we also discuss the similarity of OR in developing and developed countries by bringing cases from outside India. While demonstrating that OR in a developing country is not much different from that in the developed country, we question the validity

of the assumption that OR is technology transfer. However, we give a different prescription for making OR more relevant in developing countries.

We conclude the paper by indicating the future directions for improving the effectiveness of OR in developing countries. The paper may be slightly biased towards India and the United States because these are countries where I spent the maximum number of years.

2. OR Successes in Developing Countries

In this section we describe eight recent successful OR applications in developing countries. Our definition of success is very strict and we consider only those applications which have been selected as finalists in the Franz Edelman Prize Competition or have received top awards in the INFORMS Prize Competition. In other words, we are applying the same standard that we apply to developed countries. We have considered only publications of the last twelve years in *Interfaces*. Of these eight cases, six cases were reported in the last five years.

2.1 Integrated Production Planning of Poultry in Brazil

This is an original and pioneering work (Tabue-Netto, 1996) in SADIA, Concordia, Brazil. SADIA is the largest poultry producer in Brazil processing over 300 million chickens and 11 million turkeys in a year. Aided by UNISOMA, the OR/MS Group of the company, SADIA has been using mathematical programming models since 1990. These large-scale optimization models have helped to take major planning decisions, such as: how many and what flocks to grow, when to slaughter the flocks, what products to produce at each of the processing plants, etc. The company saved more than 50 million US dollars over a three-year period. The other benefits were better conversion of feed to live bird weight, improved delivery and reduced lead time, improved serviceability, and improved production plan with 100 per cent order fulfillment. The study is generic and is adaptable to diverse production practices and applicable to other animal processing industries. This is probably the first time that OR techniques have been implemented in the poultry industry in any country (not necessarily a developing country)

with such a huge impact.

2.2 Strategic Decision Support for Egyptian Cabinet

This study (El-Sherif H., 1990) was a joint venture of the American University in Cairo and the Egyptian Cabinet. The objective of the study is to develop and implement DSS (Decision Support System) for a series of applications such as formulating policy for customs tariff to the management of national debt, water planning for hydro-electric power generations, pricing the energy utilities, irrigation, and general administrative decision making. The projects were driven by macro strategic issues or need for management and technological development in establishing decision support systems in different ministries, sectors, and governments. This experience suggests that management of institutionalization is as important as model-building. The DSS has been implemented in managing 28 large projects in the Egyptian Cabinet starting from 1985.

2.3 Planning Coal and Electricity in China

This project (Kuby et. al, 1995) was a joint venture of the Transport Division of the World Bank and the State Planning Commission of China. The GNP of China grew at 8.9 per cent in 1981-90 and at 10 per cent in 1990-95. China produces about 1.1 billion tons of coal (1994 estimate) and will need 1.6 billion tons of coal in 2000. Transportation bottlenecks, growing pollution, coal and electricity shortages are becoming critical and threatening the double-digit growth of the economy. To address this problem, the State Planning Commission and the World Bank developed a decision support system (DSS) consisting of a large mixed integer linear program, Geographic Information System, and related sub-models. The core of this DSS is a multi-sector, multi-commodity, multi-period, multi-nodal optimization model that has been applied in several government decisions concerning GNP growth, coal investments, and various capital investments including increased investment in rail capacity. The estimated benefit from these models was about 6.4 billion US dollars.

2.4 Energy Distribution in Steel Company in India

Energy strategy is one of the constraints of rapid economic growth in a developing

country like India. Rapid industrialization and poor capacity utilization of power plants make the operations of energy consuming industries like integrated steel plants extremely difficult. Two publications by [Dutta et. al, (1994) and Sinha et. al, (1995)] discuss the development and implementation of a mixed integer linear programming model for optimal distribution of electrical energy in an integrated steel plant. The model considers the balance equations of capacity, material, thermal and electrical energy, and oxygen. It also considers the constraints of yields, product routes, net realizations, variable costs, market demands and commitments to decide not only the hierarchy of shutdowns in the event of a power crisis but also the optimal product-mix at each level of power availability. Round the clock implementation of the model increased the net profit per ton of saleable steel by 58 per cent in 1986. The model, which is generic in nature has been successfully integrated into the decision making process. The net benefit to the company was 73 million US dollars in 1986-87 and similar proportional benefits in the last ten years. This study demonstrates that a simple deterministic model, which is integrated to the planning process of the company, can make significant impact in a process industry in a developing country.

2.5 CIM Implementation in Truck Company in Mexico

This study (Nuno J.P. et. al., 1993) demonstrates the power of partnership between a developed country (US) and a developing country (Mexico). The truck manufacturing company was a joint venture of between PACCAR and the Vildososa family in Mexico. This joint venture later developed into a strategic alliance of Center de Enseñaza Tecnica Superior, Mexico (a Mexican university) and Arizona State University (an US university). The partnership launched a world-class manufacturing program to modernize Vilpac. The strategic thrust included planning and simplifying work. The project had direct measured quantified impact: 70 per cent reduction in work in process, increase in market share from 43 per cent to 59 per cent, increase in net profits from 23 million dollars in 1989 to 38 million dollars in 1991, and reduction in the total fixed cost by 26 per cent.

This is also a case of successful cross-cultural co-operation as the team consisted of

North Americans (Americans, Canadians and Mexicans) who had different cultural backgrounds, but all of them wanted to succeed and create a world class manufacturing environment.

2.6 OR Success in San Miguel in Philippines

San Miguel Corporation is an internationally renowned beer company based in the Philippines. It employs 40000 people and generates 4 per cent of the gross national product of the Philippines (2 billion dollars). Since 1987, the company has used a number of OR models in capacity planning, product-mix optimization, site location, distribution, fleet sizing, vehicle routing, risk management, banking, and marketing (Horner, 1993). The company has grown very rapidly from 1987 and has built 22 manufacturing plants with the help of OR models. These models have been integrated in the planning process of the company and a number of managers have been trained in OR. The successful implementation of these models has resulted in savings of millions of dollars.

2.7 South African National Defense Planning

A joint study (Gryffenberg et. al., 1997) by the South African National Defense Force (SANDF) and Deloitte and Touché addressed this question: "In the absence of conventional military threat, what should be the size and shape of SANDF?" The project team took advantage of an historic opportunity to restructure the military establishment and implemented several OR/MS based models: a risk model of probability and potential impact of various defense contingencies, a growth model of growth potential structure elements, a zero-based cost model, a mixed- integer programming model of all relationships, and a manual model allowing the user to experiment with different tasks and strategies. When fully implemented, the new structure for SANDF will save over \$1.1 billion dollars year representing a reduction of 22 per cent in costs. It is interesting to note that the President of South Africa, Dr. Nelson Mendela, commended the work.

2.8 OR Application in the Forest Industry in Chile

Timber is the second largest industry in Chile. Bosques Arauco S.A is the consortium of

five Chilean timber companies: Bostal Arauco, Forestal Arauco, Forestal Mininco, Forestal, and Forestal Millalemu. A study (Epstien et.al. 1999) describes the successful application of OR in the Chilean forest industry. The team developed five different systems that improved efficiency while having a positive impact on workers' life and ecology of forest plantations. The systems include a daily truck scheduling system (ASICAM); a short-term harvesting system (OPTICORT); a harvesting equipment access road location optimizing system (PLANEX); a medium range planning tool (OPTIMED); and a long-term strategic planning tool (MEDFPOR).

The impact of these systems has been considerable: Bosques Arauco reporting total savings of 5 million dollars a year over an annual production of 140 million dollars. Since implementation in 1989, the five major firms have reported minimum annual savings of \$17 million. It is equally impressive that these units have also reported up to 25% savings in operational costs.

2.9 Critical Analysis of Success Stories

We summarize the OR successes in developing countries in Table 1. We have found that OR successes have taken place in four continents: Asia, Africa, North America and South America. In four of the eight cases there was joint collaboration between an agency of a developed country and one of a developing country. In the rest of the cases, OR success has taken place without foreign collaboration. In Table 2 we list some of the economic attributes of those countries where OR success has taken place.

Most of the countries have all the attributes of a developing country as discussed in a study Bornstein and Rosenhead (1990): widespread poverty, malnutrition, high birth rate and overpopulation, high level of foreign debt, high level of inflation, gross disparities of income distribution, poorly developed institutions, and political instability.

The early success of OR in developed countries and early failures in developing countries might have prompted Bornstien and Rosenhead to treat OR as technology transfer. A

Table 1						
Comparison of OR Successes in Developing Countries						
Country	Firm/Institution	Industry	Methodology	Savings (USD)	Solo/Joint	
Brazil	SADIA	Poultry	Mathematical Programming	50 Million	Solo	
China	State Planing Commission	Energy	Mathematical Programming	6.4 Billion	Joint	
Chile	Bosques Arauco SA	Forestry/Timber	Multiple Techniques	17 Million/Year	Solo	
Egypt	Cabinet of Egypt	Government	MCDA	Not Reported	Joint	
India	Tata Steel	Metals	Mathematical Programming	73 Million/year	Solo	
Mexico	Vilpac	Manufacturing	No of Models	15 Million/year	Joint	
Philippines	San Miguel	Liquor	Mathematical	10 Million/year	Solo	
South Africa	National Defense Cabinet		Programming No of Models	1.1 Billion	Joint	

Table 2									
Diversities of Developing Countries where OR Success Have Taken Place									
Country	Economy (GDP)	Per capita GDP	Population	Population Growth rate	Energy Consumption per capita	U5MR	External De	Female Literacy	
	(Billion USD)	USD	Million	Percentage	kWh		(billion USD)	Percentage	
Brazil	976.8	6100	162.66	1.160	1589	55.30	94.0	83.30	
China	3500.0	2900	1210.00	0.980	593	39.60	92.0	72.70	
Chile	165.5	11600	14.79	1.277	1730	10.39	26.7	95.00	
Egypt	171.0	2760	67.58	1.910	695	72.80	33.6	38.80	
India	1408.7	1500	952.11	1.710	314	71.10	97.9	37.70	
Mexico	721.4	7700	95.77	1.870	1239	25.00	155.0	87.40	
Philippines	179.7	2530	74.48	2.180	278	35.90	41.0	94.30	
South Africa	215.0	4800	41.74	1.760	3558	48.80	22.0	81.70	
(Source : Central Intelligence Agency, World Factbook, 1997)									

major consideration of is that OR is technology transfer from a developed to a developing country and this assumption gets considerably weakened in the four major success stories. It is true that OR was first started in developed countries, however if winning Edelman Prize is considered a criteria can we say that the UK and France is far ahead of other developing countries? Till now winners have come from USA, Canada, France, Chile, Netherlands, India and South Africa. San Miguel from Philippines as developing country received INFORMS prize on Practice (then known as ORSA Prize for Practice) on the second year of starting this prize.

We do not disagree with the theory of underdevelopment as suggested by Bornstein and Rosenhead. However, even if they have considered a large number of studies on underdevelopment, their focus is on considering OR as technology transfer from a developed country to a developing country. We have a different view on OR, and recommend that OR should be considered as research in operations (Hillier and Liberman, 1996; Larson, 1992) or means of change for improvement with quantitatively oriented analysis. These changes may come from MS/OR/IE/DSS. Another study (Glen and James, 1980) discusses how ready availability of washing machines at subsistence pay undermines the market for washing machines in India and the Philippines. Low wage and high availability of street sweepers undermines the market for mechanical street cleaners. However, the writers have either ignored or not anticipated the effect of the electronic revolution. Availability of low wage clerks has not undermined the need for computer professionals in India. At present India is capable of exporting software worth over two billion US dollars and many major software manufacturers are considering India and China as the source for low wage high skilled labor. A major criticism against their (Glen and James, 1980 and Bornstein and Rosenhead 1990) argument is that they have not separated "Third Wave" industries (Toffler, 1981) from "Second Wave" industries. Toffler considers information technology as a third wave industry whereas washing machines, automobiles, and street sweeping machines are second wave industries. While defining OR success and failures we may have differences in first wave, second wave and third wave industries and their marketing in developed and developing world. For example from the above study we may have the following questions:

It is possible to have a third wave industry grow in a developing country (third world)?

Can this third wave industry based in third world find a market in the developed country?

Answers to the above questions may not be known and would need future research.

In this section, we have shown eight high class OR Success stories in developing countries. The studies by Bornstein and Rosenhead these success stories were either not described or have not taken place. In addition to the Edelman finalists, there are many other success stories in the developing countries which have been reported in major international journals: Interfaces, Journal of Operational Research Society and European Journal of Operational Research. In addition to that, we have the finalist entries for the IFORS OR for Development Prize Competition. We list some of the success stories where OR success has taken place without any foreign assistance:

1. OR Methodology was applied in a project evaluation system in the state economic information system (Zhang and Cui, 1996) of China is an excellent case study of application of multiple OR technique in government decision making. In 1994, this project won "Science and Technology Development Prize" by the Chinese Academy of Sciences and first prize in IFORS OR in development prize contest.
2. A mathematical model (Chaturvedi, 1996) describing transmission planning for Indian Power Grid. This project demonstrates a potential 29.75 % cost reduction or a saving of about 100 million dollars per year. The study also shows that optimal generation scheduling, suitable expenses strategy and streamlining of fuel supply schedules and suitable pricing policy can reduce the need for capacity addition.
3. A recently developed and computer implemented decision support system (Vuuren and Grundling, 1999) describes an application of linear programming model for simple decision support designed to aid reservoir managers in policy formulations and have

demonstrated a policy that was contrary to the conventional wisdom.

3. OR Practice in Developing versus Developed Country

In this section, we highlight some of the similarities of OR in developed and developing countries. The focus of our attention continues to practice of OR.

3.1 Counter example

The success story of OR in a steel company in India was discussed in the previous section. During the same time (1987-91) an attempt was made in an American university to develop a decision support system for steel plants in the United States. The model was developed jointly by AISI (American Iron and Steel Institute) and Northwestern University. The project began in 1987 and was funded by about half a dozen North American steel mills and an excellent generic model was developed. Between 1987 and 1991, no serious attempt was made to apply real data and test the model, even by those companies which funded the project. The most important criticism was that model was single-period (or static) and did not address the concerns of a dynamic (multi-period) planning system. The static model was redesigned and was replaced with a dynamic multi-period model. An American steel company that initially agreed to use the model backed out because of sensitivity of data. An initiative was made in the summer of 1994 to get data from other steel companies. But no company came forward to provide this data. In October 1994, we made another request to the first steel company that at last provided the data in May 1995. The company purchased the rights of the software from Northwestern University for using the model in its strategic planning. Yet the extent of the use of the model is not known.

This is a very interesting example, which we would like to define as reverse technology transfer with respect to OR implementation and practice. Before this project, a study of Kaiser Steel (Fabian, 1958) was the last reported work in integrated planning in US steel plants. In the seventies, some applications related to optimization of steel

industries were reported. In these studies, no apparent use of a model is reported. This counterexample demonstrates *that if an OR study is not very successful in a developed country it is not necessarily true that it would be unsuccessful in a developing country. Moreover if a study is successful in a developing country it may not be successful in a developed country.* One of the researchers associated with the study found that CEOs of large Indian steel companies have more trust in management science than the CEO of a US steel company. One study, which demonstrates the contradiction, may not be a case for generalization. This undermines the argument that OR can be considered as technology transfer. We now discuss some of the similarities of OR in developing and developed countries.

3.2 Data Consistency

A previous study on developing a mathematical model for a steel plant in India (Dutta et. al, 1994) describes that the availability of proper data is one of the problems for OR implementation. After the mathematical model was developed, the company decided to extend the model to a tube manufacturing company that was merged with this steel company. One of the most important requirements in a linear programming study is linearity of the production process. The regression equations of the total energy consumed in kilowatt-hour (kWh) and total production in tons should give a positive R-square. However, the correlation coefficients in the case of the tube manufacturing plant were found to be weak and even negative in some mills. One may conclude it to be non-linear system. Ultimately the case was referred to the electrical power department. We found that meters (measuring the electrical energy in kWh) were not calibrated for a long time. Any OR professional can go to stage one (finding weak correlation), stop the study and make a sweeping statement: "As the data are not right, OR cannot be applied in a developing country." However, if the analyst goes to the second stage (calibration of meters) he/she would find the reasons for weak correlation and would probably not come with such a sweeping conclusion.

It is our opinion that absence of rich quality of data is a problem not only in a developing country, but in a developed country as well. While developing a linear

program based DSS as part of a doctoral dissertation in an American university, a steel company in North America was asked to furnish the actual availability of manufacturing facilities in each year. The data could be used to find the expected availability of each facility through simple moving averages of last five years. The reply from the company was " We do not have suitable data". Later, we assumed the expected availability of all mills to be 80 per cent of the calendar hours. Anybody with the slightest knowledge of linear programming is aware of the likely error in such a gross generalization. The optimal profit suggested by the model is sensitive to the hours available in a year. Any modeling exercise based on this fact (that all mills are likely to be down by 20% of the time) is entirely wrong. While doing the same study in India, we assumed that the variation of the availability of a facility (mill) is caused by assignable causes and there should be reasons for downtime in each mill. This type of information is readily available in the Indian steel company, not only on a yearly basis, but also on a monthly basis. In each month the reasons for downtime are also available. This again counters the argument that data availability is a problem in developing countries alone.

3.3 Political Environment in Decision Making

A previous study (Patel, 1995) has discussed a number of cases where politicians in developing countries like India are not interested in the scientific way of decision making. However such imprudence in decision making is not the monopoly of politicians of developing countries. It may be a well-established belief that developed nations have more faith in scientific decision making. However, counter examples are also in plenty. Professor F.H Murphy, head of the modeling team at the US Department of Energy (Murphy, 1993), has discussed his frustration with the State Department of the United States. He went so far as to conclude that the incidents represent the *darker side of decision making in Washington*. Soon after he joined the Federal Energy Administration, the group analyzing internal issues produced a set of forecasts showing that world oil prices were going to rise. However, Mr. Henry Kissinger and his State Department officials refused to clear the report and demanded it to be classified. Their reasoning was that *forecasting higher oil prices would give rise to Arab ideas and actually increase the prices*. The view of the State Department won and the forecast was never published.

Murphy saw this incident as the *corruption of power and intellectual bankruptcy of the State Department.*

It is our argument that political process is an essential element of OR practice and it really does not matter whether the OR study is undertaken in a developing country or a developed country. Anybody undertaking OR studies without considering the political process of decision-making is unlikely to succeed in the long run.

3.4 Theory and Practice

Previous studies (Tripathy, 1996; Gass 1991) state that in western countries OR practice is the lifeblood of the profession. However, the reality is very different. It is known (Lilien, 1994) that the role of OR/MS in business schools is on the decline. OR professionals are getting dispersed. It is true that the number of OR applications or per capita OR applications is much higher in western countries than in developing countries. Although OR/MS (Samuelson, 1992) is considered to be one of the three fastest growing professions in the United States, it may not be correct that OR practice is the lifeblood of the profession. Moreover, lack of OR practice is a problem not only in a developing country, but also in a developed country. *Developing countries would gain a lot if they look closely to the reasons of the declining role for OR/MS in the business schools in developed countries.*

It is true that a large gap between theory and practice exists in developing countries. However, such gap exists not only in developing countries but also in developed countries. According to a study (Larson, 1992), US universities are twenty years behind applying what they know. Larson writes " Considering the allocation of doctoral students as a constraint resource allocation problem, do we need 30 Ph.D. Full Time Equivalents (FTE) working on the improved interior point methods while our national service productivity is languishing at about one percent annual improvement? Do we need 40 Ph.D. FTEs working on the mathematics of alleged flexible manufacturing problems while many have spent little time on the shop floor?" Larson further asks: " If Operations Research is the research in operations why we do not see our profession discovering more of physical laws describing ways in which the operations

work?" If the questions raised by Larson are genuine, it is difficult to assume that gap between theory and practice does not exist or that practice is the lifeblood of the profession.

Professor Stephen Graves, who was responsible for a project in China, noted that it was difficult to find a theme that would differentiate OR projects in Shanghai, from those in Boston (Graves, 1986). He noted certain differences in the availability of modern computer hardware and software. We (Dutta et. al. 1994.) also noted such problems in India According to Graves, the problems and concerns about OR modelling and implementation are seen essentially the same and the potential value from such studies appears as real in China as anywhere else.

Another study (Fisher et al. 1986) describes the most obvious difference in the US and Chinese approaches. While comparing the efficient use of physical resources, little or no importance is given to labor efficiency in China compared to that in the US. In the United States and in other countries, employers are allowed to hire and fire labor as the market demands. However, such conditions do not exist in many developing countries where labor is very inexpensive. For example, in India, labor is a fixed cost. When the power distribution model was used in India, we found that it was profitable for the company to switch off a mill (keep the labor idle and pay them) than to run it and produce unprofitable product (keep the labor force busy). Such prospects of keeping workforce idle and paying them would probably send shockwaves to US employers. Fisher noted that practice of management in China is moving in a direction that seems quite favorable for MS/OR.

4. OR Challenges for a Developing Country

In the last section we have strengthened the argument that OR in a developing country is similar to that of the developed country. Does this mean that OR in developing country is non-subject (Rand, 1986)? Does this mean that we do not need a special forum for developing countries? We certainly need a special interest group in the IFORS. IFORS has started a series of initiatives, which have resulted in a several milestones. OR

in Development Prize Competition which has been started from 1987, is now a well designed event in ICORD (International Conference for Operational Research in Development) took place in 1992 in Ahmedabad, India, and later moved to Brazil (1996) and the Philippines 1997. The next conference is scheduled in Mexico on 2000.

While the effort made by IFORS is welcome, the focus of OR in developing country needs a serious change. It is also our firm belief that OR can play a significant role in developing economies.

Developed countries have made a gross mistake by neglecting the human relations side of decision making and this has resulted in a condition where OR became less relevant to problem solving in an organizational setting. Several authors (Ackoff, 1979, Rosenhead 1996) have highlighted this issue. Unfortunately, developing countries are repeating the same mistake. It is our opinion that developing countries, possibly at this point, need not focus their research efforts on the fastest code on the interior point algorithm. Even in the Indian context, while manufacturing and service productivity is so low, top engineering and business schools doing extensive research to find a better algorithm (which will reduce the solution time of a "NP-hard" problem by one per cent) may be questioned. This type of research may be a gateway to success, which is defined, in the western academia, but should not be the prime objective of top rated institutions in a developing country. Developing countries should, instead, concentrate on actual use of models in different areas of applications, which can improve the profitability and productivity of manufacturing and service sectors. *If a steel company in India, a company in the Philippines manufacturing liquor, a poultry farm in Brazil or forestry in Chile can save millions of dollars by applications of OR modeling, it is necessary that we closely duplicate these successes and translate these successes in other countries.*

4.1 Teaching OR Differently

The business school problem is practically becoming a crisis in the developed countries (Lilien, 1992). OR is taught differently at the Colorado School of Mines which is known as the guild system of education. A series of publications (Woolsey, 1981; Woolsey, 1993) describe how this system works. The training method at the School of

Mines is important. The students are asked to go and work, as frontline persons in the organization (like a soldier in the army). This exposes the students to practical /political part of the problem which is as important as the mathematical part. While mathematical, statistical, or analytical part of the work is important, the political part is generally ignored in teaching OR. Woolsey makes it more relevant by making the quantified benefit and certification by the employee as a must for degree requirement. The student will have to pass the criteria of an academic examination committee and an organization will have to certify the project of the student. Larson (1992) says that OR should be taught as research in operations. He teaches an “OR Practicum” course at MIT where the students are exposed to the complexities of real world implementation. An interesting concept is developed by Samuelson (1992) who discusses the need to develop into the minds of the students the fact that OR/MS is not a set of techniques but a uniquely productive way of looking at things. Many a time we teach the students that OR is nothing but a set of well structured mathematical tools: linear programming problem, inventory control problem, markov chains, dynamic programming, etc. In reality, these are set of techniques or ways of improving productivity. While addressing a real world situation, the student should focus at structuring the problem first and not apply a set of techniques. In the Indian steel company example (Dutta, to appear), we observed that the standard queuing models have failed to provide a solution, but the simple graph sheet came to the rescue. In this case we did not need a sophisticated mathematical or statistical model. *Focus in OR teaching should move from technique orientation to implementation orientation.* As long as we implement what Woolsey or Larson preaches and practices, OR is going to be relevant irrespective of where it is done.

4.2 Developing OR Consultancy as a Career

A unique feature in developed countries is the availability of firms that are consulting in OR alone. In a developing country, it is very difficult to find a consulting firm specializing in OR and management science. Firms labeled as OR companies are more of information system consultants than OR consulting firms. According to Patel (1996), these firms are concentrating more on the conventional MIS/Database/ IT applications, rather than using management science. However OR has not developed to

an extent that software consulting firms can sell the concept and run a business successfully in a developing country. Even if there are firms-like Tata Steel or San Miguel in developing countries where OR is identified as corporate activity, it is a fact that OR is becoming more of a consulting profession and less of a corporate activity of a large company. It will be extremely beneficial if we can help to develop some consulting firm in the area of MS and OR in the developing country. The suggestion is not to have a branch of an international consulting firm, but an indigenous consulting form specializing in OR. This can happen only when the young entrepreneurs take OR consulting as a profession.

4.3 Encourage More National OR Societies

The United Nations has about 190 member states. Of these 190, only 45 members are members of IFORS. INFORMS have a membership of 12000 and the OR Society about 3000. It is estimated that the total membership of OR professionals in 45 nations will be about 35,000. So about 145 nations are not represented in IFORS and do not have a national OR society. We need to stress that most of the nations that do not have a national OR society are either from the former Soviet Union or are developing countries. We find that Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and Vietnam are not members of IFORS. These countries need OR for faster development and OR professionals need them too. IFORS has a role to play to develop national societies of OR in these countries.

Even if all the 45 nations have a national OR Society, not every national OR society is in good shape. For example, the Operational Research Society of India, probably one of the oldest societies from a developing country, is suffering from contrasts and contradictions. It is very scary that the membership is decreasing for the last few years.

4.4 Encourage Contests in Developing Countries

The Prize Contest for Developing Countries is a step in the right direction by

IFORS. It is also encouraging that finalists of such contests are given free registration in IFORS as an incentive. However, such steps would not promote OR in developing countries to a large extent. Even the registration fee is waived; participants do not have enough funds to travel to IFORS conferences. A better approach is to promote a national level contest in each developing country. In the United States, a unique feature is the College of Practice of Management Science in INFORMS. OR in the United States went very theoretical in 1970 (Little, 1991). In order to promote applications, the College of Practice on Management Science started a prize competition, which identifies and recognizes award applications. This remarkably well designed event, now called the Franz Edelman Prize Competition, and has completed more than 25 years. A recent effort by INFORMS is encouraging dissertations that are relevant to practice by starting a Dantzig Dissertation Prize Competition. So, it is our belief that OR needs competitions and marketing in developing countries. In order to catch up with developed countries, developing countries need to compete. It is the lack of competitive spirit for developing countries not having caught up with developed countries. If the Edelman Prize can be started to promote applications, the Dantzig Prize can encourage research in practice. It is time that developing countries start making serious efforts to start national level contests.

4.5 Improve Media Focus

One of the reasons for OR not having made an expected impact is the absence of right media focus. OR has made substantial contributions by saving billions of dollars across the globe. It has made significant impact in various disciplines like health care, banks, and stock markets, manufacturing organizations and decision making in the cabinet. However, the amount of publicity that OR has received is very little. A primary reason for this can be attributed to the fact that OR has not been marketed well in both developed and developing countries. To cite an example, Tata Steel became the first organization from a developing country to win the Edelman Prize. However, the impact this had on the Indian corporate sector, Indian business schools, and OR academia in India is marginal.

It is interesting that OR for developing countries is taught as an elective course in

London School of Economics. No such course probably exists in other parts of the developed world. We are not aware of any North American university offering such a course at the graduate or doctoral level. Although development of such courses was identified in several IFORS conferences no concrete steps were taken. We believe that marketing a new course in this direction will benefit both developed and developing world.

If OR needs to survive and maintain its position it is absolutely essential that OR is marketed appropriately. Even if OR professionals have saved billions of dollars in industry, they are not richer by the same degree. Marketing of operations research is more such a problem in a developing world. Most national societies in developing countries need to focus on and improve their marketing skills to promote OR.

4.6 Involve EURO and INFORMS

The Institute of Operations Research and Management Science (INFORMS) of the United States is the largest national OR society in the world. EURO is a conglomeration of different OR societies of Europe. INFORMS and EURO represent that part of the world which have the highest per capita income and almost all countries are developed nations. The membership of INFORMS is over 12000 and is distributed all throughout the world. So far, the concept of OR for development initiatives has come from UK, Japan, and some other Commonwealth countries. A large number of immigrants in developed countries are from developing countries. An initiative should come from these professionals in developed countries to study problems in their country of origin to play an active role in promoting OR. For an example, persons of Indian origin can play a very active role in promoting OR in their country of origin. However, it is matter of great regret that an Indian professional studying in a top American university will be more interested in studying the Intelligent Vehicle Highway System problem than improving the transportation system of Calcutta or Delhi. The efforts taken by IFORS are praiseworthy, but not enough. While IFORS can have its initiative in its triennial conferences, a similar special interest group in EURO and INFORMS will be more than

welcome.

4.7 Emphasis on Quality Management

During to lack of resources, most developing countries are unable to produce quality goods and services. As goods are not of international quality, they cannot generate revenue to invest in modern technology. Since they do not have modern technology, they are not in a position to produce goods of international quality. This vicious circle needs to be broken.

The way to break the circle is to produce quality goods at low levels of investment. Modern quality engineering principles like robust quality and quality engineering should be in any an OR curriculum. OR professionals in developed countries neglected quality management principles. It is unfortunate for OR professionals that the Malcolm Baldrige Prize or the Demming Prize replaced the Edelman Prize as the Nobel Prize of business. OR professionals in developing countries should incorporate quality management principles with a major thrust for improving competitiveness and export performance.

4.8 More Emphasis on Younger People

The students of today are the practitioners and the teachers of tomorrow. To be effective OR societies of developing countries must concentrate on developing students' chapters. In many developing countries students' chapters either do not exist or do not make any effort. As for my personal experience being a student member of ORSI (1981-1990), I did not have a voting right. However, once I was a student member of INFORMS (1992-1996), I enjoyed the same status as any other ordinary member. Even being a student member of INFORMS it was possible for me to organize a set of invited sessions at the IFORS-96 conference in Vancouver. I was seriously thinking of starting a new sub-division on steel industries in INFORMS. This was possible only after ORSA and TIMS decided that student members should be given the same rights as non-student members. A similar thinking in this direction will be more than welcome for developing countries.

4.9 Emphasis on Problem Structuring Methods

In most OR courses, the emphasis is on solving a set of problems having a rigid mathematical structure? However, in the real world, understanding of the problem is much more important. It is easy to see that different people perceive the problem in different ways. Studies by a number of authors including Rosenhead (1993) deal with the understanding and structuring of problems. These methods are popularly known as the soft OR methods and are taught in the United Kingdom. These soft methods are not a substitute to hard OR (strong analytical and mathematical techniques) methods, but complement to hard OR. In most developing countries, simultaneous teaching of hard and soft OR is desirable.

4.10 Politics as a Career

Politics has been considered to be a no-entry zone for OR professionals. However, in reality, politicians take most of the decisions, which affect the life of millions of people in a country. Many a time, we have found that a good study based on OR principles could not be implemented if politicians did not like it. Kissenger's rejection of Murphy's idea is an example in the developed country context. In developing countries, there are numerous examples of outstanding studies not implemented for political reasons. Rosenhead (1996b) points out that it will be better for OR professionals to join the political process. Consider a hypothetical situation where presidents of IFORS, INFORMS or ORSI later become a member of parliament, member of the congress or prime minister of the country. Is not such a scenario be desirable for the OR community? By joining the political set-up OR professionals have a higher chance to influence the decision making process. It may be a nice idea the idea that politics should not be considered as a no-entry zone for OR professionals is worth considering.

6. Conclusion

OR is the research of operations. It is not only a set of tools: deterministic or stochastic modeling. It is a productive way of looking at a problem for system improvement. Such improvements can be accomplished with or without mathematical models. The core of OR is not only mathematics but the implementation process also. The success of OR depends on implementation. Since many OR successes have taken place in developing countries without the assistance of developed countries, it cannot be bracketed as technology transfer. In certain situations, knowledge of mathematical modeling helps in structuring the decision making process, but emphasis in teaching OR should move from study of formulation and solution to implementation of recommendations.

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Contribution Statement

For last three decades, OR for developing country has grown up as a separate Discipline. There is a strong viewpoint that OR-approach in a developing country needs to have a different direction than the OR-approach in a developed country. With personal experience of working with two similar models for 11 years in the steel companies in two different countries, the author had a very different experience to this traditional viewpoint. OR in developed country (USA) was found to be less successful than the developed country (India). The author challenges the traditional viewpoint with additional literatures and shows that OR in developing country is not different from OR in developed country. A different prescription is suggested for making OR more relevant in developing countries. OR teaching should change its focus from modeling to implementation.

