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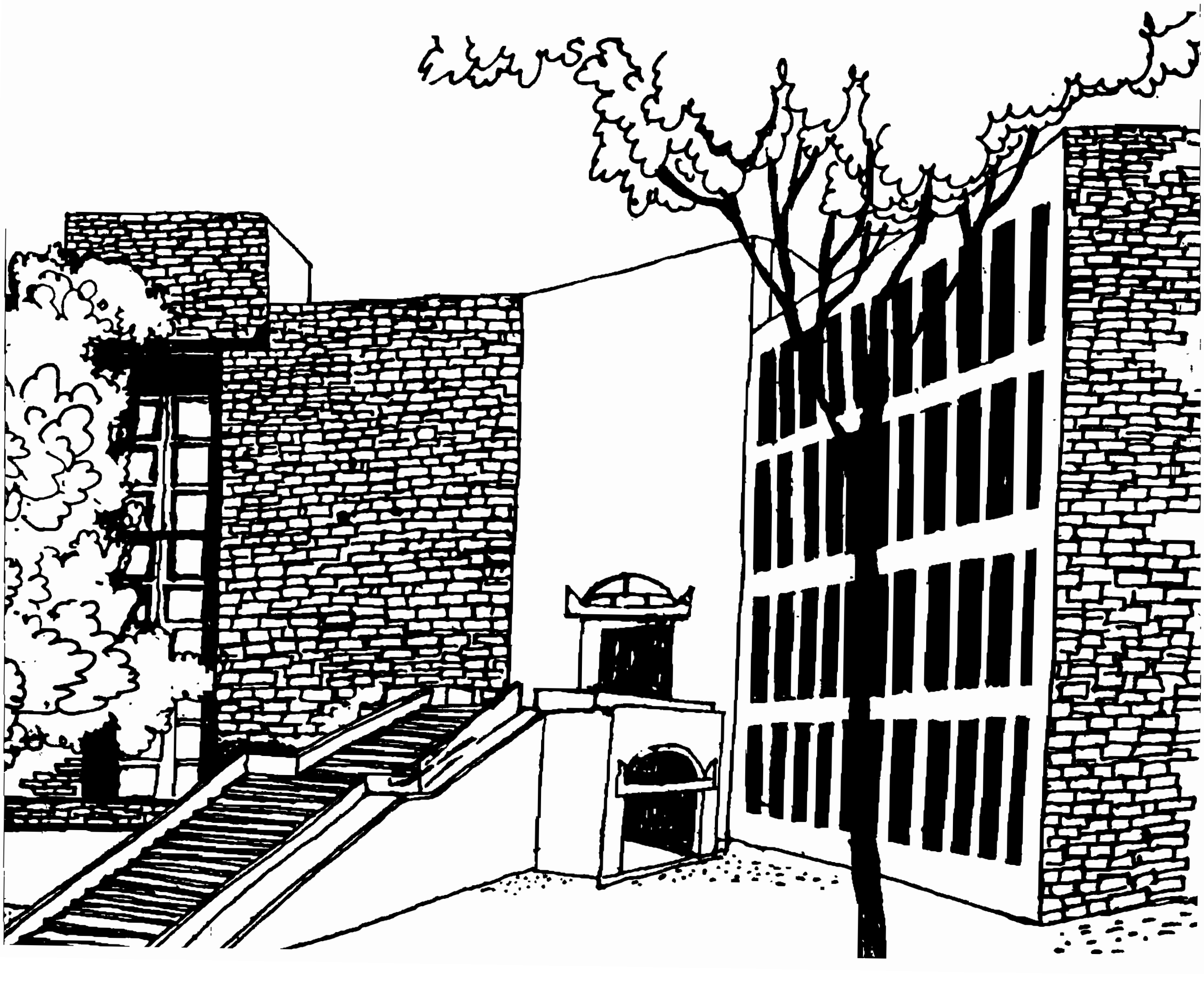

LESSONS FOR SUCCESS IN OR/MS PRACTICE GAINED FROM EXPERIENCES IN INDIAN AND US STEEL PLANTS

By

Goutam Dutta

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Goutam Dutta

Indian Institute of Management

Ahmedabad, India 380015

Abstract

I worked on modeling integrated steel plants in India (as an analyst) and in the USA (as a doctoral student). The following factors influence the successful OR/MS practice: positioning of OR/MS in Operations and not in Research and Development, selecting the right problem, emphasising on problem solving and not on model building, learning lessons from failures, right academic and practical training of OR teams, experiences of working in the shop-floor of a factory. Universities should give more emphasis in teaching OR as research in operations and to the process of implementation.

Key Words: OR/MS Implementation, Mining/Metals Industries

After a team of Indian OR/MS workers won the 1994 Edelman competition with a report on successful OR/MS study of a very large steel plant, Gary Lilien asked, "What is this plant doing with respect to OR/MS practice and implementation that other steel plants are not doing?" What follows is a partial response based on experience in India and observations in the US.

Background

After earning an undergraduate engineering degree in India, I spent two years in a training program in a large Indian steel company. In this company, I gained some experience in various divisions, including project engineering, information technology services, and the OR/MS group of the company, where the OR/MS approach to solving applied problems captured my interest. My colleagues went into project engineering, operations engineering, maintenance engineering, design engineering, and so forth, but I chose operations research. I later earned a doctorate in industrial engineering and management science at Northwestern University in a program centered on the problems of a steel company. I was able to validate the work of my doctoral dissertation with actual data from the operations of a US steel company and to gain an overview of OR/MS activities in US steel companies. During this period, I also acted as a consultant to an American steel company.

OR/MS in the Administrative Hierarchy

The steel company analysis program at Northwestern gave me a chance to compare the status of OR teams in the organizational hierarchy in India and in the US. I also looked into the relationship of OR teams with respect to plant operations. I observed that the head of the OR/MS group in US steel companies generally reported to the head of research rather than to someone in charge of operations, which gave OR/MS a research focus rather than an operations focus.

In contrast, the OR group at the steel company in India where I worked reported to an official responsible for operations. New ideas for managing operations, therefore, were put into practice promptly. To emphasise this operating focus, the group was called the " Plant Engineering and Process Analysis Group," not the "OR Group."

This posture was the result of an interesting history. During the period 1978 to 1983, the assistant general superintendent for maintenance saw the need for an OR group to help the plant engineering functions, a view that became stronger when he was promoted to be general manager (works). In this part of the company, the head of the plant engineering group had a doctorate in industrial engineering and operations research. He guided his group into works problem solving. While the general manager (works) had no formal training in OR, he understood how it could increase effectiveness in operations and save money, and it was he who determined the directions of the OR group from 1986 to 1992. Most of the OR/MS projects that were implemented, such as power distribution [Dutta et al. 1994, Sinha et al. 1995] and product-mix optimization [Dutta, Sinha and Roy, 1993] were carried out under his aegis. Having worked in operations all his life, he was sure that, to be effective, the OR/MS group should have an operations focus.

My doctoral dissertation at Northwestern dealt with a product-mix optimization problem [Dutta, 1996]. While I was completing my work, my adviser and I were invited to present our findings to researchers at a large American steel company. Since our subject was how to organize operations, we suggested that it would be useful for key operations personnel to be present at the talk. Much to our surprise, this suggestions had a negative reception; there was apparently a wide diplomatic gap between the research and operations people. The researchers did not accept the notion that research on operations should involve operations.

Observation 1: If the research and operations people have a poor relationship in a steel company, OR/MS will have better chances of implementation if the OR/MS group is part of operations rather than research.

Composition of the OR Team

In the Indian steel company, the leader of the OR/MS group had both an MBA degree and a doctorate in industrial engineering and operations research. Two others in the group were engineers with MBA degrees; another had an undergraduate degree in commerce; and a fifth an undergraduate degree in economics and an MBA. At the time, I had only an engineering degree and was studying for an MBA and a degree in operational research. Most of us had been trainees in various aspects of the company's operations and had worked in some other department, such as production, accounts, or marketing. These experiences gave us all useful knowledge about the operations of the company.

None of us had advanced degrees in mathematics, and none of us had been trained outside India. Although most of us had undergraduate majors in some engineering discipline, later experiences had broadened our outlooks. The members of the team had discriminating intellects, were willing to take risks, and were strongly driven to complete projects. Thus, our situation was similar to that of many of the earliest analysis teams who founded operations research.

We experimented with some students of mathematics; some came as summer interns. While they were very good at writing programs in the office, they were unwilling to go to the shop floor. We deemed them unsuitable for continuing work in our organization.

Was the absence of training outside India good or bad? It meant that we were thoroughly acclimated to the setting in which we worked, but it also meant that we could encounter problems that were beyond our technical mastery. For example, in 1986 and 1987, we confronted a production, distribution, and transportation problem, which could be represented by a linear program with 30,000 equations and 120,000 variables. It had constraints of different zones of Indian Railways. In each zone, a minimum number of wagons is required to form a rake (which is a series of wagons). We named this problem the rake rormation problem. We did not know then how to solve this problem so as to produce daily results in half an hour or less.

On the other hand, we were the first outside North America to win the Edelman prize as a sole company entry, and we did it without technical assistance from any country outside India.

Observation 2: To apply OR successfully requires training in operations as well as in research. This model is multiplicative: work that has value purely as research but no value to operations implementation will yield a practical benefit of zero.

Observation 3: It is easier to train an operations person in research than it is to train a pure mathematician in operations.

Selecting Problems for Analysis

Choosing what problems to work on is crucial for a new operations research team; it is important to build credibility early. It is better to reject a problem than to accept it and not deliver a solution promptly. In choosing what problems to work on, we used five criteria:

(1) What is the expected financial benefit?

(2) Who needs the solution?

(3) How does the political process look?

(4) Can we solve the problem?

(5) Do we have the resources we need to do the work?

In principle, we welcomed suggestions and assignments from any senior manager. In practice, however, we were primarily interested in working for very senior executives, such as the general manager for operations, the vice president for operations, or the managing director. Because our group was new and we wanted to build credibility, we concentrated on the projects from top management.

Nevertheless, before accepting a problem and starting work on it, we always evaluated it in light of our five criteria. For example, we rejected any project with potential savings of less than 10 million rupees (about $1.5 million at the 1987 exchange rate). We also considered the amount of effort needed for implementation and the political difficulties it might entail.

When the top managers saw a problem, they often asked different staff agencies to look at it and give their views about how to solve it; the OR group was often one of those agencies. When we could not propose a rational and well based solution within the managers' time limit, we found it better not to respond. We wanted to avoid proposing a solution based on a short-term superficial effort that might be contradicted by a more thorough analysis, a situation that would destroy the OR group's credibility.

Observation 4: Selecting the right problems is the key to the growth of a new OR team.

Model Building versus Problem Solving

In the summer of 1986, a senior executive called me in and described the problem of ingots bunching in the stripper yard. This bunching meant that many ingots could not be sent promptly to the rolling mill for further work while they were still hot, and they would have to be reheated. This caused higher in-process inventory and costs than would be the case if all ingots could move promptly to the rolling mill.

By that time, I had read Fundamentals of Queuing Theory by Gross and Harris [1985], and I thought I knew how to solve the problem. As soon as I could discern the arrival and service-time distributions, I would be able to apply the theory.

To start, I put on my safety helmet and shoes and went to the stripper yard to see what was going on. In the summer of 1986, the outside temperature was 110 degrees Fahrenheit, and temperatures in the stripper yard near the ingots could be as high as 125 degrees. Nevertheless, I had to understand how the stripping process worked and gather data on the arrivals and service times of the ingots. These data were recorded in a log book by the person in charge of the stripper yard, but he would not let me have the book, so I had to copy the data by hand.

Back at the office I tested the data against all the distributions I knew of: binomial, Pascal, Poisson, exponential, hypergeometric, and Erlang. None was close to the data.

When the senior executive called me in again, I reported that I had not been able to fit a recognised distribution to the data. His response was immediate: "Who asked you to fit a distribution? Just plot the data on a graph on a heat-by-heat basis for at least three weeks, and then let's see how it looks." I did just that.

We found that no heat was tapped to form ingots between midnight and 4.00 am; they were all tapped between 4.00 am and 7.00 am. Indeed, of the 24 hours in the day, 80 percent of the heats were tapped in only seven. Since the shop had seven furnaces, it seemed clear that their heat times could be scheduled so that a furnace would yield ingots approximately every hour, and this did not appear to be a difficult problem. This meant that it was important to find out why the delivery of ingots to the stripper yard was so uneven.

A surprise visit yielded the answers: For example, the furnace operators wanted to rest during the night, so they had an arrangement whereby any night-shift heats (that is 10.00 pm to 6.00 am) would be tapped early in the morning to 7.00 am. The shop manager soon changed the scheduling, with beneficial results.

Observation 5: The OR group must be oriented toward solving problems, not building models (which may in fact be unrealistic). For solving problems, a graph may be more useful than queuing theory.

Operations Research as Research on Operations

Larson [1992] has urged that we think of OR as research on operations and that OR students in research universities do OR projects involving real systems. He asks (pp. 36, 38), "Rather than some branch of applied mathematics, isn't OR about discovering the physics of complex systems involving people and technology ?" Before awarding an advanced degree in his program, Woolsey [1993] requires students to do the same work that is done by an ordinary worker in the factory or in service centers.

Our OR group in the Indian steel plant had a similar outlook. We considered it absolutely necessary to go to the shop floor to see how the operations we were analyzing were actually carried out. However, unlike Woolsey's students, we were prevented by company rules from doing workers' jobs. We also attended important company meetings, such as the morning address by the general manager (works) , meetings dealing with marketing, production planning, and special steel. These activities kept us abreast of what was going on in the company's operations, made it easy for managers to ask us about incoming problems, and helped us to understand potential user requirements.

Work on a problem often took members of our group to the shop floor. For example, while implementing a power-distribution model, we were asked to work in shifts. (I spent New Year's Eve of 1986 working the night shift to give guidance to the men in the central control room about where best to allocate power.) Our explorations of actual working conditions took us to such unusual places as underground mines 1,200 feet below the surface and inside the coke-ovens gas holder (where poisonous carbon monoxide gas was a deadly threat). In addition to working with the power distribution supervisors, some of us worked with the person in charge of production scheduling to see how this work was done. Most of these experiences were fun.

In my view, product-mix optimization is an important problem in a steel plant. I believe that any steel company with revenues of over a billion dollars can increase its profit margin by one to five million dollars a year by adopting the results of an appropriate analysis. I found this to be true in both India (where I worked) and America (as I discovered while working on my doctoral dissertation). Achieving such results, however, calls for great patience and a thorough understanding of the company's political processes. It does not require difficult and complex computations. Successful implementation calls for mastering both computational and political processes, although few OR people have written about the latter.

At a recent international conference, an analyst with a large American steel company said that his team had never used the integrated planning model because the data for it were never available. In my experience, analysts seldom find the precise data they need for any model. Rather, they must adapt the available information creatively and refine it to make it usable: processes that are feasible if the analysts fully understand their company's operations. To fail to model because the right data do not exist reflects a defeatist attitude.

Observation 6: I call some problems NDP (not difficult but politically) hard. These problems do not involve difficult mathematical complexities but do incorporate major political complications. Implementing solutions to such problems requires political will and skill, matters often ignored by OR's academic community.

A Learning Process

The OR group of the Indian steel company began working informally in 1983 and was recognized formally in 1986. During these three years, top management guided our evolution. Its support was critical, as we were often criticized. Top managers told us to be more applied and less theoretical: one senior manager said, "You are not doing research in an ivory tower in the Empire State Building." Then, too, we were not always successful in our projects as the following case illustrates.

The company used blast furnace technology, for which scrap is a substitute for hot metal from the blast furnace. We had in-process generation of scrap at the finishing mills, and we used to buy some amount of scrap from outside. We had developed a model for finding the optimal price of scrap that the company used in making steel. The inputs about the scrap were its composition, the internal costs of generating different types of scrap, its selling price, and the internal demand for it. The optimization principle was a simple one based on deterministic planning models.

One of the assumptions we made in this model was that the steel company could make any amount of steel scrap of a certain kind to meet a given shortage at a fixed selling price. In reality, however, there were shortages of more than one kind of steel. So we decided to find out what the shortage scenarios of scrap were for different types of steel and their selling prices. We used a stochastic model to find the optimal price of scrap, which turned out to be different from the price found with the deterministic model.

With these results in hand, the head of the OR group wrote to the senior manager as follows: " We have been finding the optimal prices of scrap with a deterministic model. This analysis, however, is based on a shortfall scenario of a single product at a given price. We have now corrected our analysis by fitting a statistical distribution to a population of shortfalls. We propose that management adopt the results of the stochastic analysis in place of the deterministic ones now in use." The manager's response was blunt " This subject is closed."

This reply sent a shock wave through the OR group. While some OR-friendly persons understood the difference between deterministic and stochastic analyses, most senior officials did not. In this case the manager was neither interested in using the OR model for the price of scrap, nor did he understand the difference between a deterministic model and a stochastic model. Who was responsible for this disaster? As Cassius says in Shakespeare's Julius Caesar, " The fault, dear Brutus, is not in our stars, but in ourselves."

Observation 7: While an OR group must understand operations know-how to do research, to succeed it must also understand the organization and its people, including what they know and how they work together.

Conclusion

In addition to shedding some light on Professor Lilien's question, one of my purposes in writing this essay is to call attention to the fact that not enough OR people are working on the problems of the process industries. The methods and practices of the steel industry, taken as a whole, are not very modern. Thus, successful OR work in this setting can yield substantial benefits.

I am also concerned that those in the OR/MS academic community seem to think that solving practical problems is less respectable than doing theoretical research and hence should not be encouraged for doctoral theses. I view this as a dangerous trend that may lead to the decline of the subject whose foundations lie in practical problem solving.

Rabindranath Tagore was the first Asian to win the Nobel Prize. Here is a poem from Gitanjali [1913, pp 27-29], his Nobel Prize winning book of poems, and my parellel poem on OR/MS:

Where the mind is without fear
[Where OR is in reverse gear]
and the head is held high
[and alpha, beta, gamma, delta are our cry]

Where knowledge is free;

[Where the world is more difficult than a minimum spanning tree]

Where the world has not been broken up into fragments by narrow domestic walls;

[Where the world has been broken up into the fragments of
theory and practice wars]

Where words come out from the depth of truth

[Where words come from the depth of untruth];

Where tireless striving stretches its arms towards perfection;

[Where tireless theorems, optimality, and bounds stretch their arms towards perfection;]

Where the clear stream of reason has not lost its way into the dreary desert sand of dead habit;

[Where the clear stream of wisdom has lost its way into the dreary desert sand of hyperplane, polyhedral and facet]

Where the mind is led forward by thee into ever-widening thought and action-

[Where the mind is never led forward by application]

Into that heaven of freedom, my Father, let my country
awake.

[Into the heavens of freedom, oh God, let my academic community (INFORMS and ORSI) awake!]

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