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RESEARCH Newsletter

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Chairperson's Message

I am glad to report that Professor Girja Sharan's work on dew harvesting as a supplementary source of water in the coastal villages of Kutch has won the India Country-Level Development Market place award for 2004. The competition received about 1500 entries in six categories: rural water supply and sanitation, health, roads, finance, electricity, and education. Professor Girja Sharan's entry was in the rural water supply and sanitation category. The award carries a citation and price money of $ 20000.

Professor Girja Sharan has also been instrumental in setting up the Cummins Foundation-IIMA Laboratory for Environmental Technology for Arid Areas. A joint effort of the Cummins Foundation, Pune, and the Institute, the Laboratory will develop appropriate technologies to solve the problems facing arid areas such as Kutch.

Noticing the arid condition, malnourished cattle, and dried-up water sources during a visit to Kutch in 1995, Professor Girja Sharan started working on developing technologies suited for hot and arid areas. The first step in this direction was the earth tube heat exchanger and greenhouse to improve agricultural productivity. There were difficulties and setbacks. Support came from unexpected quarters. A write-up in the *IIMA Alumnus* in 2000 on the earth tube heat-exchanger caught the attention of one of our alumni, Mr. Shashi Sharma, who was then working for Cummins Foundation, Pune. In no time, Cummins Foundation came forward with financial support. Since then, Sir Ratan Tata Trust, Gujarat Energy Development Agency, and the World Bank have also lend financial support for his work. The Laboratory will focus on: developing techniques of protected agriculture for arid areas, evaluating technologies developed elsewhere for adoption in arid areas, and developing management systems for making good use of the newly developed technologies.

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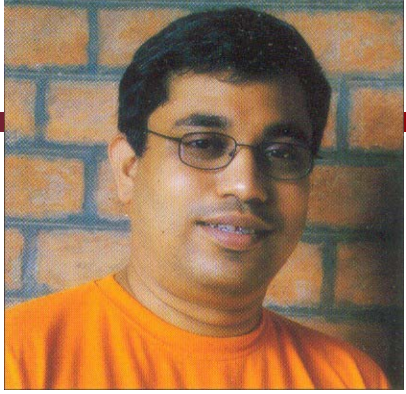

Efficient Choice of Locations for Facilities

Diptesh Ghosh

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B. Goldengorin, D. Ghosh, and G. Sierksma, "Branch and Peg Algorithms for the Simple Plant Location Problem," ***Computers and Operations Research,*** **Vol. 30, No. 7, 2003, pp. 967-81.**

B. Goldengorin, G. A. Tijssen, D. Ghosh, and G. Sierksma, "Solving the Simple Plant Location Problem using a Data Correcting Approach," ***Journal of Global Optimization,*** **Vol. 25, No. 4, 2003, pp. 377-406.**

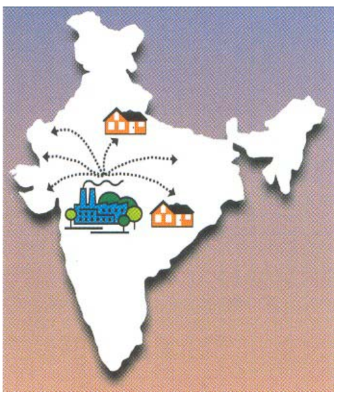
D. Ghosh, "Neighbourhood Search Heuristics for the Uncapacitated Facility Location Problem," ***European Journal of Operational Research,*** **Vol. 150, No. 1, 2003, pp. 150-62.**

B. Goldengorin and D. Ghosh, "A Multilevel Search Algorithm for the Maximization of Submodular Functions Applied to Quadratic Cost Partition Problems," ***Journal of Global Optimization,*** **forthcoming.**

D. Ghosh, B. Goldengorin, and G. Sierksma, "Data Correcting Algorithms in Combinatorial Optimization" in D.-Z. Du and P.M. Pardalos (eds.), ***The Handbook of Combinatorial Optimization,*** **Volume 5. Amsterdam: Kluwer Academic Publishers, forthcoming.**

In facility location problems the decision maker needs to choose sites to locate facilities such as warehouses, schools, and computer servers so as to serve a set of customers such as retail outlets, students, and client machines most cost-effectively. Uncapacitated facility location problems deal with situations where each facility is large enough to serve all customers – hence one does not worry about the size of the facility being set up. The tradeoff in such problems is between the cost of setting up facilities and the cost of serving customers from those facilities. These problems are solved, for example, when companies decide to locate large warehouses to serve demand in certain countries, or when governments decide on location of schools or hospitals in sparsely populated areas.

Unfortunately, these are hard problems: it may not be possible to solve uncapacitated facility location problems with a large number of candidate locations and a large number of customers within reasonable execution times. All current solution methods essentially work by analysing what happens if facilities are located in a given subset of candidate locations. The number of such subsets is typically large – for a problem with, say, 50 candidate locations the number of subsets is around 1125 trillion. So, even if a computer evaluates a million of such subsets every second, it will require more than 35 years to evaluate all subsets for such a problem. Hence, good algorithms cleverly eliminate a large number of unpromising subsets without actually evaluating them.



Professor Diptesh Ghosh and his coauthors have developed algorithms for the uncapacitated facility location problem. In the first publication they provide a new formulation of the problem, which allows them to come up with rules to decide about locating (or not locating) facilities in most of the sites, without performing elaborate computations. Using these rules, they show that conventional computation procedures can be speeded up considerably. In the second and fourth publications, the rules mentioned above are embedded in a completely new algorithm called the data-correcting algorithm. In several situations, it is possible to solve with the help of the algorithms large and difficult uncapacitated location problems (with up to 100 candidate locations and customers) in about one-tenth of the time taken by existing algorithms. A tutorial on data-correcting algorithms, the fifth publication, has been accepted as a chapter in the *Handbook of Combinatorial Optimization.* In addition the authors have also compared two of the most promising metaheuristic procedures for the uncapacitated facility location problem in the third publication. Metaheuristics are general purpose algorithms that can be tailored to provide high quality (though not always the best) solution to many problems. The results show that a popular metaheuristic procedure called tabu search is the metaheuristic of choice for solving large uncapacitated facility location problems (with up to 750 candidate locations and customers).

Logistics of Tractor Distribution in an Agriculture-Driven Economy: An Indian Case Study

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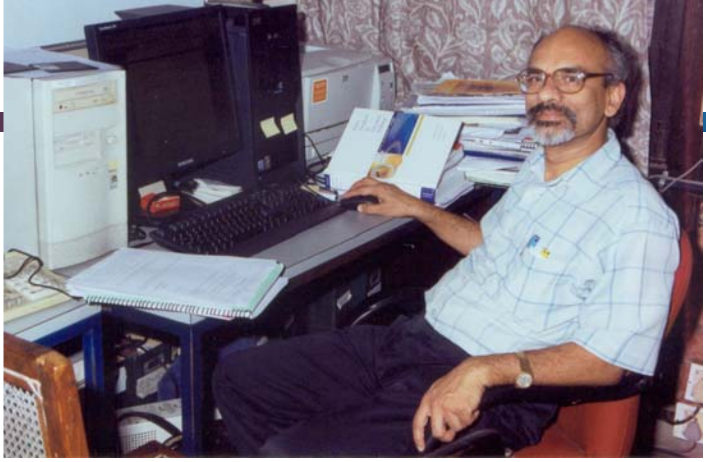


G. Raghuram, "Logistics of Tractor Distribution in an Agriculture-Driven Economy: An Indian Case Study," ***International Transactions in Operational Research,*** **forthcoming.**

This paper examines critical decision areas in outbound logistics and their analytical resolution (using OR models) for a tractor company in India. Customer preferences and demands had changed owing to the competitive environment. The challenges lay in increasing service levels to the customer through improvements in supply chain management and supporting infrastructure. Apart from value through improved service levels, cost savings of Rs 22 million per year (benchmarked against a profit before tax of Rs 1,000 million per year) could be extracted through a better distribution structure involving a new central despatch yard and revised stockyard locations.

Not surprisingly, India is the largest tractor market in the world. However, in terms of total tractors in use in the country, it is eighth in the world. The country has a tractor density of 10.5 tractors per thousand hectares of gross cropped area (GCA) compared to the international average of about 28 tractors per thousand hectares of GCA. Tractor sales in numbers increased from 1,21,106 in 1989-90 to 2,54,871 in 1998-99, giving a compound annual growth rate of 8.6 per cent.

In 1999, six major players controlled the tractor industry in India. All had been in the industry for more than 20 years. The tractor industry in India had become very competitive, with growth in capacity outstripping growth in demand. The company we studied had one factory, manufactured 15 models (four accounting for 90 per cent of sales), had 18 regional offices (each with a stockyard, one in a given state), had 300 dealers, and had sold 60,000 tractors in the previous two years. During 1998-99, the revenue was Rs 12,000 million with a profit before tax of about Rs 1,000 million. These figures were achieved with 7,000 employees. Until 1997, the company's sales had steadily grown, ever since it started production in the mid 80s. The promoters were familiar with the automobile industry; for many decades they were making utility vehicles for the Indian market.

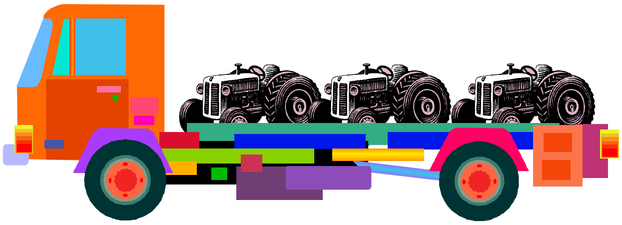
In summer 1999, as part of a major effort in organizational restructuring and business process reengineering, the company decided to engage the services of the author for a study on supply chain management, focused on outbound logistics. After an in-depth study of manufacturing, production planning, and despatch, and some of the regional offices, stockyards, and dealers, various issues and decision areas were identified. An in-company logistics team of four executives lent support to this exercise.

Significant logistical issues were: order processing and inventory planning; distribution structure (including location of stockyards and central despatch yard); and transportation related issues (optimal mode choice, partnership with railways for appropriate rolling stock and loading and unloading facilities, investing in trucks with appropriate design, and coordination between tractor manufacturers for minimizing empty back hauls).

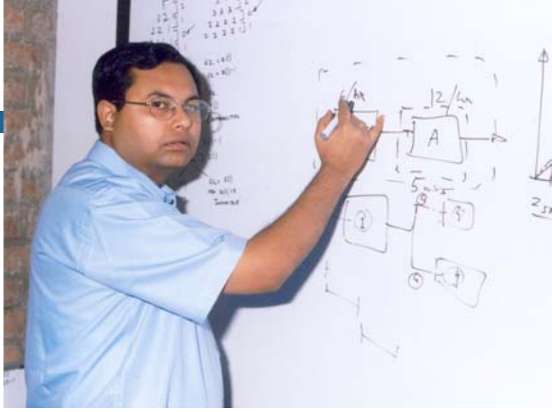
This paper demonstrates how a supply chain perspective can identify areas of improvement in the tractor industry. A zero-one ILP model could be used to optimize stockyard locations and allocation of dealers to locations, with an appropriate recognition of service levels.

The OR modelling context recognizes the changing expectations of farmers (for example, requiring the secondary distribution by trucks rather than locomotion), the changing power balance in favour of dealers (for example, their desire to minimize inventory at the dealer level and push it upstream to the stockyard but with appropriate responsiveness), and the competitive context (for example, requiring better quality during transportation and storage). The quantitative benefits demonstrated by the use of OR, with an openness to examining different scenarios, aided a much-needed mindset change from a functionally driven focus to a supply chain focus. The willingness of marketing to consider stockyard locations away from their marketing offices (given the better communication facilities) and of production to consider a two weekly production planning time bucket rather than the monthly bucket (given the possibility of better decision support for production planning) are examples.

Tractors play a significant role in improving agricultural productivity in developing countries. Consequently, methods to improve the use of this resource gain significance. With better logistics practices aided by OR, tractor firms in large developing countries like India would contribute not only to agricultural productivity, but also to the export of tractors owing to scale economies.



An earlier version of this paper was a finalist in the OR for Development prize competition of the International Federation of Operational Research Societies (IFORS) Triennial Conference, Edinburgh, 2002.



The Concept of Average Shadow Price for Managerial Decision Making

Saral Mukherjee and A. K. Chatterjee
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Saral Mukherjee and A. K. Chatterjee, "The Average Shadow Price for MILPs with Integral Resource Availability and Its Relationship to the Marginal Unit Shadow Price," ***European Journal of Operational Research,*** **forthcoming.**

The concept of shadow price of a resource plays an important part in managerial decision making. First introduced by Kantorovich in 1939, the concept has been enlarged in recent times to include buying and selling shadow prices.

The concept of shadow price is well understood for linear programmes. However, efforts to extend the concept to integer and mixed integer linear programming problems have been unsuccessful. A huge variety of real life decision problems can be formulated as integer programmes. These include a significant number of real managerial problems. A breakthrough was achieved when the concept of average shadow price was advanced for integer programmes in 1988.

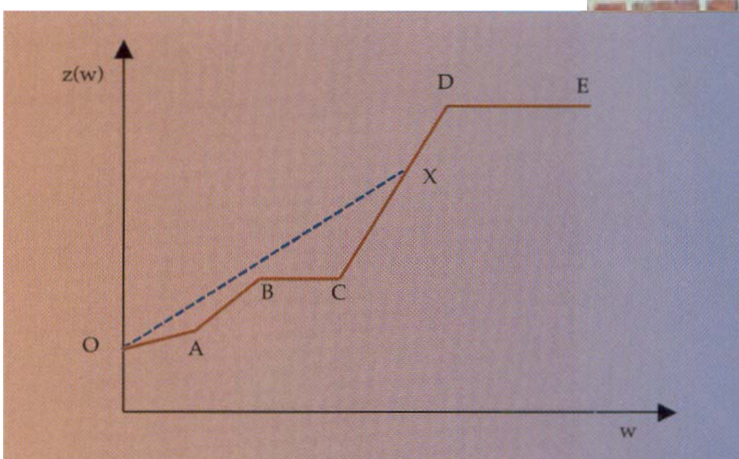
Consider the mathematical programme $z(w) = \max\{cx: Ax \le b + w\Delta b, x \text{ integer}\}$. The integer vector b representing resource availability is perturbed by adding w amounts of a package Δb of resources. Let O-A-B-C-D-E be the curve obtained by plotting the objective function value $z(w)$ as w increases and let X be any point on this curve. The average shadow price is then defined as the maximum gradient of the straight line OX.

The average shadow price obeys the complimentary slackness conditions and its existence and uniqueness can be guaranteed. From a managerial viewpoint, the average shadow price represents the maximum price per unit that a decision maker is willing to pay for buying the package of resources.

The concept of average shadow price assumes that resources can be added in infinitesimal steps. In this paper, the authors focus on mathematical programmes where some or all of the resources are available in discrete steps. Such cases occur frequently in managerial decisions since capacity may only be available in large chunks. For example, a manager of a software project may be concerned with finishing all the work at hand to meet a customer's deadline. He may wish to determine the number of additional programmers to be hired for each skill category. Note that fractional availability of programmers may have no real significance.

An average shadow price for integral resource availability (ASPIRA) has been formulated for mathematical programmes where some or all of the resources are available in discrete steps. A marginal unit shadow price (MUSP) is introduced for such a resource as the change in the objective function value when an incremental unit of that resource is available. It is shown that a sufficient condition for MUSP to equal ASPIRA is that the law of diminishing returns should be valid. Polyhedral structures that will guarantee this equivalence are identified. A significant discovery is the role totally unimodular matrices play in such equivalence. Problem classes where MUSP may equal ASPIRA even when the law of diminishing returns does not hold are identified.

The main implication of the equivalence of the average and the marginal unit shadow price lies in understanding that, in such a situation, the marginal unit shadow price would have all the economic significance that we normally associate with the shadow price in a linear programme. Such understanding may play a vital role in evaluating resource acquisition plans and defining efficient market clearing prices in the presence of indivisibilities.



What's in a Drink You Call a Chai

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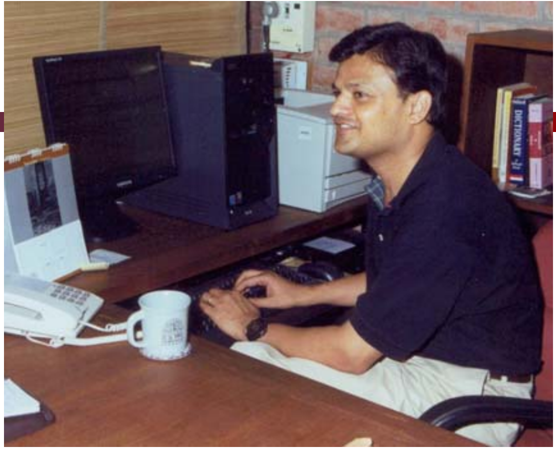

Satish Y. Deodhar and **Vijay Intodia,** "What's in a Drink You Call a Chai? Quality Attributes and Hedonic Price Analysis of Tea," *Journal of International Food and Agribusiness Marketing,* Vol. 15, No. 3, 2003.

Chai, as tea is known in various countries including Turkey, Russia, and India, is an important agricultural product traded the world over. India has been a leading producer and supplier of tea. However, India is losing its export market share to other countries. While a few decades ago the share was about 25 per cent, in the recent past it has gone below 16 per cent. Moreover, the absolute size of the domestic market is not very large to absorb the declining exports. This has an impact on the profitability and employment in the Indian tea industry. In fact, there are a number of tea brands competing in the domestic market. In this context, it would be interesting to know what consumers are looking for in a cup of tea.

To understand valuations placed by consumers on various quality attributes, we applied hedonic price analysis to data on prices and quality attributes of 43 Indian tea brands. Hedonic price analysis is based on the hypothesis that every good / brand can be treated as a bundle of various quality attributes. The good / brand is valued for its utility generating attributes, and, based on experience, purchase decisions are made by evaluating price and quality attribute combinations. Hedonic price analysis is used, therefore, to measure the relative importance of various quality attributes. Data on prices of tea brands and their scores on organoleptic (sensory) quality attributes were taken from tests conducted at the Consumer Education Research Centre, Ahmedabad. Scores of four sensory variables – aroma, flavour, colour, and strength – were used. We did control for tea types such as Darjeeling, CTC, and dust, and for national and regional brands. For estimating the relation between price and the sensory attributes, Box-Cox transformation, a methodology used to ascertain best fit to the data, was used. Based on this, an exponential functional form was estimated.

Ceteris paribus, aroma and colour seem to be important considerations in tea quality. Flavour and strength attributes were not statistically significant indicating that these attributes were not as important to Indian consumers as aroma and colour were. It must be noted that Indians drink tea with cream / milk and sugar. Moreover, preparing tea with cardamom, ginger, or *chai masala* is very common. This could explain the fact that tea flavour and strength by themselves are not important quality attributes. On the other hand, with the addition of cream / milk to tea, getting the right colour could be important. Aroma can also be experienced by smelling the dry tea powder / leaves which may give an indication to Indians about quality.

What are the managerial implications of these results for plantation owners, tea processors, and traders? Whichever type of tea the Indian consumer buys, *ceteris paribus*, aroma and colour seem to be two attributes (s)he valued most over other attributes. If possible, plantation owners may want to choose those varieties of tea that give more aroma and colour. Given the peculiar way of preparing tea in India, tea tasters may want to consider giving more weight to these attributes in developing and selecting newer blends. Moreover, brand specific advertisements may communicate these attributes to consumers. However, what is true for the Indian market may not be true for other markets. In recent times, Indian FMCG companies have bought tea companies in other countries. Similar studies could be done for other markets as well.

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