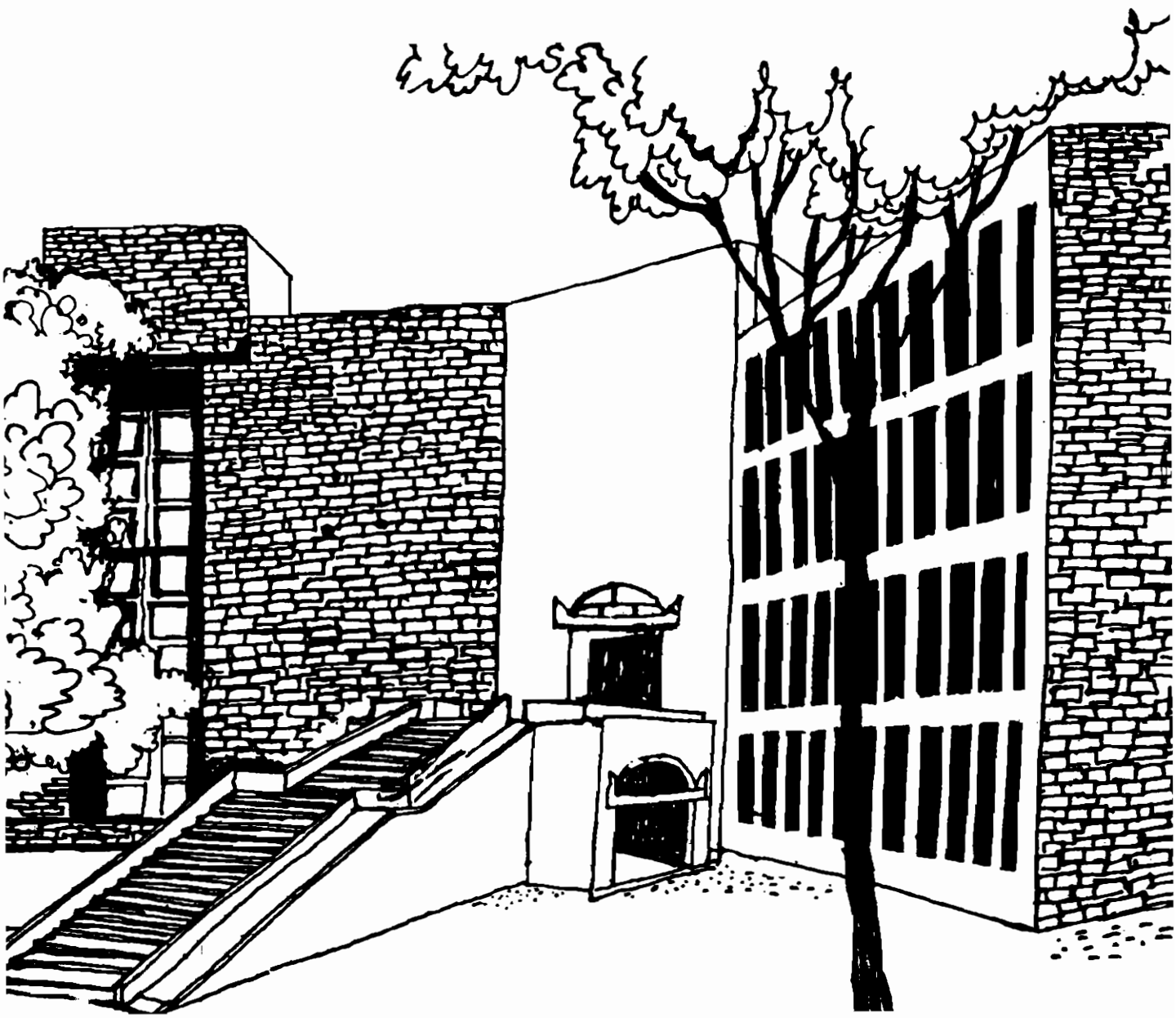
विद्याविनियोगाद्विकासः
IIM
AHMEDABAD

Working Paper



Product Planning and Diffusion Models - I

Girja Sharan

W.P. No. 1256
May 1995

Indian Institute of Management
Ahmedabad 380 015, India

Product Planning and Diffusion Models - I

Girja Sharan
Centre for Management in Agriculture
Indian Institute of Management
Vastrapur, Ahmedabad

Abstract

First purchase sales volume curve of box type solar cooker indicates that the product has passed maturity in Gujarat. We have initiated collaborative redesign work to improve the product. Central element of redesign concept is the addition of an electrical back up. This will enable users to cook food even when insolation and or ambient temperatures are low. It is hoped that this will enhance the appeal of the cooker.

It is important to estimate the market potential and the likely growth trajectory of the 'new' cooker. One of the ways suggested in marketing literature is to identify an existing product which may be 'analogous' to the new product and use it to draw diffusion related inferences. This is the aim of the present work which will be reported in two parts.

In this, first part, we review works relating to diffusion of products in India and present results of using Bass model to describe the growth of the present cooker. In the second part to be reported later, we will explore the use of diffusion models as aid to identify product analogues.

The Problem

Wood, the main cooking fuel in rural Gujarat, is increasingly difficult to get. Devices like solar cookers, biogas plants, and improved wood stoves have been introduced to alleviate this problem. The solar cookers (cookers for short) were introduced in Gujarat in 1979. By 1994, about 34000 units had been sold (Table 1). Considering the large number of households that use wood, the impact of cookers will fall considerably short of the desired level. Also, the annual sales of late, have begun to decline, suggesting that perhaps this cooker is nearing the market saturation limit.

This led us to initiate collaborative work to redesign the cooker. We are collaborating with an institution which has been engaged in R&D, testing of cookers manufactured by various manufacturers, and training of users since the early phase in Gujarat.It has contributed many improved features in the present cooker.

It is intended to add an electrical back up in the cooker. This is motivated by our view that the present cooker being vulnerable to climatic conditions (low insolation and low ambient temperatures) is not viewed by people as a reliable substitute for the conventional device. When insolation and or the ambient temperature are low, the cooker fails to cook. Low insolation, is partly

a (predictable) result of seasonal changes in solar angles at any location, and partly of atmospheric obscurity due to random local effects. The electrical backup can make the cooker usable even under sub-optimal weather. The new cooker with backup is likely to be ready soon.

Table-1
Solar Cookers in Gujarat

Year	Annual sales (no)	Cumulative (no)
1983	Not available	6725
1984	1294	8019
1985	856	8875
1986	1510	10385
1987	2566	12951
1988	3334	16285
1989	4101	20386
1990	2559	22945
1991	2666	25611
1992	3544	29155
1993	1898	31053
1994	2827	33880

Source: Gujarat Energy Development Agency, Baroda, Gujarat.

Note: Though introduced in 1979, break-up of sales data not available for the first three years.

While the work on design is on, we wish to examine some aspects of its marketing. We would like to know what could be the size of its potential market and what would be its likely growth trajectory. This will help in deciding the required production capacity. Too small a supply can constrain diffusion, too large can lead to losses. Large errors in estimation of production capacity can be especially destabilising to small enterprises which are the ones commonly engaged in manufacture of devices using newer, renewable sources of energy, like the cooker. Prior knowledge of diffusion dynamics can also be helpful in working out a launch program.

Thus, our task is to forecast the likely diffusion trajectory of the new cooker. We have data on the present cooker but not on the new one. The new cooker , although an improved version of the earlier one, is also significantly different. Mathematical models of diffusion have been used for decision making and product planning (1). We shall explore the usefulness of such models as aid in identifying existing products which could be considered as analogues of the new product (new cooker) which is yet to be launched and for which no real market data exists.

This paper reports the initial part of the ongoing work. We shall briefly review works relating to diffusion of new products. We shall be interested mainly in works of application. By that is

meant works where diffusion models were used to help make managerial decisions such as related to product planning or marketing or production. We shall model the diffusion of the existing cooker. In subsequent part, to be reported later we shall explore ways by which diffusion models could be used to identify analogues.

Review of Literature

Innovations refer to inventions that are turned into new products or devices and made available to the users through the market. Thus, solar cookers, biogas plants, improved wood stoves can be called innovations, with reference to Gujarat, although these may not be new elsewhere. Spread of these devices among users is called diffusion. It can be measured by the proportion of the potential users that have adopted the innovation.

It is generally held that the process underlying diffusion of innovation is spread of information about it among the target population. Potential adopters may get this information from the current adopters and or directly from mass media. Although, there is yet nothing comparable to Fick's laws, in the field of diffusion of innovations, considerable research effort has gone in the past decades to formulate mathematical models.

Large number of models have been proposed. Efforts are on to make these models more capable of accounting for the complexity of the phenomena. Efforts are also on to fashion models that are more general. A resume of the important models can be seen in Brown (1) and Mahajan and Wind (2).

We have not come across published examples of application (as defined earlier) of mathematical models in India. We do find works that seek to use known diffusion models to describe the data of growth of innovations or products that have been in the market for a long time. Some of these are given below.

Lavraj and Gore (3) studied the diffusion of artificial insemination services in one village consisting of about 2000 households. The agency providing service was located in the same village. They visited homes of a sample of adopters and gathered that the information about the efficacy of the service and therefore the motivation to adopt, came from those households who had already adopted. This led them to hypothesise that internal influence was the major cause of the diffusion. Accordingly they tried the logistics equation to describe the process. The equation, described the data well. They also presented a modified model to describe the diffusion from this village further into the surrounding, the hinterland.

As against Lavraj and Gore, whose work focused on one village of relatively homogeneous population, Jain *et al* (4) and Sharma *et al* (5) made country as a whole the unit of analysis.

Jain *et al* first reviewed several important mathematical models to argue that more general, unified model will be very desirable. They proposed one and showed that many models enumerated in their paper (including that of Bass) can be its special cases. In the second part of their paper they used Bass model to study the diffusion of 15 items in India. They also compiled from literature, results of using Bass's model for corresponding products abroad. Items where Bass model described the Indian data well were - sewing machines, duplicators, diesel engines, radio-sets, jeeps, typewriters, water coolers, tractors, electric fans and refrigerators. Whether some of these could be used for a new, yet to be launched product, was not within the scope of their study.

Sharma *et al* compared the efficacy of four different models including that of Bass and Mansfield, in describing the diffusion of several products in India. They also proposed a new model of their own - based on exponential logistics difference equation. They concluded that in general three - parameter models (such as Bass) fared better than two - parameter ones. Their own new model was recommended particularly for the fast growing systems.

Both the above papers have interesting aspects. Jain *et al* present results of using one model (Bass) to same product-different markets, and different products-same market situations. Sharma *et al* present results of using four different models to describe the diffusion of several products in one market.

Bass model is given in equation (2). The assumptions underlying it are given below.

1. Diffusion process is binary, i.e. there are either adopters or non-adopters; one adopter adopts only one unit of the product or innovation.

2. p, q and m (see equation 2) are constant over time; innovation too does not change in the time span under consideration.

3. The time horizon relevant for model is the diffusion phase of the product life cycle, that is from introduction to just before replacement or repeat purchases begin to be significant.

When first proposed, Bass had demonstrated the efficacy of his model by using it to describe the diffusion of 11 consumer durables in the US. To choose the interval of time for empirical work he stated, "The period of analysis was restricted in every case to include only those intervals in which repeat purchasing was not a factor of importance."

In Sharma *et al* the period of analysis of refrigerators, for instance, was 1952-1988, a span of 36 years. It turns out, refrigerator was also one of the products included in Bass's own study. The span he considered was only 20 years long. Similarly, the span for air-conditioners in Sharma *et al* study was 31 years (1956-1987) and in Bass's study 15 years. One wonders if the use of such a long span would not have jeopardised the validity of assumption (3). Jain *et al* have not given explicitly

the period of analysis for some of the items included. The question about the validity of this assumption may be relevant in their case as well.

In fact in such a long span, even the assumption about the constancy of the innovation could be called in question. We do know that cars and refrigerators did indeed not change much for a very long time in India. But advent of transistors did probably change the radio sets significantly at some stage.

The type of data used is another factor of importance in use of diffusion models. Sharma *et al* have explicitly indicated the nature of data used, which in most cases was the production data. Jain *et al* have not explicitly stated the nature of data (production or sales) in some cases. Production data will have in it replacement sales, which need to be eliminated, especially if long intervals of time are used. It is not clear if this was done.

And finally, the national boundary is equated with the market. When this is done, question of validity of the assumption about the homogeneity of the market, which is implied in Bass's model will also arise. This aspect has been discussed in detail by Redmond (6), who demonstrated that when unit of analysis is smaller subnational regions, the diffusion parameters can not in general be expected to remain the same as for the nation as a whole.

The lack of homogeneity could be due to variations in incomes, climate if the product is sensitive to it, marketing and after sales services infrastructure, communication infrastructure etc. These aspects are specially relevant for India.

The comparative results presented by Jain *et al* and Sharma *et al* do provide an opportunity to raise a point relating to the nomenclature of Bass parameters (p and q). In order to make this point we shall draw attention to table (2), which lists the parameters (p, q, m) for some of the products studied by Jain *et al.* As stated they also compared the results for corresponding products in markets abroad. We have listed only one (tractors) in the table.

Table shows that parameters (p and q) for the same product (tractors), differ considerably from one market to another. The table also shows that the parameters for several products in the same market (India) differ from each other.

Clearly, the parameters (p, q) are influenced not just by the nature of market or society but also by some attributes of innovation. Bernhardt (7) has stated for instance "that diffusion depends on the product, the potential adopters characteristics, his linkage to the social structure, change agents, and the adopters culture". Redmond(6) too citing literature has stated that "diffusion parameters are subject to a range of situational variables including product characteristics, product improvements or price changes".

Table 2
Parameters of Bass Equation

Product	Market	p	q	Estimated by
Sewing machines	India	0.021	0.058	Jain *et al*
Duplicators	India	0.011	0.090	Jain *et al*
Diesel engines	India	0.008	0.068	Jain *et al*
Radio sets	India	0.002	0.148	Jain *et al*
Jeeps	India	0.001	0.137	Jain *et al*
Type-writers	India	0.002	0.080	Jain *et al*
Water coolers	India	0.003	0.152	Jain *et al*
Refrigerators	India	0.001	0.188	Jain *et al*
Tractors	India	0.002	0.132	Jain *et al*
	Brazil	0.078	0.160	Cited in Jain *et al*
	China	0.046	0.250	"
	Japan	0.023	0.210	"
	Korea	0.0001	0.447	"
	Pakistan	0.018	0.305	"
	Phili-ppines	0.06	0.133	"
	USSR	0.03	0.036	"

Source: Jain *et al* (4)

Viewed in this way, the use of terms like coefficient of innovation (p) and coefficient of imitation (q) would appear somewhat inappropriate in as much as such nomenclature appears to ignore the attributes of the product and emphasises only the behavioral aspect of the adopters. Having drawn attention to this, we will continue to use this nomenclature because it is widely accepted.

In the above context, it may also be of interest to compare the concept of diffusion of innovation with diffusion of matter. In physical sciences diffusion is defined as a process by which matter is transported from one part of the system to another as a result of random molecular motion (8). Diffusion is driven by concentration gradient of the diffusant in the medium. Fick formulated the

basic equations describing quantitatively the process of diffusion. Fick's laws of diffusion for one dimensional case, are given below.

$$F = -D\frac{dc}{dx} \tag{1a}$$

$$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2} \tag{1b}$$

where

F	amount of material diffusing across a unit section
D	diffusion coefficient
C	concentration of diffusant
X	space coordinate
t	time

The coefficient of diffusion (D) depends on the properties of both the diffusant and the medium. By analogy one can think of the diffusant as the product or innovation and medium the market or society. Fick's laws formulated in 1885 continue to be the foundation of mass transport theory and engineering.

Solar Cookers in Gujarat

As stated earlier, our aim is mainly to determine diffusion parameters that could be valid for the new planned cooker. As a step towards that, we shall first model the diffusion of the present cooker. **Table-1** gives the data on the annual sales since introduction.

Design Changes

The cookers being marketed now are improved versions of the earlier ones. Some of the modifications were made on the basis of feedback received from the users. For a brief account of major changes made in the cooker over time in Gujarat, see Singhal *et al* (9). Early cookers were heavy, weighing about 23 kg. Now the weight has been reduced to about 11 kg. Castor wheels have been added for easy portability. Frequent breakage of glass covers has been remedied by use of polycarbonate sheets. Problem of peeling of paint on absorber has been remedied by making grooves on the surface. Altogether, present day cooker takes less time to cook, requires less frequent tracking is much lighter, has fewer maintenance problems.

Manufacturing

Gujarat Energy Development Agency (GEDA), Baroda, is the nodal organisation responsible for promotion of cookers. GEDA encourages entrepreneurs to take up manufacture, organises testing of cookers to ensure adherence to stipulated standards, disburses subsidy against sales, organises training and has prepared solar recipe book and other promotional literature.

Marketing and Promotion

Dissemination of information about cookers has ben done through newspapers, radio, TV, video cassettes and posters (8). A large number of dealers were identified at district and block level and trained. Field level workers were appointed to visit homes and motivate the people to buy cookers and use them. Housewives were trained in the proper use of cookers and maintenance. A network of dealers has been developed through which the cookers are sold.

Let us recapitulate. People living in rural areas of Gujarat have increasing difficulty getting fuelwood. Solar cooker is one of the innovations introduced to alleviate this problem. High insolation, high ambient temperatures and low cloud cover makes Gujarat especially suited for use of solar cookers.

Cookers were introduced in 1979 and promoted through the media as well as though direct efforts of the field workers. This is in addition to the information exchange that takes place by word of mouth. Thus, both the so called internal and the external influences can be said to have been at work.

The aspect that is less clear is whether the network of dealers was extensive enough to ensure that all those living in towns and villages of Gujarat had ready and equal opportunity to purchase and to get after sales services. This question is relevant because the development of market infrastructure was spread out in time.

And finally, as stated earlier, design modifications were also being made periodically based on experience and feedback. Thus, the innovation too has changed somewhat over time even though the basic design and working principle of the cooker has remained unchanged.

Choice of Model

We shall assume that the supply network was extensive enough to enable all potential adopters to buy the cooker with equal convenience. We shall also assume that cooker has remained the same, ignoring for the present the design changes made over time. We know that information about cookers was disseminated both through the media and through interaction of current and potential users. Above facts and assumptions lead us to try the Bass model. Unit of analysis is Gujarat state.

Bass Equation,

$$\frac{dN}{dt} = \left(p + \frac{q}{m}N\right)(m - N) \qquad (2)$$

where N cumulative no. of adopters, at time t

p coefficient of innovators

q coefficient of imitators

m saturation level of N

In terms of proportions, equation (2) can be written,

$$\frac{dF}{dt} = (p+qF)\ (1-F) \tag{3}$$

where F = N/m proportion of adopters

Its solution, with F(0) = 0 is

$$F(t) = \frac{1-e^{-(q+p)t}}{1+\frac{q}{p}e^{-(q+p)t}} \tag{4}$$

or

$$N(t) = m\ \frac{\left(1-e^{-(q+p)t}\right)}{\left(1+\frac{q}{p}e^{-(q+p)t}\right)} \tag{5}$$

Estimation of Parameters

The data maintained at GEDA office is of annual sales. It is reasonable to assume that each adopter has acquired only one cooker. The cooker has no moving parts. With proper maintenance, its life can be long. We shall, therefore, assume that the annual sales data is for fresh purchase only. Accordingly we used it to compute cumulative number of adopters, shown in Table (1).

We used **Equation-5** to estimate the parameters by non-linear least square (NLS) procedure. Thus the model was,

$$N(t_i) = m\ F(t_i) + e_i \tag{6}$$

where e_i error term and $F(t_i)$ as in equation (4)

Mahajan and Wind have indicated that this form is usually less satisfactory. But we found it better than the two other alternatives we tried. Using discrete form of equation (2) to get expression for annual sales and then using OLS gave wrong signs of parameter. Using equation (4) to get the expression for annual sales which Mahajan and Wind term as *ex ante* procedure did converse but the estimates of m was lower than the total number of cumulative adopters currently.

The estimates are,

p = 0.018 q = 0.186 m = 53,700

Thus, the Bass equation customised to cooker in Gujarat is

$$N(t) = \frac{53700\left(1 - e^{-0.204t}\right)}{1 + 10.3\, e^{-0.204t}} \qquad (7)$$

Figure 1 shows the comparison of the actual cumulative sales and the values computed from equation (7). **Figure 2** shows the actual annual sales and values derived from computed cumulative sales. It is seen that the model describes the cumulative sales data well. It is also seen from **figure 2** that it predicts the timing of the peak sales satisfactorily. It does not predict the annual sales satisfactorily, however.

One can use equation (7) to delineate the stages of product life cycle. The cooker would appear to be past its maturity. It is this that has led us to the view that major improvements may be needed in the product now. One can also use it to categorise the adopters, as done for instance by Rai (10) for several products in India and in several markets abroad.

Our interest is however in knowing the likely diffusion trajectory of the new cooker. We would like to know whether the rate parameters (p and q) of the existing cooker or other products referred to in the review of literature, could serve as analogues.

Figure 1

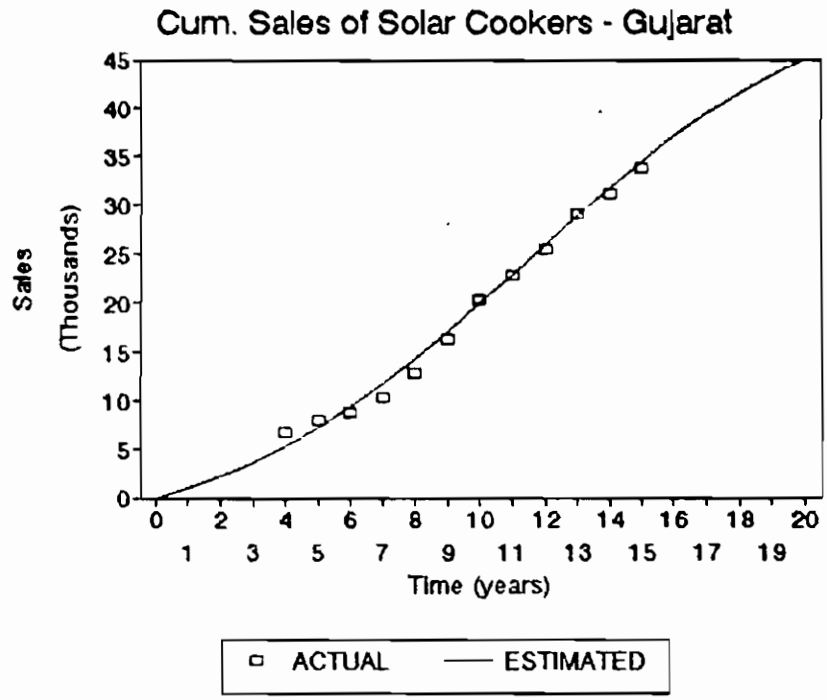
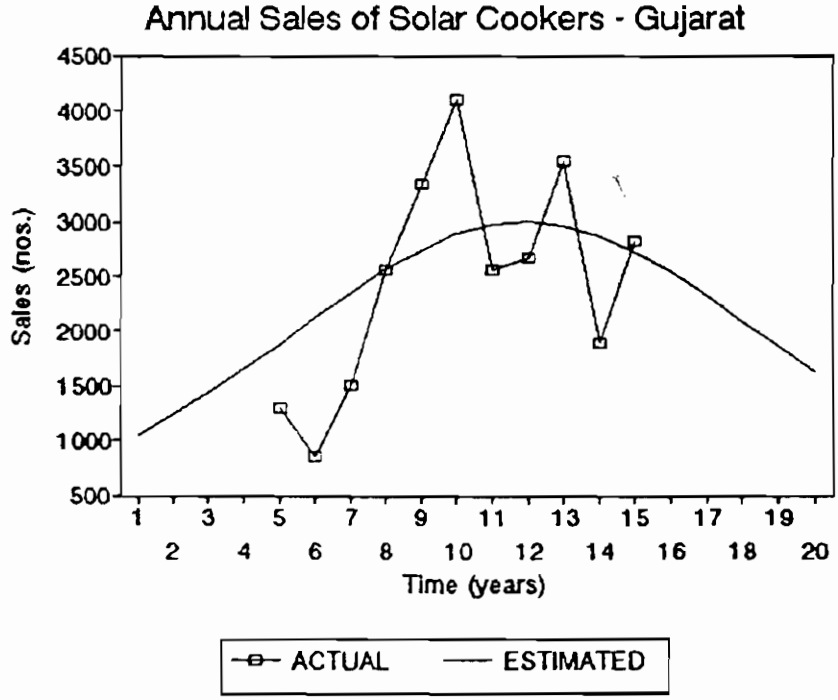


Figure 2



Diffusion Models as Aid to Identify Analogue

Bass in his original paper (11) stated "it does seem likely that for some (new) products it would be possible to make plausible guesses of parameters". The question is how should such a guess be made?

We have not come across any actual application of analogue method in Indian context. Apparently even abroad such works appear to be small in number. Kalish and Lilien (12) describe the use of analogues in forecasting the sales of a new industrial product, in France, before launch. The method used by them consisted of the following steps. First diffusion rates of a large number (112) of products was made. Diffusion rates of each was estimated from data of five year span. The relationship between the diffusion rate and a number of factors that can be observed and measured during the process of product development was established. Based on these a decision support system was developed which yields sales forecasts when the data on those factors for the new product is provided as input. The data requirement of such a procedure is quite large. It is not clear if the results are generalisable.

Sounder and Thomas (13) in a recent review indicated the need for more research in this area. We plan to examine this area more fully in our next paper. In particular we would explore the use of mathematical model of diffusion in aiding the search for an analogue.

Summary

Bass model of diffusion describes the cumulative sales data of box type solar cooker satisfactorily. It also predicts the timing of peak sale quite well. It does not describe the annual sales that well however. The model suggests that the cooker is past maturity stage in Gujarat.

A new version is planned which will have provision of an electrical backup. Forecast of the sales of the new cooker and the size of its potential market would be useful. It has been suggested by Bass and some others that in such a situation the method of analogy could be used. Actual works using this method are very small in number and to our knowledge none in India. We plan to explore this further in the next part of the work.

References

1. Brown L. (1988) Diffusion Innovation, Methcun, London

2. Mahajan, V. Yoram Wind (Ed.) Innovation Diffusing Models of New Product Acceptance, Ballinger, 1986.

3. Lavraj U.A., A.P. Gore (1992) Modelling Innovation Diffusion -Some Methodological Issues, J Sc. Ind. R. Vol. 51, March 1992, p. 291-295.

4. Jain A, LP Rai, Sushma Sharma, S.C. Bhargava (1991). Modelling Technology Diffusion - Its Basis and applications to Indian Market J Sc. Ind. R. Vol.50, July 1991, 496-515.

5. Sharma, L. Aparna Basu and SC Bhargava (1993) A New Model of Innovation Diffusion J. Sc. Ind. R. Vol. 52, 1993, p.153-158.

6. Redmond W.H. (1994) Diffusion at Subnational Levels: A Regional Analysis of New Product Growth, J Product Innovation Management, 11(3), 207-212.

7. Bernhardt, I. and K.D. Mackenzie (1972) Some Problems in Using Diffusion Models For New Products, Management Science Vol. 19, No. 2, Oct. 192.

8. Crank J. Mathematics of Diffusion

9. Singhal A.K. S.K. Philip and CS Rao: Research and Development of Solar Cookers: An Overview, In Renewable Energy Programmes. The Gujarat Experience, 1981-1991.

10. Rai L.P. (1994) Behavioral Characteristics of Adopters in Different Countries, J Scientific & Industrial Research 53, January 1994, p. 27-33.

11. Bass F.M. (1969) A New Product Growth Model for Consumer Durables Management Science 15 (1969) 215-227.

12. Kalish, Shlomo and G.L. Lilien Applications of Innovation Diffusion Models in Marketing, In V Mahajan and Yoram Wind (Eds.) Innovation Diffusion Models of New Product Acceptance, Ballinger, 1986.

13. Sounder Wm. E. and Robert J. Thomas (1994) Significant Issues for the Future of Product Innovation, J Product Innovation Management 11; 344-353.