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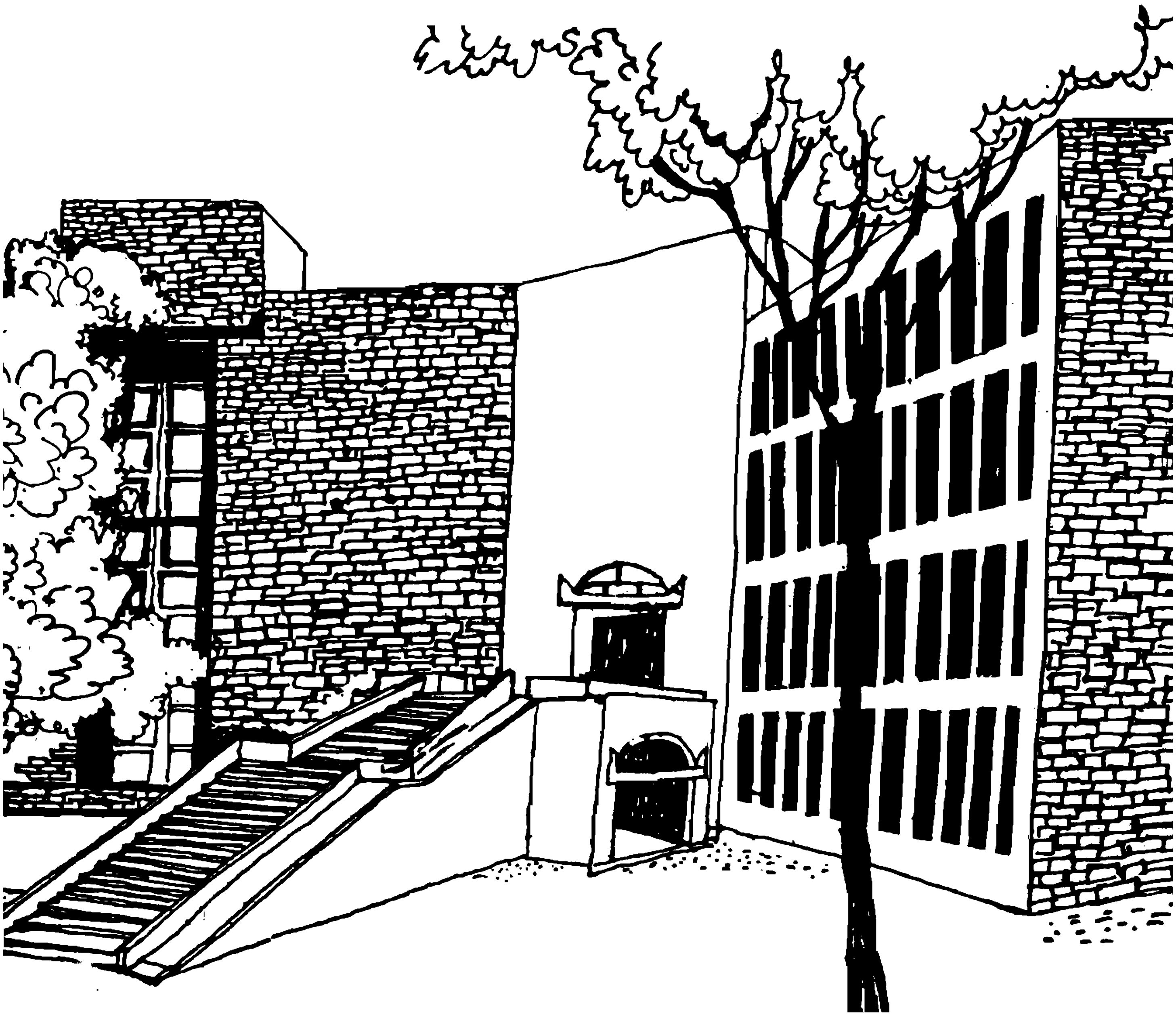

A SYSTEM DYNAMIC STUDY OF APPLE MOVEMENT FROM ORCHARDS TO WHOLESALE MARKET

BY

Girja Sharan
Sandeep Kayastha

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INDIAN INSTITUTE OF MANAGEMENT
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INDIA

A System Dynamic Study of Apple Movement from Orchards to Wholesale Market

Girja Sharan **Sandeep Kayastha**

Centre for Management in Agriculture
Indian Institute of Management, Ahmedabad

Abstract. Two northern states, Jammu and Kashmir (J&K) and Himachal Pradesh (HP) account for most of the apple grown in India. Fruit is graded and packed near orchards and sent to Agricultural Produce Market Committee (APMC), Delhi for auction. This paper presents a simulation model of fruit movement from orchards in HP to APMC market in Delhi.

Daily arrival of fruit in Delhi as predicted by the model is compared with the data on actual arrivals from records maintained at APMC. The comparisons appear satisfactory. Simulations indicate that transit delays during peak phase will be long enough to reduce the storage potential of fruit to a negligible level. Cold stores in Delhi, therefore, are likely to remain under-utilized, which is indeed the case. These results suggest that the systems dynamics approach to modelling is promising.

Key Words: apple, post-harvest movement, mathematical model, simulation, systems dynamics

Introduction

Apple is raised in two states--Jammu and Kashmir (J&K) and Himachal Pradesh (HP). In the season of 1990, 4,950,000 qtl of apple was sold through Agricultural Produce Market Committee (APMC) at Delhi. Slightly more than half (52 percent) came from J&K and slightly less (47 percent) from HP (see **Table-1**). Some fruit is grown in UP too, but as yet its contribution is negligible. Fruit that passes through Delhi, excludes the culls, pre-falls and other diverted to local markets. The total production including all these would be larger.

Table 1

Arrival of Apple in APMC, Delhi : 1990-91
(Tonnes)

Month	HP	UP	J&K	Cold Stores	Total
May '90	7	0	7	59	73
June	12	1	0	0	12
July	9741	257	8017	0	18015
August	71497	10	18750	0	90258
September	77675	0	20288	0	97963
October	53912	0	56602	0	110513
November	12604	0	79591	24	92218
December	3499	0	41872	42	45412
January	1741	0	14822	15	16578
February	315	0	10922	204	11442
March	25	0	11183	77	11285
April		0	683	86	769
May 1		0	15	7	22

Source: Agricultural Produce Market Committee, Delhi

Production has risen over the years, both in HP and J&K. But the problems in post - harvest handling have persisted in both areas. For, the early studies (Kahlon 1968, Malik 1977) as well as more recent ones (Sikka 1985) reveal the persistence of problems like shortage of labor, packaging boxes, transport and storage facilities. These studies relate to Himachal. A study of J&K fruit situation undertaken by Agricultural Finance corporation Ltd., in late 70s enumerated similar problems. Accordingly both, quality of table fruit and the prices obtained by growers are poor. Respective state governments are making efforts to modernise the industry. Improvement in orchard management, harvest methods, creation of on-site stores, introduction of mechanical grading and packing centres and removal of transport bottlenecks are part of these programmes.

In recent years some mechanical grading centres have been established in HP. Handling capacity of these is still negligible compared to the annual production. Even so these are not fully used. Himachal Pradesh Horticultural Produce Marketing and Processing Corporation (HPMC) has built cold stores in the state. Utilisation of these also is low. Orchardists apparently prefer immediate sale, as they find it difficult to organise transport off the season. In the report relating to J&K cited earlier a comprehensive program to mechanise and modernise handling, transport and stores facilities was outlined. Some of these may have come up.

In the context of effort to modernise the facilities, it appeared fruitful to develop a mathematical model of post-harvest movement. Such a model could supplement the earlier studies which mostly focused on one or other segment. While using the insights from the existing works, a system dynamic model could provide an integral view of the entire system. Second, it could yield more precise assessment of effects of various constraints, thereby indicate the facilities possibly needed.

A brief description of operations involved in movement of fruit from orchards to Delhi. It is followed by construction of a simulation model of HP system. Daily arrivals as predicted by this model are compared with the data on arrivals from APMC market records. Possible uses of the model are discussed.

Post-Harvest Movement:HP

Picking

Orchards are generally small, with an average size of 1 ha., largest not exceeding 3 ha. (Malik 1978,Sikka 1985). Average annual yield per tree is frequently quoted as 40 kg. Apparently this is mean of the productive years(i.e between 8-40 years) and will mean an yield of about 100 qtl/ha (250 trees/ha).

The harvest period and percent share in production for various varieties in Himachal is shown in **Table-2**. Commonly, harvesting is spread over 40-45 days.

Picking is manual. One crew (consisting 3 persons) can pick 3-4 qtl/day. During the span of harvest, picking could be continuous and uniform. Or the pace may vary, slow in the start, reaching a peak and then declining.

In an effort to help the growers realise better prices, the Market Information Service of APMC, radios prices to Himachal daily. This could be responsible for occasional slow down of harvest. But as picking of mature fruits can not be delayed for more than 4-5 days, the pace of harvest is likely to be influenced more by operational constraints.

Table 2 Harvest dates and share of varieties		
Variety	Harvest period (calender days)	Share in production(%)
Early	182-243	5
Red June	182-201	-
King of Pippine	186-206	-
Worcester Pormain	201-243	-
Delicious	201-263	90
Royal	201-243	45
Rich-a-Red	206-253	5
Red	213-258	20
Golden	217-263	20
Late	213-273	5
Red Gold	213-258	-
Granny Smith	222-268	-
Rus Pippin	222-273	-

Source: Sikka 1985

Grading and Packing

Grading is done manually in orchardist's godown. Fruit is sorted into three quality grades ('A','B' and 'C') and three sizes (large, medium and small). 'C' grade apples, the culls, are sold to processing units. 'A' and 'B' grade fruit is packed in 18 or 10 kg boxes and exported. A skilled worker can grade and pack 8 qtl/day.

Assembly and Forwarding

From orchards boxes are transported to road-heads or forwarding points (FPs). Local forwarding agents lift the fruit from road-heads and send it to the destinations indicated by the orchardists. From the forwarding points it is either sent directly to Delhi or to Transhipment centres (TCs) of which there are three- Kiratpur for Kullu apples, Kalka and Parwanoo for that of Shimla.

TCs also act as distributing centres. A small proportion (about 20%) is sent from here directly to northern markets, and rest to Delhi. Almost all apple is transported by trucks.

Auction

Commission agent, to whom the grower destinates the fruit, unloads it at his shed in APMC, Delhi for auction.

Storage

Delhi has 32 cold stores. Discussions with officials at APMC, and examination of data of one of the large facilities indicated that cold stores in Delhi are used mostly by wholesales and that too very little.

Modelling Approach

The objective of modelling here is to get a clearer idea of operational aspects of the system. Following assumptions are made to simplify the task of modelling.

1. All operations are continuous.
2. Orchards are lumped, so also the forwarding points and transhipment centres.
3. Prices do not affect the harvest schedule.
4. Cold stores are ignored.

The description given above and the assumptions made, enable one to draw a schematic of the entire system as shown in **fig-1a**. A close reading of the operations at the grading points, forwarding points and transhipment centres also enables one to discern a possible analogy with a simple fluid flow system as shown in **fig-1b**. Such an analogy is the basis on which modelling of grading and packing centres, forwarding and transhipment centres has been done.

Harvest Rate

Beta function was chosen to represent the rate of harvest. This was preferred since a suitable choice of parameters can yield the profiles of uniform, early or delayed harvesting (see **fig-2**). Early varieties as well as the lates have been clubbed as these contribute only 5% each. The Delicious varieties have been treated separately. Thus there are six separate harvest functions, four for the individual Delicious varieties and one each for earlies and lates.

Grading Station

Rate of grading and packing has been made dependent on the amount of fruit piled up at the orchard. That is, the rate increases when there is more apple piled up and reduces when there is less. This form was chosen as orchardists do indeed hire-in more hands when there is large stock and dispense with them when there is less. This form, of course is slightly unrealistic, in as much as the depletion rate will (theoretically) linger on when there is only a small quantity left. The practical effect however is small.

Transport

Transport by trucks requires a finite amount of time. In continuous framework this can be approximated by several cascaded first order exponential delays, of the type, used to represent the operations of grading station. Larger the number in cascade, better the approximation. Here three have been used.

As in case of grading centre, the rate of despatch from FPs and TCs have been made to depend on the amount of material accumulated, at these points.

Model

Let

t	time (calender day)
H	estimated total production in the season (qtl)
n	no of varieties grown
i	index of variety, $i = 1 \ldots n$
p_i	proportion of variety 'i' in the total production
$h_i(t)$	harvest rate of variety 'i' at time t (qtl/day)
$h(t)$	combined rate of harvest (qtl/day)
$QG(t)$	stock of ungraded apple at godown (qtl)
$g(t)$	grading rate (qtl/day)
c	proportion of culls and fruit set aside for local consumption
$QC(t)$	culls and fruit set aside for local consumption upto time t (qtl)

GF(t)	despatch rate from godown to FP (qtl/day)
FG(t)	arrival rate at FP from Godown (qtl/day)
QF(t)	stock at FP (qtl)
RF(t)	despatch rate from FP (qtl/day)
k	proportion of fruit despatched from FP to Delhi
FT(t)	despatch rate from FP to TC (qtl/day)
FD(t)	despatch rate from FP to Delhi (qtl/day)
TF(t)	arrival rate at TC (qtl/day)
QT(t)	stock at TC (qtl)
RT(t)	despatch rate from TC (qtl/day)
m	proportion despatched to Delhi from TC(%)
TM(t)	despatch rate from TC to terminal markets(Punjab, Haryana etc) (qtl/day)
QM(t)	fruit stock despatched to terminal markets (Punjab, Haryana etc.) from TC upto time t (qtl)
TD(t)	despatch rate from TC to Delhi (qtl/day)
DT(t)	arrival rate at Delhi from TC (qtl/day)
DF(t)	arrival rate at Delhi from FP (qtl/day)
QD(t)	fruit arrival in Delhi from TC & FP upto time t (qtl)

Time Constants

T1	grading at godown (days)
T2	transport from godown to FP (days)
T3	despatch from FP (days)
T4	transport from FP to Delhi (days)
T5	transport from FP to TC (days)

T6 despatch from TC (days)

T7 transport from TC to Delhi (days)

$$h_i(t) = H.p_i \left[\frac{\Gamma(\theta+\phi)}{\Gamma(\theta)\ \Gamma(\phi)} \cdot \frac{1}{HP_i}\left(1-\frac{t-HS_i}{HP_i}\right)^{\theta-1}\left(\frac{t-HS_i}{HP_I}\right)^{\phi-1}\right] \qquad ..(1a)$$

θ, ϕ parameters of Beta function

Term in parenthesis is the scaled up Beta function for variety 'i' with harvest starting on day HS_i, ending on HE_i, length of harvesting period $HP_i = (HE_i - HS_i)$.

$$h(t) = \Sigma\ h_i(t) \qquad ......(1b)$$

$$\frac{d}{dt} QG(t)=h(t)-g(t) \qquad ......(2a)$$

$$g(t)=QG(t)/T1 \qquad ......(2b)$$

$$\frac{d}{dt} QC(t)=c*g(t) \qquad ......(2c)$$

$$GF(t)=(1-c)*g(t) \qquad ......(2d)$$

EXPND DELAY3(FG(t),GF(t),T2) ......(3a)

$$\frac{d}{dt} QF(t)=FG(t)-RF(t) \qquad ......(3b)$$

$$RF(t)=QF(t)/T3 \qquad ......(3c)$$

$$FT(t)=RF(t)*(1-k) \qquad ......(3d)$$

$$FD(t)=RF(t)*k \qquad ......(3e)$$

EXPND DELAY3(TF(t),FT(t),T5) ......(4a)

$$\frac{d}{dt} QT(t)=TF(t)-RT(t) \qquad ......(4b)$$

$$RT(t)=QT(t)/T6 \qquad ......(4c)$$

$$TM(t)=RT(t)*(1-m) \quad ......(4d)$$

$$TD(t)=RT(t)*m \quad ......(4e)$$

$$\frac{d}{dt}QM(t)=TM(t) \quad ......(4f)$$

EXPND DELAY3(DT(t),TD(t),T7) ......(5a)

EXPND DELAY3(FD(t),DF(t),T4) ......(5b)

$$\frac{d}{dt}QD(t)=DT(t)+DF(t) \quad ......(5c)$$

Equations (3a,4a,5a and 5b) represent transport. These too could have been written in the form of differential equations. However, in view of subroutines available these are written directly in form of DYNAMO statement. DYNAMO is a continuous system simulation language in which the model was run.

Simulations

Case 1

No constraints on the labor, boxes, trucks or stores space at any point.

HS_i, HE_i and p_i, for six varieties(n=6), taken from **table-2**.

H(1987) = 2400,000 qtl, estimate based on industry officials understanding .

$\theta = \phi = 2$ choice influenced by the discussions with industry officials

Parameters:

c=0.20	k=0.50	m=0.60	
T1=7	T2=0.50	T3=3	T4=0.66
T5=0.29	T6=2	T7=0.33	

Harvesting begins on day 182 (July 1) and ends 92 days later (Sept-30), as modelled here (see **fig-3**). It picks up momentum when harvesting of Royal Delicious begins. The peak phase lies between days 212-248, which accounts for 80% of the harvest.

Curve A shows simulated cumulative harvest normalised against the season's total. The output, that is cumulative fruit arrival in Delhi is shown by curve B. Values are normalised against its respective total. The time lag between the harvest and arrivals in Delhi, small in the beginning, ranges from 9-13 days during the peak phase. Large part of this, 6-9 days, is contributed by grading operation and 3-4 days by transport and handling.

How do the computed arrivals in Delhi compare with the actual data? Curve C shows the cumulative arrivals in Delhi as recorded by the APMC in the season of 1987. Note the gap between the computed arrivals and the actual. We shall presently show that realistic restriction on availability of trucks in peak phase almost bridges this gap, indicating thereby the plausibility of shortages being the main causes of delayed arrival.

Case 2

APMC records the number of trucks arriving each day. It makes it possible to estimate their maximum availability. Trucks can be in short supply at FP or TC or both. For illustration constraint has been imposed only at FP.

Under unconstrained conditions, the week during which maximum amount of fruit is despatched from FP occurs between days 234-240. During this week on an average 546 trucks would be needed at FP each day. The data on trucks checking into APMC market shows that such a large number of trucks never arrived on any day. Note that the trucks reaching Delhi came not only from FPs but also from TCs. The combined number never exceeded 370 in the last season. During the peak phase the number fluctuated around 250. It was considered reasonable, therefore, to choose 300 as the upper limit for availability of trucks at FP.

With this constraint imposed, fruit will reach Delhi market as shown in curve D. The delay during the peak phase now ranges from

11 to 31 days, with average being 20 days. Note that gap between the computed curve(D) and the actual(C), is much smaller now. Reducing availability of trucks further(say to 250) can even bridge the gap.

Attention will be drawn here to the implication of transit delays. Stores quality though intrinsic to varieties, can be affected severely by long time spent in transit. Some US studies (Childer 1973) indicate that the stores life of Delicious varieties can be as long as 7 months, if apple is cooled to holding temperature of 0 °C within 7 days of harvesting. Each week of exposure in transit or stores (temperatures 21 °C) reduces the shelf life by as much as 9 weeks.

A study by Narsimham (1984) would seem to corroborate this. Himachal apples were stored after 10 days of harvesting in a cold stores in Bangalore. Temperatures varied between 0-5 °C and relative humidity between 65-95%. For Royal Delicious(large size) shrivelling reached 9% after 2 months, 25% after 3 months and 48% after the fourth. The magnitude for other varieties differed somewhat, but the trend was the same. Storing beyond 25% shrivelling was not considered worthwhile. The above will also imply that if the transit under ambient conditions extends beyond about three weeks, the stores potential will virtually be exhausted, especially as ambient temperatures in these parts are higher than 21 °C.

It was stated earlier that cold stores in Delhi are not fully used even though prices fall sharply during the peak arrivals. In the season of 1987, the prices of 'A' grade, large size 18kg box of Royal Delicious apples of Shimla started out to be Rs.210/- and dropped to Rs.130/- soon after the peak phase began and stayed at that level. The prices rose sharply to about Rs.180/- after mid-December.

In order to benefit from off-season price rise the fruit reaching Delhi must have sufficiently long (about three and a half months) stores potential. As discussed above, this is not likely to be the case for the apple coming through normal channels during the peak phase. This may, therefore, be the reason why cold stores are not fully used.

Thus, establishment of cold stores in Delhi and even keeping the orchardists informed about the daily prices, by itself will not enable them to take advantage of the facility, unless the transport is improved simultaneously.

More illustrations of constraints such as labor and packing boxes etc. can similarly be given. But the above discussion may be sufficient to indicate the utility of simulation model like this. It enables one to see the effect of various constraints clearly, making it possible to establish priorities for modernisation of industry.

Who Can Use Such Models?

The model can be used by all the agencies involved, in the apple business. It is better suited for those having large scale operations such as co-operatives and other corporate bodies. They can develop schedule for requirement of labor, trucks, boxes etc. for the entire season. The model has the provision to generate report for each day of the season. The computations such as the requirement of trucks can be useful to the forwarding agencies. Box suppliers can plan delivery schedules well ahead of time. Processing agencies can use it to plan their procurement schedule.

Further Refinement

Although the model gives satisfactory results, there are aspects that will call for further refinement. The estimate of total produce and actual schedule of harvest followed by orchardists need to be understood better. The model also needs to be tested at intermediate nodal points. Lumping, especially the orchards will need to be re-examined. The results may improve further if the model is converted into a hybrid or entirely discrete framework.

Summary and Conclusions

A simulation model for movement of HP apple from orchards to Delhi was made. Daily arrivals in Delhi as predicted by the model and as recorded by APMC are compared. The predictions and the actuals appear to similar in form. When realistic constraint on availability of trucks is imposed, besides the form, magnitudes of arrivals also come close. The model is capable of indicating day to day the resource requirement (labor, trucks, boxes etc.) at all nodal points.

Additional insights emerge from the simulation runs. Simulations show that improvement in one segment may not lead to anticipated results unless related segments are simultaneously improved. It gives clue to the handicap growers face in preventing the fall of prices during the peak phase and in being able to benefit from the subsequent price rise.

Figure 1

Post-Harvest Movement of Apple and an Analogue

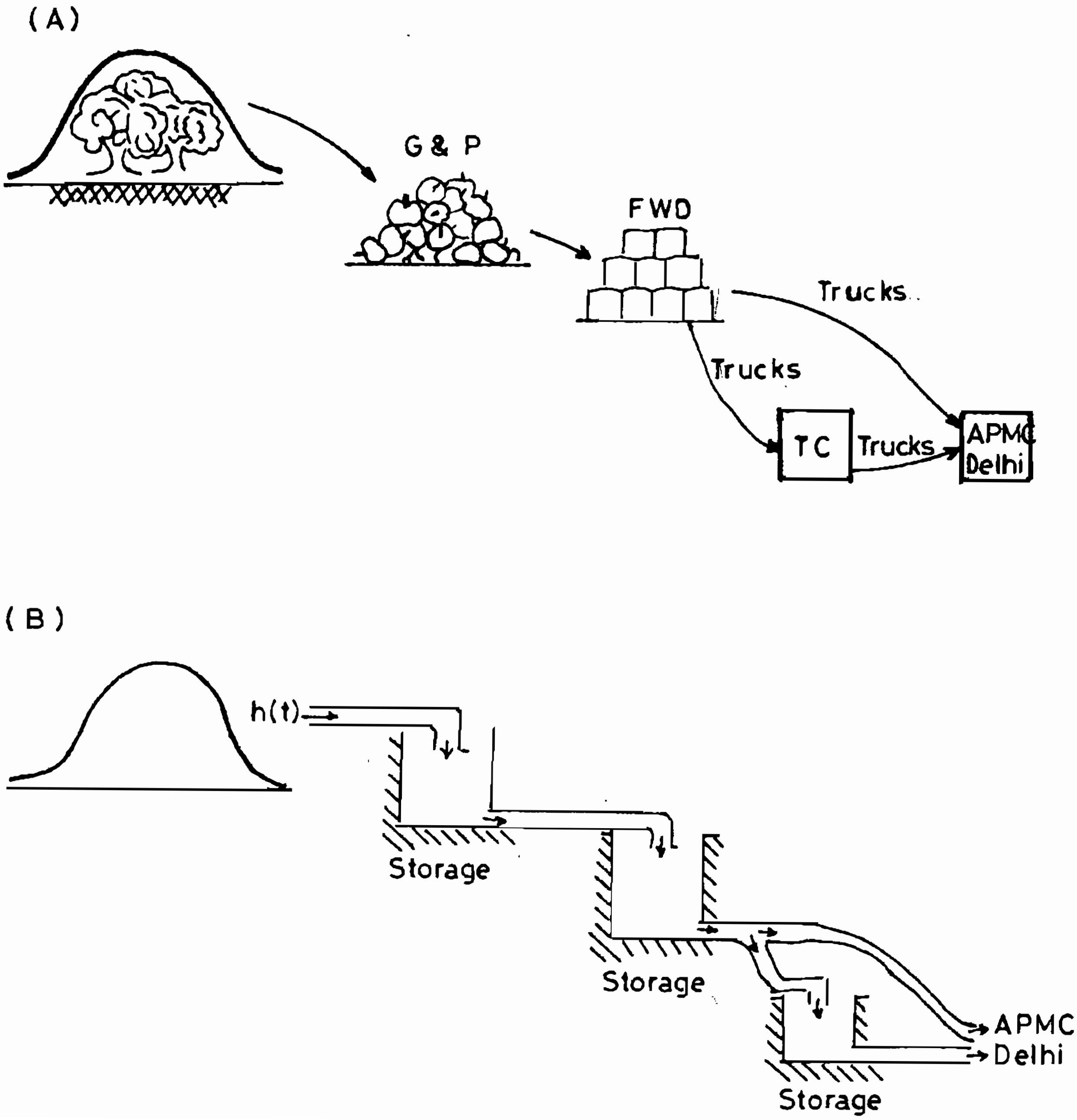


Figure 2

Beta Function - Profiles

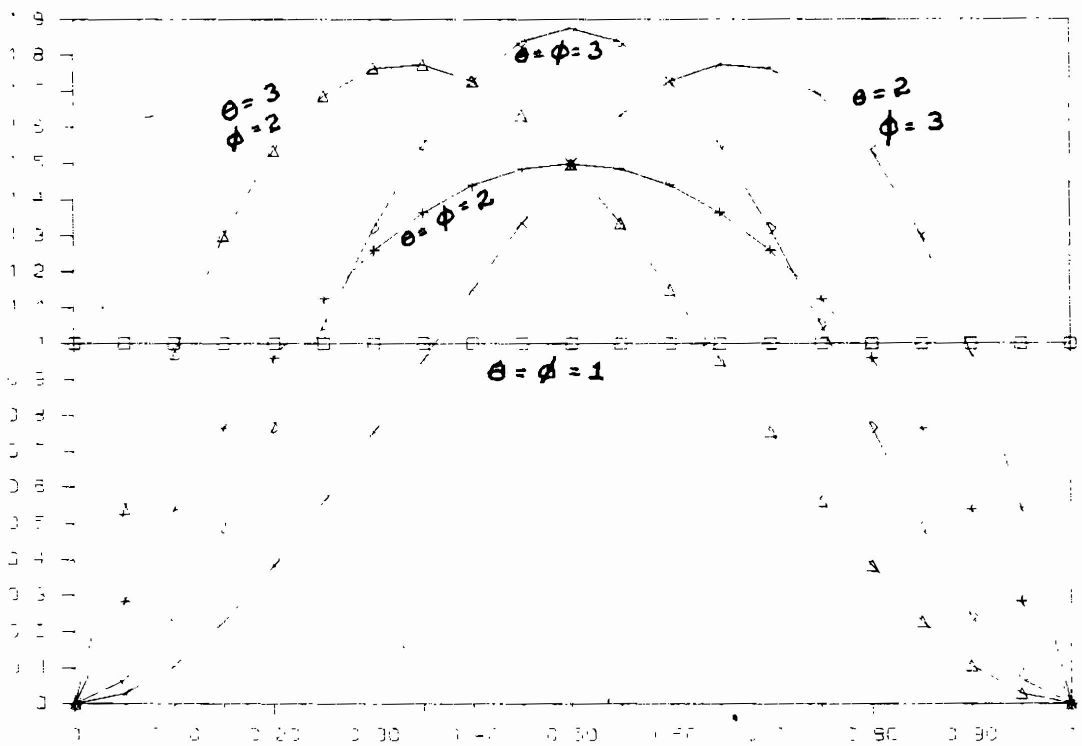
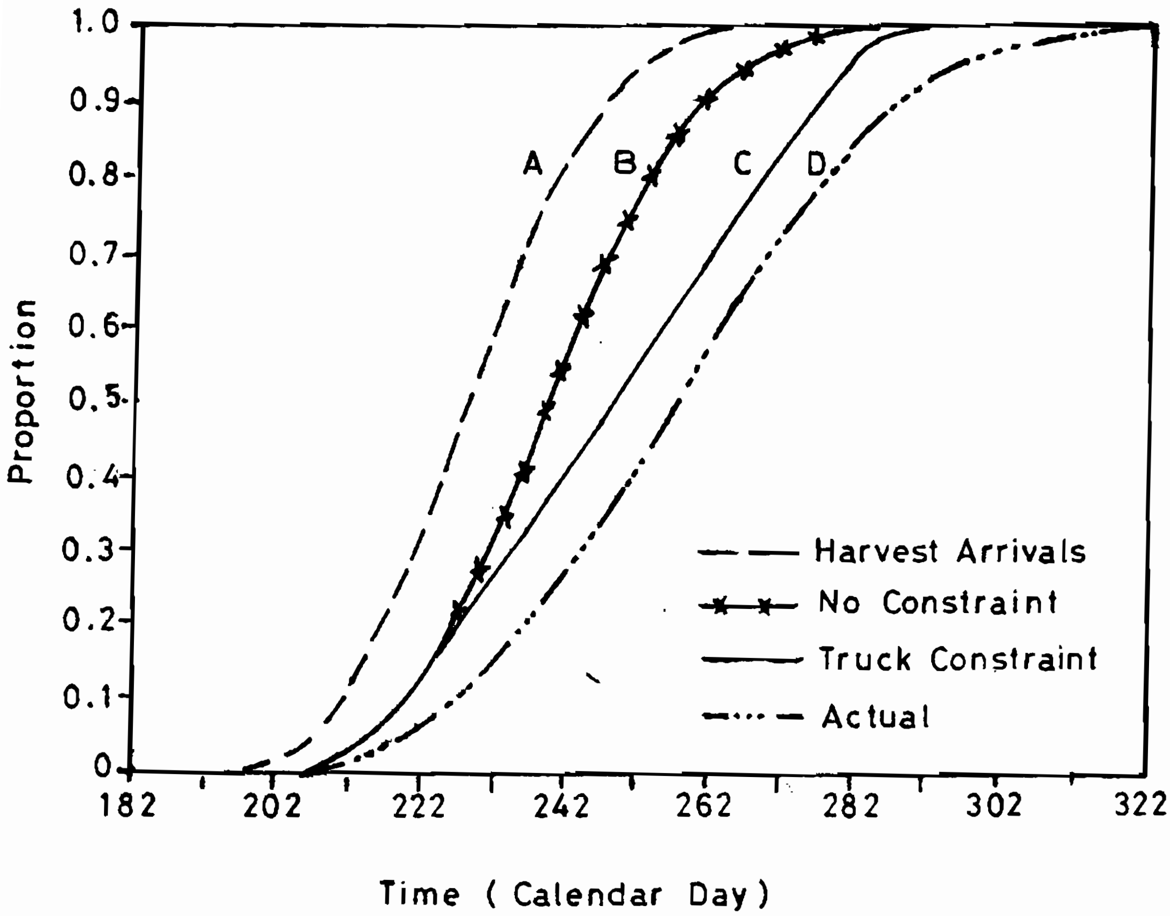


Figure 3

Arrivals : Predicted and Actual



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