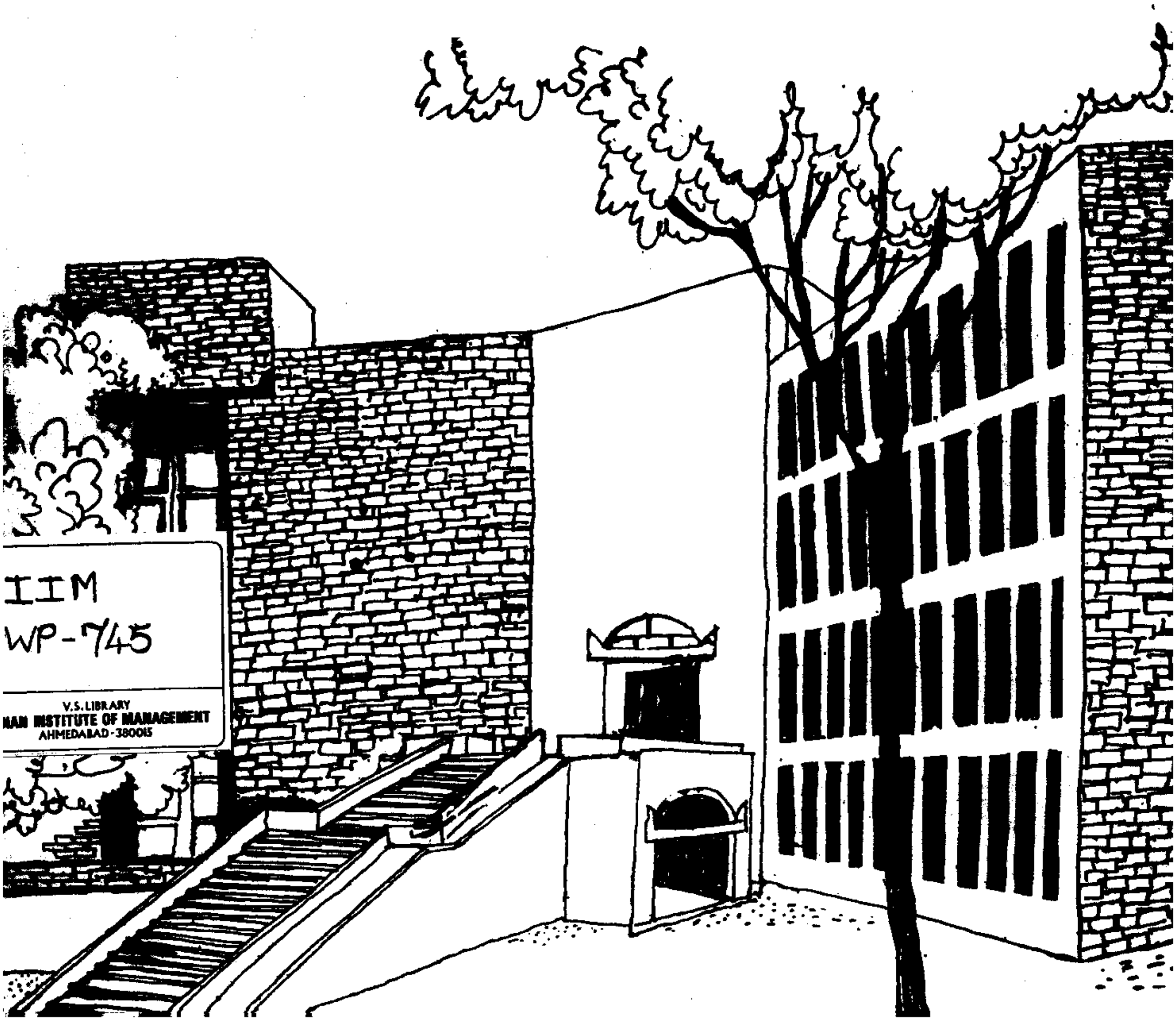
विद्याविनियोगाद्विकासः
IIM
AHMEDABAD

Working Paper



POST - PRODUCTION SYSTEM : HIMACHAL APPLES

By

Girja Sharan

&

Sandeep Kayastha

W P No. 745
May, 1988

INDIAN INSTITUTE OF MANAGEMENT
AHMEDABAD-380015
INDIA

POST-PRODUCTION SYSTEM : HIMACHAL APPLES

Girja Sharan
Sandeep Kayastha

A dynamic continuous mathematical model for post-production system of Himachal apples has been made. The model includes all operations from harvesting to arrival in the wholesale market at Delhi. Beta density function appears appropriate to define harvesting schedule that drives the model. Parameters used in the model are built on the basis of insights gained from published literature and discussions with the officials handling Himachal apples.

The model is capable of indicating in advance the resource requirement(labour, trucks, boxes etc.) at any or all nodal points in the post-production phase. It can readily show the effect of constraint on any of the resources.

At present APMC market, Delhi is the only source of definitive statistics on apples. The model is therefore tested against data from the records of APMC for the season of 1987. In particular, the arrivals in Delhi as computed from the model and as recorded by APMC are compared. The form of curve resulting from computations and that of the actual are similar. When realistic constraint of shortage of trucks(inferred from APMC data) is imposed, besides the form, magnitudes of arrivals also come close. Thus, the model appears satisfactory.

The model can be useful to large orchardists, cooperatives or other corporate bodies. It can also be useful to forwarding agents, cold storage facility owners and the APMC market. Design engineers working on mechanisation of harvest, grading and handling will also find it useful.

'RODUCTION

'ammu & Kashmir and Himachal Pradesh are the two main apple growing states in the country. In Himachal, apple is the most prominent fruit. Its production there has been rising. In 1983, 48,000 ha. was under apple orchards. The production was 26 lakh quintals, twice as much as in 1971. The production is concentrated in two districts, Shimla(70%) and Kullu(20%), Mandi(5%) is the third. Barring the culls and a small fraction that is consumed within the state, the rest(80%) is exported. Bulk of the export is sent to Delhi where it is auctioned at Agricultural Produce Marketing Committee(APMC) market. APMC is the prime wholesale market in the country.

While the production has increased, the handling facilities have apparently not kept pace. For, the early studies(Kahlon 1968, Malik 1977) as well as more recent ones(Sikka 1985) reveal the persistence of problems like shortage of labour, packaging boxes, transport and storage. As the season advances freight charges are pushed up, arrival of fruit in the market is delayed, resulting in reduced shelf life, spoilage and low prices.

In recent years 14 mechanical grading centres have been established in HP. Total handling capacity of these is less than 2% of the annual production. Even so these are not fully used. Himachal Pradesh Horticultural Produce Marketing and Processing Corporation(HPMC) has built 5 cold storages in the state of 1000t capacity each. Utilisation of these also is low as the orchardists prefer immediate sale and reportedly find it difficult to organise transport off the season. The need to mechanise and modernise handling, transport and storage facilities has been recognised. A report, relating to Jammu & Kashmir which was prepared by the Agricultural Finance Corporation(1977) recommended construction of storage facilities at orchards, installation of mechanical grading equipment, use of rail for transport and development of a transhipment centre near Delhi. Some of these have come up.

In the context of increasing production and need to upgrade handling facilities, it appeared fruitful to develop a dynamic model of the entire post-production operation. Such a model could improve on the earlier studies in two ways. One, while using the insights from the existing works, it could provide an integral view of the entire operation. Second, it could yield more precise assessment of effects of various constraints, thereby indicate the facilities possibly needed.

This paper presents a mathematical model of post-production system for Himachal apples. The model restricts itself to movement from orchards to APMC market in Delhi. First, a description of operations is presented. The description is then translated into a mathematical model consisting of a set of differential equations. The variety of results that can be obtained are then illustrated. The results are compared with the data obtained from the Market Information Service(MIS) of the APMC. Possible uses of the model are highlighted.

PRODUCTION

The data base for horticultural produce is yet weak. Periodic census, as is done for a variety of agricultural commodities is not conducted for horticultural crops. Some sample surveys (Malik 1974, Sikka 1983) indicate that the orchards are generally small, with an average size of 1 ha. and largest not exceeding 3 ha. in Himachal. Around 250 trees are found in one ha. Orchardists usually raise a mix of two or more varieties.

Apple bears fruit after 8 years. Thereafter, till nearly 40 years of age the fruiting take place alternate years, with yields peaking around the 25th. The variety and age ofcourse are prime determinants of yield, but it is also influenced by climate(altitude) and management practices. Average annual yield per tree is frequently quoted as 40 kg. Apparently this is mean of the productive years and will mean an yield of about 100 quintals per hectare.

The model presented below requires as an input, the estimated total harvest of the season. One way to determine this is through the acreage and (average) yield data of each variety grown in the region. This will be a crude estimate. Ideally the estimate should be based on the detailed data on productivity of orchards, variety and age mix of trees. As stated, such a detailed data base is not available. For the present therefore, the estimated production for the season 1987, used for the purpose of testing the model is based on the data from APMC sources and the understanding of the officials handling Himachal apples.

PICKING

Picking at proper stage of maturity ensures good dessert quality, long storage life and high commercial value. If the fruit is allowed to ripen on the tree, it continues to gain marginally in weight and size, but the probability of fruit drop is increased and storage quality reduced.

In practice, picking maturity is judged by days elapsed after full bloom, ground colour, size, colour of spur and firmness of flesh. Scientific tests for determining maturity are yet not in vogue in Himachal.

The harvesting period and percent share in production for various apple varieties in Himachal is shown in (Table 1). Commonly the harvesting is spread over 40-45 days. In the US where operations are mechanised, management more tight and better informed, the span of harvest is shorter. Sluggish pace in Himachal could be due to shortage of labour and transport. In an effort to help the growers realise better prices, the MIS of APMC, radios daily prices to Himachal. This could also be responsible for occasional slow down of harvest. But as picking of mature fruits can be delayed only by 4-5 days, it is more likely that the pace of harvest is influenced more by operational factors. Presently the model, therefore, has been kept 'harvest driven' as it were and not 'price driven'.

Picking is done manually. It is a skilled task and generally a set of experienced labourers(or family members) are assigned to it. When accelerated picking is called for, more hands are hired. Fruit is picked 3-4 times from a tree at a interval of 5-6 days. The picker climbs a tree and plucks the mature fruits and puts it into a 4-5 kg padded basket. When full, the basket is lowered to the ground emptied into bigger baskets and pulled back up. A picker can pick 3-4 quintals of fruit in a day. The harvested fruit is taken to godown for grading and packing, on headloads or mules.

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. Beta density function has been chosen to represent the rate of harvest, as it can easily yield the profiles of uniform, early or delayed harvesting(fig.1). In the model, the early varieties have been clubbed into one as all these contribute only 5% of the total. Similarly, the late varieties too have been clubbed. The four delicious varieties have been treated separately. Thus the model has 6 separate harvest functions 4 for the individual Delicious varieties and one each for earlies and lates. Fig.2(a) shows the harvest functions for individual varieties and Fig.2(b) the combined one.

GRADING AND PACKING

Grading is done manually and proceeds along with picking. Since apple requires careful sorting, only skilled person are given this job, Apples are sorted into three quality grades namely ('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 quintals of apples per day.

In the model, rate of grading & 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(eqn 2b) was chosen so as to reflect the fact that orchardists do indeed hire-in more hands when there is large stock and dispense with them when there is less. This form, called first order exponential delay ofcourse has an element of unrealism, in as much as the depletion rate will reduce exponentially, lingering on long when there is only a small quantity left. The practical effect however is small.

ASSEMBLY AND FORWARDING

From orchards boxes of graded fruit are transported to roadheads or forwarding points(FPs) by head loaders or on mules. If the orchards are easily accessible, trucks can lift the fruit directly. The responsibility of lifting the fruit from roadheads and sending it to the destinations indicated by the orchardists is that of the local Forwarding Agent. From the forwarding points/roadheads 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. The reason for routing the fruit through TCs is apparently the shortage of trucks at FPs.

The route through TCs involves an extra operation of transfering the fruit from one truck to another. Some times it also involves waiting for 2-3 days. TCs also act as distributing centres. Some of the fruit is sent from here to markets of Punjab, Haryana and some other terminal market. The rest is sent to Delhi. The proportion of fruit being sent to Punjab, Haryana etc. was indicated by the officials to be about 20% of total exports from the state.

Almost all apple is transported by 9-10 ton trucks. Three persons load a truck in an hour. A schematic diagram of the fruit movement is shown in fig(3).

Transport by trucks requires a finite amount of time. In continuous model this can be approximated by several cascaded first order exponential delays, of the type mentioned earlier. Larger the number in cascade, better the approximation. Here three have been used which provide good results. In

NDTRAN(DYNAMO-II) in which this model is coded, has builtin subroutines for delays(eqn 3a, 4a, 5a, 5b).

Trucks take 14-18 hrs to reach Delhi from Shimla and 16-20 hrs from Kullu. Time taken from valley to TCs is 6-7 hrs and TCs to Delhi 8-10 hrs.

As in case of grading and packing, the rate of despatch from assembly points to either Delhi or TCs and from TCs to Delhi have been made to depend on the amount of material accumulated, at these points(eqn 3c, 4c).

DELHI MARKET

Commission agent, to whom the grower destinates the fruit, unloads it at his shop in APMC market for auction. Trucks arrive at all hours though mostly between 10PM and 7AM. Unlike in the past, now trucks donot have to wait long for unloading. If grading is found improper, wholesalers take the fruit to nearby grading yards for regrading and repacking before sending to the other terminal markets. The officials reported, however, that regrading is seldom necessary in case of Himachal apples.

Auction take place between 8 AM and 12 Noon. All fruit which reaches here before auction hours is sold same day. The market is closed on sundays and other national holidays. Delhi market caters to the wholesalers of other terminal markets and local retailers. Buyers lift the auctioned lot in next 4-6 hrs and send it to their terminal markets.

STORAGE

Delhi has 32 cold stores which are used mostly by local wholesalers and some large growers. Growers may keep the fruit in cold storage for 15 days to 3 months. Wholesalers cater to the daily demand during off season. Wholesalers may store longer, 2-5 months.

Discussions with the industry officials at APMC and examination of data of one of the large facilities in Delhi indicated that in the season of 1987, apple coming to cold stores in Delhi was no more than 10% of the combined arrivals of Himachal and J&K. We have definite idea of the apple storage in one of the large facilities in Delhi run by National Agricultural Cooperative Marketing Federation(NAFED). In the last season it handled 2000t of HP and J&K apples combined. NAFED's facility is one of the largest. There are 32 other smaller cold stores handling apples. Assuming all these handled 1000t each in the last season, total apple cold stored would be approximately 34000t. This comes out to be less than 10% of the total estimated arrivals from HP and J&K. The impression of the officials appears reasonable. In view of the smallness of the quantity of Himachal apples cold stored, it was neglected. Incorporating this into the model, however, will be readily possible, should it be desired.

Let us recapitulate. Harvest of early varieties, accounting for only 5% to the production, usually begins by July 1st in Himachal. The greatest proportion is that of the Delicious varieties which begin to be harvested some 20 days later. The harvest peaks around 20th August. Late varieties follow. But these too make only a small proportion. Harvested apple is manually graded and packed. Culls are taken out, 'A' and 'B' grades are packed and hauled to roadheads/forwarding points. Forwarding agents lift and take these to Delhi or one of the TCs. A part of apple reaching TCs is sent to northern market and rest to Delhi. The trucks arriving in APMC market are unloaded and fruit auctioned usually the same day. Though some cold storage facilities are available in Delhi these are yet used only marginally(here neglected).

MODEL

Assumptions:

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.

Let

t	time(days)
H	estimated total production in the season(q)
p_i	proportion of variety 'i' in the total production
n	no of varieties grown
$h_i(t)$	harvest rate of variety 'i' at time t(q/day); i=1 to n
h(t)	combined rate of harvest(q/day)
QG(t)	stock of ungraded apple at godown(q)
g(t)	grading rate(q/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(q)
GF(t)	despatch rate from godown to FP(q/day)

FG(t)	arrival rate at FP from Godown(q/day)
QF(t)	stock at FP(q)
RF(t)	despatch rate from FP(q/day)
k	proportion of fruit despatched from FP to Delhi
FT(t)	despatch rate from FP to TC(q/day)
FD(t)	despatch rate from FP to Delhi(q/day)
TF(t)	arrival rate at TC(q/day)
QT(t)	stock at TC(q)
RT(t)	despatch rate from TC(q/day)
m	proportion despatched to Delhi from TC(%)
TM(t)	despatch rate from TC to terminal markets(Punjab, Haryana etc)(q/day)
QM(t)	fruit stock despatched to terminal markets(Punjab, Haryana etc.) from TC upto time t(q)
TD(t)	despatch rate from TC to Delhi(q/day)
DT(t)	arrival rate at Delhi from TC(q/day)
DF(t)	arrival rate at Delhi from FP(q/day)
QD(t)	fruit arrival in Delhi from TC & FP upto time t(q)
T1	time constant for grading at godown(days)
T2	time constant for transport from godown to FP(days)
T3	time constant for despatch from FP(days)
T4	time constant for transport from FP to Delhi(days)
T5	time constant for transport from FP to TC(days)
T6	time constant for despatch from TC(days)
T7	time constant for transport from TC to Delhi(days)

$$h_i(t) = H \cdot p_i \cdot \left\{ \frac{\Gamma(\theta+\phi)}{\Gamma\theta\,\Gamma\phi} \cdot \frac{1}{HP_i} \left(1 - \frac{t-HS_i}{HP_i}\right)^{\phi-1} \left(\frac{t-HS_i}{HP_i}\right)^{\theta-1} \right\} \quad HS_i \leq t \leq HE_i \qquad \text{......(1a)}$$

Term in parenthesis is the scaled up Beta density function for variety i with harvest starting on day HS_i, ending on HE_i, length of harvesting period $HP_i (HE_i - HS_i)$, θ and ϕ are positive constants

$$h(t) = \sum_{i=1}^{n} h_i(t) \qquad \text{......(1b)}$$

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

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

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

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

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

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

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

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

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

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

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

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

$$TM(t) = RT(t) * (1-m) \qquad \text{......(4d)}$$

$$TD(t) = RT(t) * m \qquad \text{......(4e)}$$

$$\frac{dQM(t)}{dt} = TM(t) \qquad \text{......(4f)}$$

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

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

$$\frac{dQD(t)}{dt} = DT(t) + DF(t) \qquad \text{......(5c)}$$

Equations(3a,4a,5a and 5b) represent transport of fruit. These too could have been written in long hand in the form of differential equations. However, in view of subroutines available these are written here compactly, in form of NDTRAN command.

In addition to the above, the program also contains some auxillary equations to compute items like- labour, boxes and truck requirement.

RESULTS AND DISCUSSION

Case:1.

No constraints on the labour, boxes, trucks or storage space at any point in the flow of fruit.

HS,HE and p., for six varieties(n=6), taken from Table(1).
H(1987)=24 lakh quintals,estimate based on industry officials understanding

θ=ϕ=2;choice is influenced by the discussions with industry officials

Parameters:

c=Ø.2Ø	k=Ø.5Ø	m=Ø.6Ø	
T1=7	T2=Ø.5Ø	T3=3	T4=Ø.66
T5=Ø.29	T6=2	T7=Ø.33	

Harvesting begins on day 182(July.1) and ends 92 days later(Sept-3Ø), as modelled here(fig2b). The harvest is slow in the beginning and picks up momentum only after about 2Ø days when Royal Delicious begins to be harvested. Indeed 8Ø% of the total produce of the season is harvested between day 212(July.31) and 248(Sept.5). This period of 36 days can be treated as the peak phase.

Fig(4) curve.A shows simulated cumulative harvest normalised against the season's total. With this input 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 the arrivals in Delhi is small in the beginning. During the peak phase the transit delay ranges from 9-13 days. 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.

Published literature frequently mentions about constraint on availability of trucks, especially during the peak phase. The fact that APMC records the number of trucks arriving each day, makes it possible to estimate the severity of constraint, more definitively. Trucks can be in short supply at FP or TC or both. For illustration we impose constraint 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 FP 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 3ØØ 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 2Ø days. Note that gap between the computed curve(D) and the actual(C), is much smaller now. Reducing availability of trucks further(say to 25Ø) can even bridge the gap entirely. This suggests the p'ausibility of the transport bottleneck being a cause of the delayed arrivals.

Case:3.

Besides transport, shortage of labour is the other frequently reported problem. When there is no constraint, peak labour requirement occurs during the week 232-238, when on an average 78ØØ labourers are needed for grading and packing each day.

Assuming for the sake of illustration that the availability is limited to 5Ø% of the peak requirement, the resulting cumulative arrivals is shown by curve E. The gap between the computed(E) and the actual(C), is rather small.

More illustrations of constraints such as the packing material etc. can similarly be given. But the two illustrations should be sufficient to indicate that the shortage of transport or labour etc. could very plausiblly be the major cause of delays. Of course, other reasons for delay could be late start of harvest or a schedule different from the one used. The effect of different harvest schedule- early, delayed or uniform -can be done equally readily in this model.

Storage quality though intrinsic to varieties, can be affected severely by long time spent in transit. Some US studies(Childer 1973) indicate that the storage 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 storage (temperatures 21°C) reduces the shelf life by as much as 9 weeks. In unconstrained case, transit delays during peak phase was 9-13 days. This will mean that the storage potential of Himachal apples by the time they reach Delhi, will be three and a half months at best.

A study by Narsimham(4) would seem to corroborate this. Himachal apples were stored after 10 days of harvesting in a cold storage 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.

With the constraint on trucks(300), transit delay during peak phase averaged to 20 days. As this constraint is quite realistic, it will imply that the fruit will have virtually no storage potential left, by the time it reaches Delhi through normal channels.

This may have a significant implication in as much as it may provide a clue to the phenomena of orchardists not putting more fruit in stores despitesharp fall in prices. 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 began to pick up November onwards after the passing of peak phase. Question that arises therefore is- why do the orchardists not make more use of the cold stores.? For if they did, low prices may not persist. A plausible conjecture is that it is result of realisation that owing to long transit delays incurred in the movement, as seen above, the fruit does not have much of a potential left. In other words, establishment of cold stores in Delhi and keeping them informed about the daily prices, by itself will not enable orchardists to take advantage of the facility. Unless the handling and transport facilities are improved, so as to reduce the transit delays, fuller advantage of the cold storing facility may not be realised and precitipitate drop in prices not prevented.

Uses of Model:

The model can be used by all the agencies involved, directly or indirectly, in the apple business. The model is suited better for those having large scale operations such as co-operatives and other corporate bodies. They can develop schedule for requirement of labour, trucks, boxes etc. for the entire season. The model has the provision to generate report for each successive day of the season. For brevity, here only weekly summary is presented(Table.2). The table shows the requirement of labour, boxes, and trucks at FP and TC. Arrivals in Delhi and week end pile-up at godown, FP and TC are also shown. 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 plan for culls procurement and subsequent crushing schedules.

The APMC market can use such models to (re)design their facilities. Such models can easily be made for other perishable fruits and vegetables that are marketed through APMC. When combined, these can provide useful basis for development of handling, storage and other facilities.

State government can use the model to evolve policies for overall development of the industry, by getting a clear idea of constraints and their severity.

Engineers working on mechanisation can similarly derive broad specifications for such facilities like collective grading centres etc.

SUMMARY AND CONCLUSIONS

1. A dynamic continuous mathematical model for post-production system of Himachal apples has been made. The model is capable of indicating in advance the resource requirement(labour, trucks, boxes etc.) at any or all nodal points in the post-production phase. It can readily show the effect of constraint on any of the resources, as also the effect of various harvest schedules on operational resources.

   The arrivals in Delhi as computed from the model and as recorded by APMC are compared. The form of curve resulting from computations and that of the actual are similar. When realistic constraint of shortage of trucks(inferred from APMC data) is imposed, besides the form, magnitudes of arrivals also come close. Thus, the model appears satisfactory.

The model can be useful to large orchardists, cooperatives or other corporate bodies. It can also be useful to forwarding agents, cold storage facility owners and the APMC market. Design engineers working on mechanisation of harvest, grading and handling will also find it useful.

2. Some significant insights emerge from the simulation runs. Under the assumption of no constraints the transit delay incurred in reaching Delhi ranges from 10-12 days. Under (realistic) transport constraints it increases to an average of 20 days. Given the storage properties of Delicious varieties such long transit delay is likely to reduce the storage potential to a negligible value. This will suggest that creation of cold stores in Delhi and keeping the orchardist updated on prevailing daily prices will not be enough to make them derive full advantage until the transport constraints are overcome. During the peak phase the availability of trucks appears to be only 55% of the peak requirement.

3. 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 parameters used will need to be refined by actual observations. Lumping, especially the orchards will need to be re-examined. The results may improve further if the model is converted into a mixed type- with harvest as continuous but other operations discrete.

Table 1: Harvest Dates and Share of varieties (HP)

Variety	Harvest Period Calender days	%production	
Early		5	
Red June	182-201		-
King of Pippine	186-206		-
Worcester Pormain	201-243		-
Delicious		90	
Royal	201-243		45
Rich-a-Red	206-253		5
Red	213-258		20
Golden	217-263		20
Late		5	
Red Gold	213-258		-
Granny Smith	222-268		-
Rus Pippin	222-273		-

Source:(Sikka 1985)

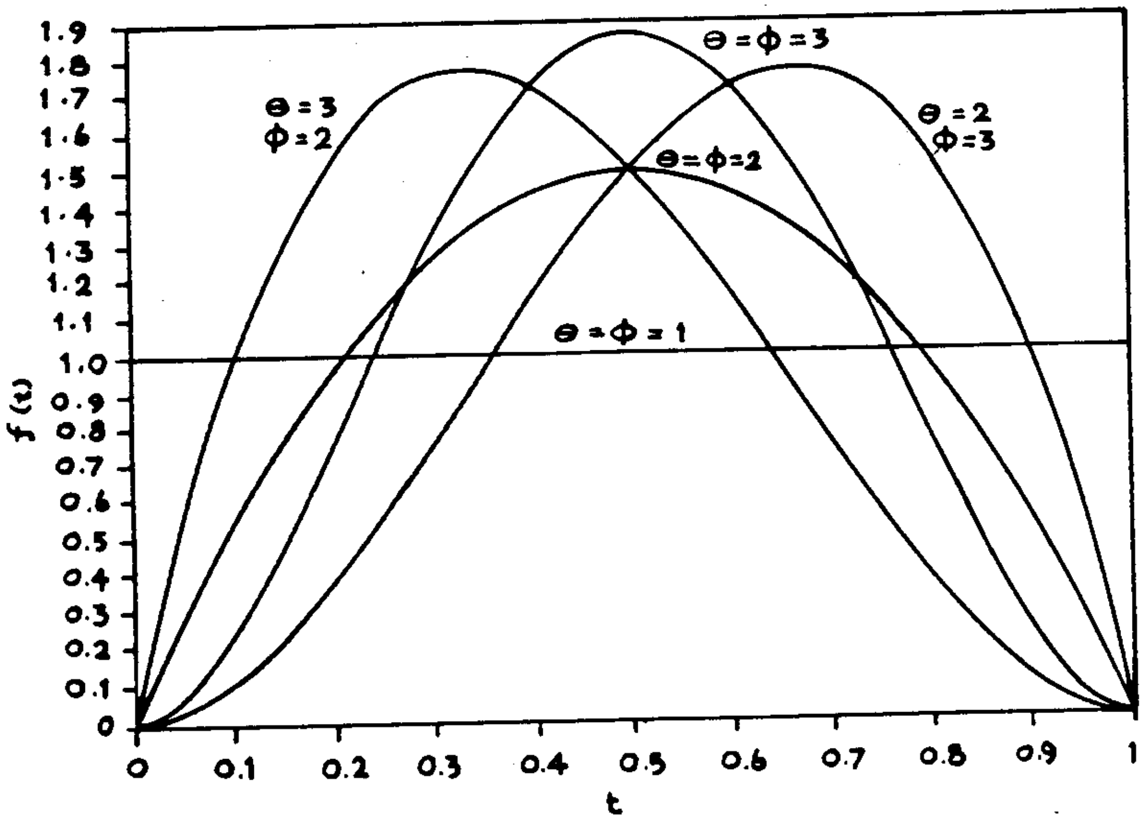


Fig. 1: Forms of Beta density function for different values of constants

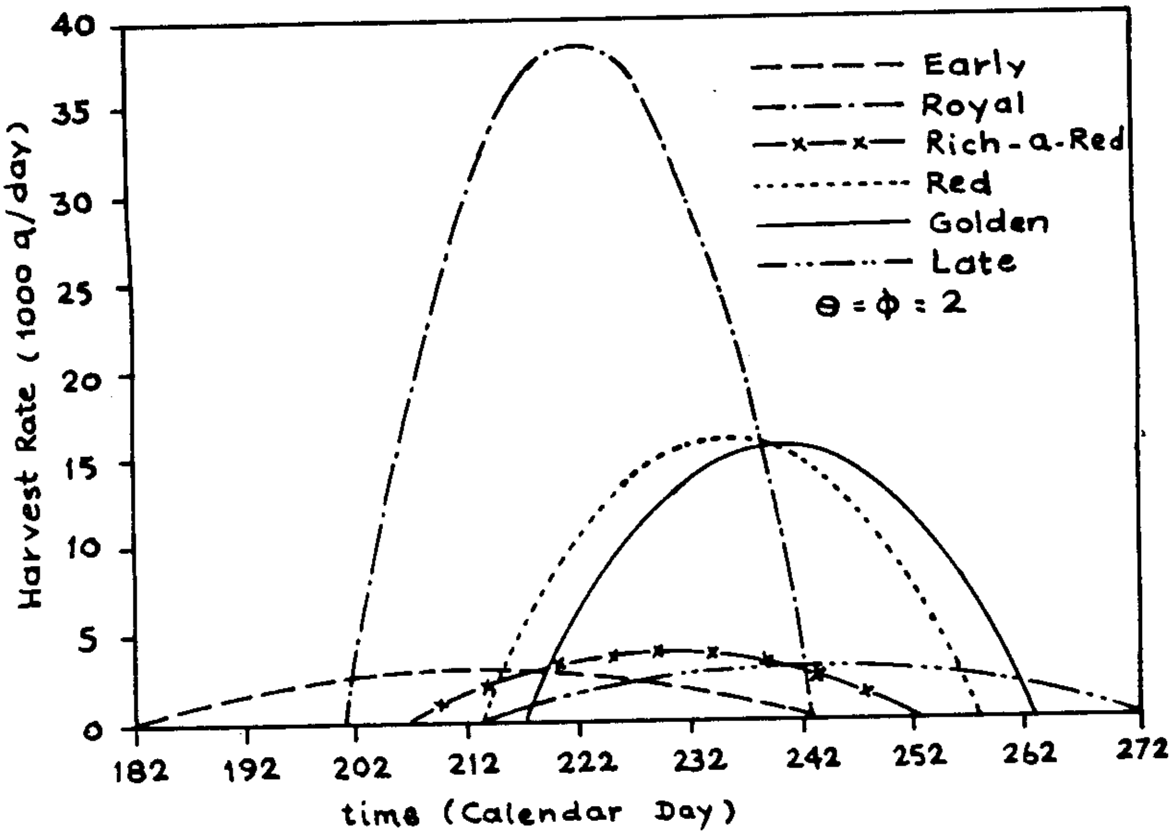


Fig.2a: Harvest rates of 6 varities during the season

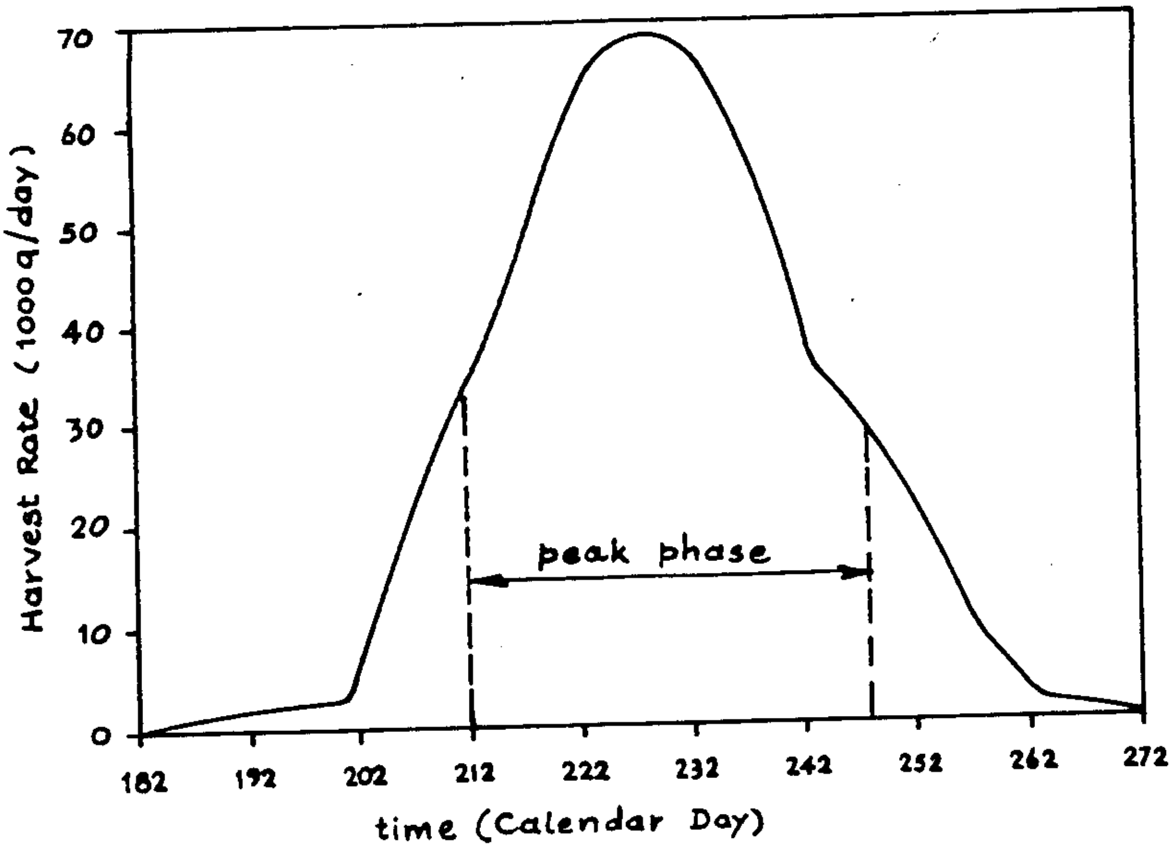


Fig. 2b: Combined harvest rates of six varieties during the season

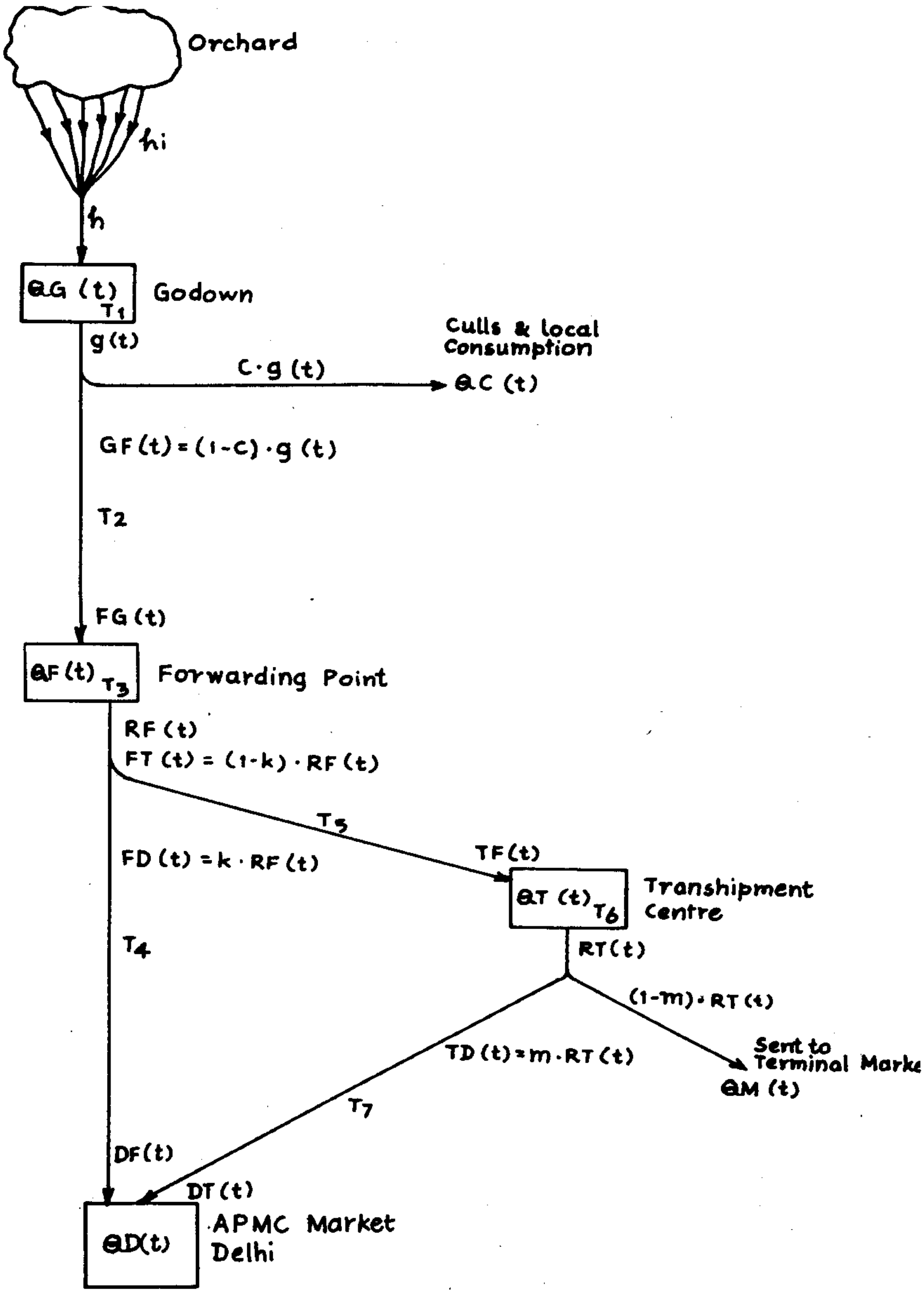


Fig. 3 : Schematic diagram of Post-Production System

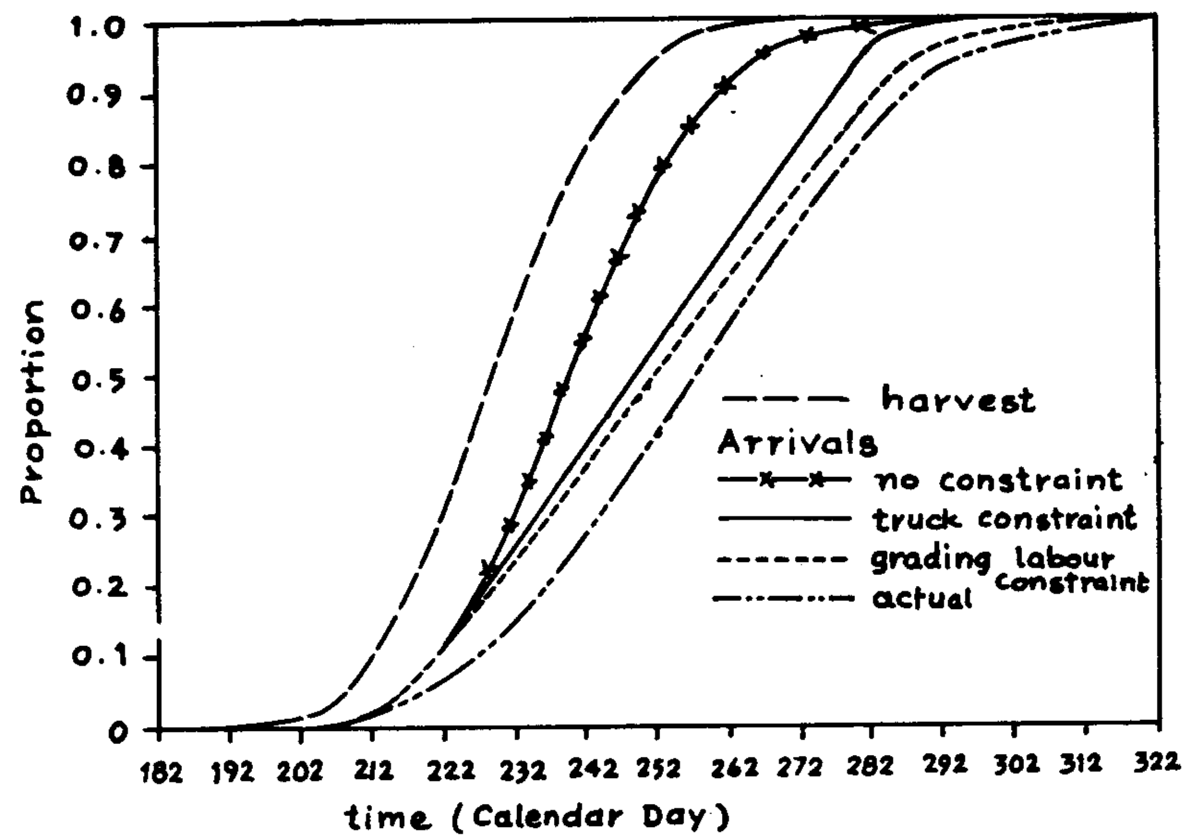


Fig. 4 : Proportion of cumulative harvest and arrivals in Delhi

Table 2: Weekly apple harvested, graded, resource required, arrivals in Delhi and weekend inventories at nodal points for no constraint case

WEEK	Harvested	Graded	Culls&local Consumption	18 kg.Box Reqd (No)	Labour reqd for Harvesting	Labour reqd for Grading	Sent to TMs	Arrivals in Delhi	Trucks reqd at FP	Trucks reqd at TC	Weekend Inventories Godown	Weekend Inventories FP	Weekend Inventories TC
	------lakh quintals--------			-lakhs-	-lakh(man days)-		-lakh quintals-		--hundreds--		-thousand quintals-		
182-188	0.03	0.01	0.00	0.04	0.01	0.00	0.00	0.00	0.0	0.0	2	0	0
189-195	0.11	0.05	0.01	0.23	0.04	0.01	0.00	0.02	0.3	0.1	8	1	0
196-202	0.18	0.11	0.02	0.48	0.06	0.01	0.01	0.05	0.8	0.3	15	3	1
203-209	1.22	0.47	0.09	2.08	0.41	0.06	0.03	0.14	2.5	0.8	90	13	4
210-216	2.53	1.44	0.29	6.38	0.84	0.18	0.12	0.57	9.5	3.5	199	36	14
217-223	3.90	2.62	0.52	11.66	1.30	0.33	0.29	1.25	19.4	8.0	327	64	27
224-230	4.78	3.88	0.77	16.90	1.59	0.48	0.48	2.03	31.9	13.4	422	91	41
231-237	4.50	4.37	0.86	19.40	1.50	0.55	0.64	2.62	35.4	17.8	437	100	49
238-244	3.19	4.03	0.81	17.91	1.06	0.50	0.69	2.74	37.9	19.1	353	89	47
245-251	2.08	3.03	0.61	13.48	0.69	0.38	0.59	2.29	30.1	16.4	257	66	37
252-258	1.15	2.11	0.42	9.36	0.38	0.26	0.44	1.68	21.7	12.2	162	45	26
259-265	0.29	1.16	0.23	5.14	0.10	0.14	0.29	1.07	13.2	8.0	75	24	15
266-272	0.06	0.50	0.10	2.22	0.02	0.06	0.15	0.54	6.3	4.1	31	10	7
273-279	0.00	0.19	0.04	0.86	0.00	0.02	0.06	0.23	2.6	1.8	11	4	3
280-286		0.07	0.01	0.32		0.01	0.02	0.09	1.0	0.7	4	1	1
287-293		0.03	0.01	0.12		0.00	0.01	0.03	0.4	0.3	2	1	0
294-300		0.01	0.00	0.04		0.00	0.00	0.01	0.1	0.1	1	0	0
301-307		0.00	0.00	0.00		0.00	0.00	0.00	0.0	0.0	1	0	0
308-314		0.00	0.00	0.01		0.00	0.00	0.00	0.0	0.0	1	0	0
315-321		0.00	0.00	0.00		0.00	0.00	0.00	0.0	0.0	1	0	0
Total	24.00	23.99	4.80	106.64	8.00	3.00	3.84	15.36	213.2	106.6			

REFERENCES

1. Kahlon AS and Singh B (1968), Orientation of Pome Stone Fruits Market Structure to the Expanding Volume of Fruit Production in Kulu and Parvaty Valleys, Deptt of Eco. and Socio., PAU, Ludhiana.

2. Childer, Norman F (1973), Modern Fruit Science, Horticultural Publications, Rutgers University- The State University., New Jersy

3. Malik RSP, Swarup R and Tewari RN (1977), A Comprehensive study on the marketing of Apples of Himachal Pradesh, Vol-1 Orchardist Survey, Agro Economic Research Centre, HP Univ., Shimla.

4. India: Jammu and Kashmir Integrated Horticultural Produce Marketing and Processing Project, Agricultural Finance Corporation, Bombay. Report Submitted to International Bank of Reconstruction and Development. 1977.

5. Maini SB and others (1982), Packaging, Transport and Storage of Apples in Wooden Containers, Indian Food Packer, Vol 36,No 3.

6. Venkatasubbaiah G and others (1983), Packaging and Transport Studies on Apples, Indian Food Industry, Oct-Dec'83.

7. Narasimham P and others (1984), Semi-commercial trails on Cold Stroage and Marketing of Apples of Himachal Pradesh, Indian Food Packer, Vol 38, No 2.

8. Sikka BK and Swarup R (1985), Economics of Apple Production in Himachal, Agro Economic Research Centre, HP University, Shimla

9. Bose TK(ed)(1985), Fruits of India: Tropical and Subtropical, Naya Prakashan, Calcutta.

10. Tewari SC (1987), Horicultural Development: Summary of Discussion Group of Conference (July-Sept 87), Indian Journal of Agricultural Economics, Vol 42, No 2.