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

Girja Sharan and Sandeep Kayastha

This paper presents a simulation model of fruit movement from orchards in Himachal Pradesh to the market of Agricultural Produce Market Committee (APMC) in Delhi. Daily arrivals in Delhi as predicted by the model are compared with the data on actual arrivals from records maintained at APMC. The comparisons appear satisfactory.

The results suggest that the system dynamic modelling approach is promising and, with some refinement, can provide an analytical support for those engaged in formulation of policies to improve the post-harvest systems of fruit industry.

Girja Sharan is Professor in the Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad and Sandeep Kayastha is Assistant Professor at the Kirloskar Institute of Advanced Management Studies, Harihar, Karnataka.

Introduction

India ranks nearly on top in the magnitude of production of fruits and vegetables in the world. Its post-harvest system—the phase during which the produce moves from farms and orchards to the ultimate consumer—is, however, still primitive. Modernization of post-harvest system has now been recognized as critical to the development of fruit and vegetable based industry. This paper deals with a part of post-harvest system of apple. The work reported here forms part of a research project undertaken by the authors (Sharan and Kayastha, 1989,1993). The aim of this work is to devise an analytical support for those in government and industry, dealing with modernization of post-harvest systems.

Nearly half a million tonne of apple is produced annually in the country. Jammu and Kashmir (J&K) and Himachal Pradesh (HP) contribute nearly equal amount each (Table 1). Arrivals from HP are concentrated between August and October with September being the peak. Arrivals from J&K peak in November. Thus, the combined length of season for marketing of fresh fruit is of about eight-month duration from August to March. During the peak season, prices fall considerably below the levels in the beginning and the end of the season. Transport and other bottlenecks constrain the producer to sell a major part of the produce when prices are at their lowest. This is one pointer to the weakness of the post-harvest system.

Table 1
Arrival of Apple in APMC, Delhi : 1990-91
(Tonnes)

Month	*HP*	*UP*	*J&K*	*Cold Stores*	*Total*
May	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	201	11442
March	25	0	11183	77	11285
April		0	683	86	769
May 1		0	15	7	22

Source: Agricultural Produce Market Committee, Delhi.

Fruit is a live entity and continues to respire after being detached from the tree. Higher the ambient temperatures, more rapid the respiration, leading to deterioration in quality. In addition, it is exposed to mechanical damages during transit. Mechanical damages interact with biochemical processes, leading to accelerated deterioration. Improved post-harvest system can lead to better revenues for the producers and better quality fruit for the consumers. Early studies by Kahlon (1968), Malik (1977), and more recent ones by Sikka (1985) reveal the persistence of problems like shortage of labour, packaging boxes, transport and storage facilities.

Respective state governments have initiated programmes to modernize the post-harvest facilities. Introduction of mechanical grading facilities, supply of packaging boxes, creation of cooling and storage facilities are part of this effort. However, discussion with industry personnel indicates that some of the new facilities are not being utilized well. The low amount of fruit sent to cold stores in Delhi (Table 1, col.5) corroborates this.

It is surprising to find that even though cooling and storage facilities have been created, orchardists continue to sell fruits at low prices during the peak season rather than put the fruit in stores and wait for prices to rise. It is possible that improvements in various parts of the post-harvest system have not been mutually compatible or synchronous. While the storage facilities have been created in Delhi, the transport facilities from orchards to Agricultural Produce Market Committee (APMC) market may not have improved.

Available literature only indicates the inadequacies presently prevailing. Sikka (1985), for instance, reported shortage of transport, packaging boxes, etc. but did not indicate how much additional transport would be needed to meet the requirement. It is the answers to such questions that would be of interest to those formulating programmes of modernization.

Programmes that aim at improvement of a large system need to have a framework of analysis appropriate for the task. We propose an easy-to-use simulation model for such a framework. Accordingly, we formulate a model of a part of the system wherein apple moves from orchards to the wholesale market in Delhi. The modelling approach employed here is similar to that found in the field of systems dynamics. As far as we are aware, such an approach has not been used to model apple (or any other fruit) movement. This paper is, thus, exploratory in nature. The main goal is to see what insights can be gained by use of systems dynamics and whether such a model could be a suitable analytical support system for use of those engaged in formulating programmes to improve the system.

A brief description of operations involved in movement of fruit from orchards to Delhi is given first, followed by a description of the simulation model. 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., with the largest not exceeding 3 ha. (Malik, 1978; Sikka, 1985). Average annual yield per tree is frequently quoted as 40 kg. Apparently, this is the mean of the productive years (i.e between 8-40 years) and suggests an yield of about 100 qtl/ha (250 trees/ha). The harvest period and per cent share in production for various varieties in Himachal Pradesh are shown in Table 2. Commonly, harvesting is spread over 40-45 days.

Picking is manual. One crew (consisting of 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 decide when to sell, the Market Information Service of APMC sends via the radio network auction prices of each day. This could be responsible for occasional slow down of

Table 2
Harvest Period and Share of Varieties

Variety	*Harvest Period (Calendar Days)*	*Share in Production (%)*
Early	182-243	5
Red June	182-201	-
King of Pippine	186-206	-
Worcester Pormain	201-243	-
Delicious	20-263	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.

harvest. But, as picking of mature fruits cannot be delayed for more than 4-5 days, the pace of harvest is not likely to be influenced by prices, though grading and despatch may be.

Grading and Packing

Grading is done manually in the 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 the 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 FPs, 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 the rest to Delhi. Almost all apples are transported by trucks.

Auction

The commission agents of the growers unload the fruit in their sheds in APMC, Delhi, for auction.

Storage

Delhi has 32 cold stores. Discussions with officials at APMC and examination of data of one of the largest facilities indicated that cold stores in Delhi are used mostly by wholesalers and that too sparingly.

Modelling Approach

The following assumptions are made to simplify the task of modelling and be able to use the system dynamic framework:

1. All operations are continuous.
2. Orchards are lumped, so also the forwarding points and transhipment centres. This assumption is required since detailed distances between orchards and nearest road-heads are not available. However, the distances up to road-head are known to be small compared to subsequent travel distance of the fruit.
3. Prices do not affect the harvest schedule. Information on prices is broadcast on radio in the growing areas each day with a view to enable growers to change their schedule of harvest. In reality, however, growers are unable to alter their harvest schedule for two reasons. One, picking cannot be delayed without risking fruit-drop. Second, transport facilities cannot be obtained at short notice.
4. Cold stores are ignored, as the quantity of apples going into and coming from these is presently negligible.

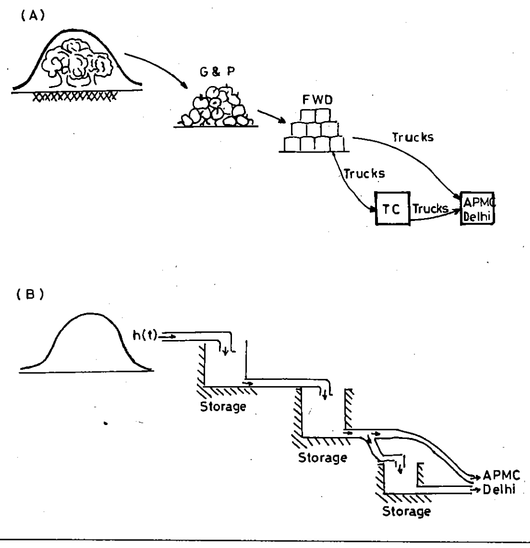
The description given above and the assumptions made enable one to draw schematically the entire system as shown in Figure 1a. A close reading of the operations at the grading points, forwarding points, and transhipment centres also enables one to discern a possible analogy with a simple fluid flow system as shown in Figure 1b. Such an analogy is the basis on which modelling of grading and packing centres, forwarding, and transhipment centres has been done. This approach is very similar to that followed in systems dynamics.

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. Early as well as late varieties have been clubbed as these contribute only 5 per cent 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 early and late varieties.

Figure 1

Movement of Apple and an Analogue



Grading Station

The 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 the orchardists hire 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 the 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 .... n
p_i	share 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 fruits set aside for local consumption
QC(t)	culls and fruits set aside for local consumption up to 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 up to 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 up to 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)

$$h_i(t) = H.\ P_i\left[\frac{\Gamma(\theta+\phi)}{\Gamma(\theta)\,\Gamma(\phi)} \bullet \frac{1}{DP_i}\left(1-\frac{t-DS_i}{DP_i}\right)^{\theta-1}\left(\frac{t-DS_i}{DP_i}\right)^{\phi-1}\right]$$

θ, ϕ parameters of Beta function (1a)

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

$$h(t)=\Sigma\, h_i(t) \qquad \text{......(1b)}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\frac{d}{dt}QD(t)=DT(t)+DF(t)$ ......(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 the form of DYNAMO statement. DYNAMO is a continuous system simulation language in which the model was run.

Simulations

Case 1

No constraints on labour, boxes, trucks or stores space at any point. DS_i, DE_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:

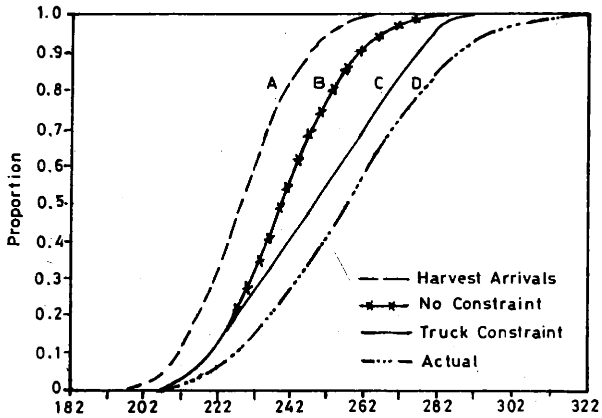
c=0.20	k=0.50	m=0.60	
T1=7	T2=0.50	T3=3	T4=0.66
T5=0.29	T6=2	T7=0.33	

Harvesting begins on day 182 (July 1) and ends 92 days later (Sept-30), as modelled here (Figure 2). It picks up momentum when harvesting of Royal Delicious begins. The peak phase lies between days 212-248, which accounts for 80 per cent of the harvest.

Curve A shows simulated cumulative harvest normalized against the season's total. The output, that is, cumulative fruit arrival in Delhi, is shown by curve B. Values are normalized 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. A large part of this, 6-9 days, is contributed by grading operation and 3-4 days by transport and handling.

Figure 2

Arrivals : Predicted and Actual



How do the computed arrivals in Delhi compare with the actual data? Curve D 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. Actual arrivals incur more delay than predicted by the model. The delay could be the result of one or more factors — shortage of labour, boxes, transport, etc. Data available at the APMC market do not permit making judgement about which factors may have been responsible. They, do, however, permit estimation of possible transport bottleneck. This is discussed below.

Case 2

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 arriving at APMC market show 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 C. 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(C) and the actual(D) 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 the long time spent in transit. Some US studies (Childer, 1973) indicate that Delicious varieties can be stored for as long as seven months, if apple is cooled to holding temperature of 0°C within seven days of harvesting. Each week of exposure in transit or stores (temperatures 21°C) reduces the shelf life by as much as nine weeks.

A study by Narsimham (1984) would seem to corroborate this. Himachal apples were stored after ten days of harvesting in a cold stores in Bangalore. Temperatures varied between 0-5°C and relative humidity between 65-95 per cent. For Royal Delicious (large size), shrivelling reached 9 per cent after two months, 25 per cent after three months and 48 per cent after the fourth. The magnitude for other varieties differed somewhat, but the trend was the same. Storing beyond 25 per cent shrivelling rendered the fruit unserviceable. The above will also imply that if the transit under ambient conditions extends beyond about three weeks, the storage 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 18 kg 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) storage 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. This insight emerged mainly because the model provided an integral view of the entire system.

Thus, the establishment of cold stores in Delhi and even keeping the orchardists informed about the daily prices will not enable them to take advantage of the facility, unless transport facilities are improved simultaneously. It may be argued that this would have been intuitively obvious. Simulations, however, help in determining the level of transport needed to overcome the problem which may not have been so easily possible.

Simulations give day-to-day requirement of labour, boxes, in addition to trucks. Estimates of packing box requirement can help determine the adequacy of the existing supplies and the need for raising the production capacity of factories supplying boxes.

Who can Use Such Models?

The model can be used by all the agencies involved, in apple and other fruit businesses. It is better suited for those having large scale operations such as cooperatives and other corporate bodies. They can develop a schedule for requirement of labour, 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.

Limitations and Further Refinement

This model is akin to a picture of an object taken from a great distance, giving realistic broad contours, but not the details. Therefore, it cannot be used for a single small orchard. Moreover, the model will be appropriate only for those commodities that are perishable and, therefore, have built-in compulsion to be moved until consumed. Although the model appears useful, there are aspects that will call for further refinement. The estimate of total produce and actual schedule of harvest followed by the orchardists needs 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 of 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 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 resource requirement (labour, 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 subsequent price rise. The model is easy to use and can be an analytical support for those in government and industry, engaged in modernization of apple movement system.

References

Sharan, G and Kayastha, S (1989). "Post-production System : Himachal Apples" in Srivastava, U K and Vatsala, S (eds.), *Agro-processing*, New Delhi: Oxford & IBH.

Sharan, G; Kayastha, S and Krishnakumar, M (1993). *Post-production System of Apple : A Mathematical Model.* Ahmedabad : IIM, CMA Monograph No 165 (mimeo).

Childer, NF (1973). *Modern Fruit Science.* New Jersey: Horticultural Publications, Rutgers University-The State University.

Jammu & Kashmir Integrated Horticultural Produce Marketing Processing Project (Mimeo) (1977). Bombay: Agricultural Finance Corporation.

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.* Ludhiana: Department of Economics and Sociology, Punjab Agricultural University.

Malik, RSP; Swarup, R and Tewari, RN (1977). *A Comprehensive Study on the Marketing of Apples of Himachal Pradesh, Vol.1, Orchardist Survey.* Shimla: Agro Economic Research Centre, Himachal Pradesh University.

Narasimham, P; Habibunnisa; Prakash, MSK; Prasad, CAK; Rao, ARV and Rodriquetz (1984). "Semi-commercial Trials on Cold Storage and Marketing of Apples of Himachal Pradesh," *Indian Food Packer,* Vol 2.

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

STATEMENT OF OWNERSHIP OF VIKALPA

The following statement about ownership and other particulars of *Vikalpa : The Journal for Decision Makers* is published in accordance with Rule 8 of Newspapers (Central) Rules, 1956.

FORM IV

1.	Place of Publication	Indian Institute of Management Ahmedabad 380 015
2.	Periodicity	Quarterly
3.	Name of Printer Nationality Address	P S Seshadri Indian Indian Institute of Management Ahmedabad 380 015
4.	Name of Publisher Nationality Address	P S Seshadri Indian Indian Institute of Management Ahmedabad 380 015
5.	Name of Editor Nationality Address	K V Ramani Indian Indian Institute of Management Ahmedabad 380 015
6.	Names and addresses of individuals who own the newspaper and partners or shareholders holding more than one per cent of the total capital	Indian Institute of Management Ahmedabad Indian Institute of Management Campus, Ahmedabad 380 015

I, P S Seshadri, hereby declare that the particulars given above are true to the best of my knowledge and belief.

March 1, 1997

(sd.) P S Seshadri
Publisher