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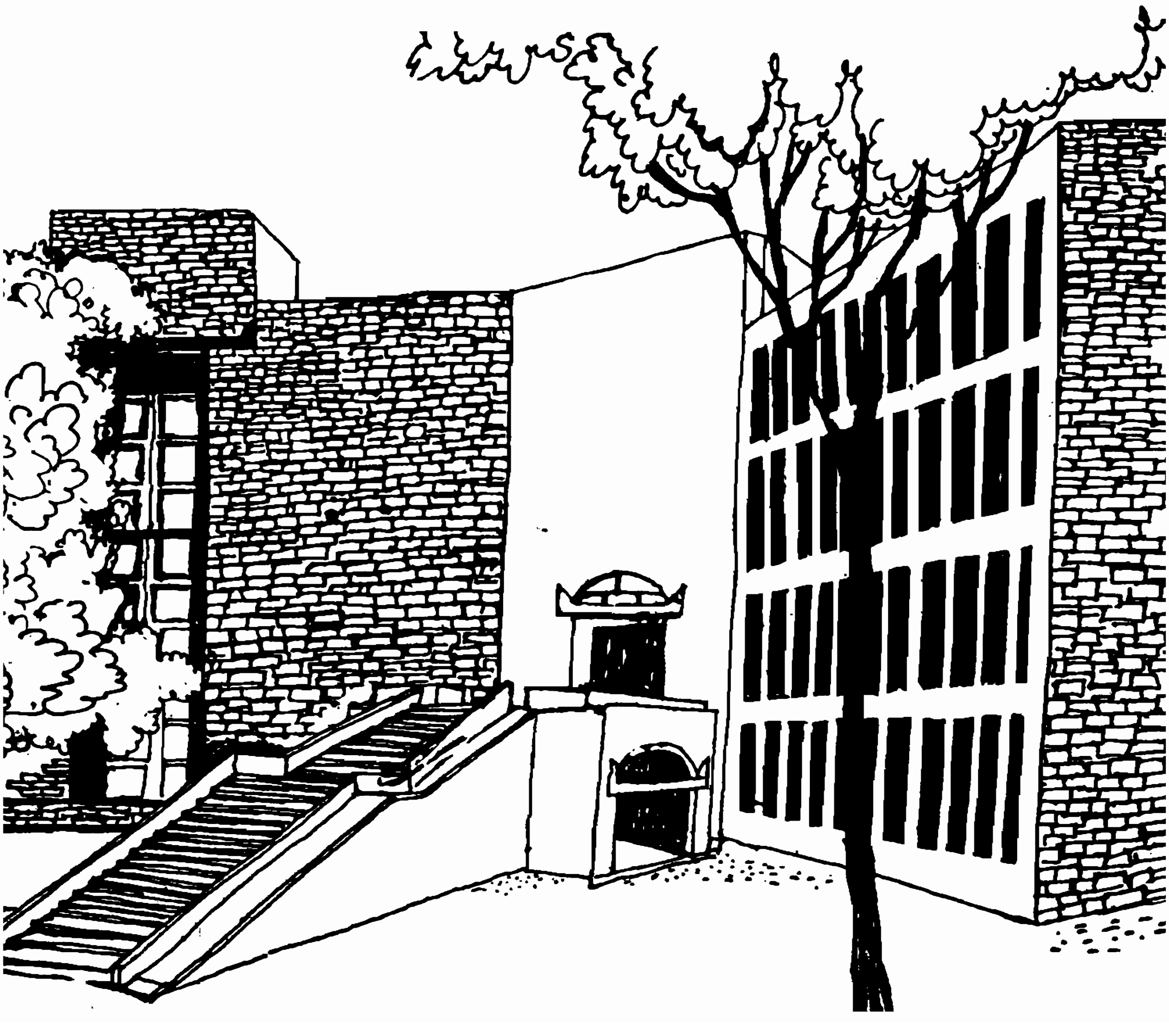

MODELLING A VEGETABLE AND FRUIT MARKET TO AID MODERNISATION

By

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Modelling a Vegetable and Fruit Market to Aid Modernisation

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Abstract

We present in this paper, an operational study of CJ Patel Wholesale Fruit and Vegetable Market of Ahmedabad city using simulation. This market was built in the year 1996 in order to reduce congestion in another older market. Viewed as a dynamic queuing system, simulations suggest that even though the buildings are designed to last a lot longer, utility of this complex as a market place will diminish considerably in just 10 to 15 years. So much so that by the year 2010 A.D., it may become necessary to move out yet again.

Such an eventuality can be warded off, if loading, unloading and other handling systems are modernised and made speedier. A more general conclusion is that design procedures for such markets in future need to recognize these as dynamic queuing systems and not just an assembly of buildings and road.

Key Words: ***Simulation, Vegetable Market***

1. Introduction

India ranks second in the world in vegetables and fruits with combined annual production of 60 m tons. Primitive post harvest (PH) system prevents this high ranking in production from being translated into equally impressive presence in market. System is unable to move produce rapidly over long distances without excessive damage and spoilage. Fresh vegetables and fruits are therefore available mostly in the vicinity of growing areas and near the time of harvest.

The Regulated Wholesale Markets in cities are vital nodes of PH system and first stop for produce meant for the table. Growers send produce daily to these markets for auction. Small traders and retailers buy here for sale to consumers in their areas. Most other big cities also have such markets. Striking feature of these markets is congestion,crowding and litter. Even though the produce spends only a few hours in these markets, significant mechanical damage and contamination occurs in the course of loading, unloading and handling. This is in addition to damages that occurred in transit till then. Modernisation of handling systems in these markets is important if consumers are to get better quality.

Modernisation is imperative from another angle. Demand for fresh produce grows faster than the population in cities. Markets therefore get congested rapidly. Those who run these markets solve the problems by moving into a bigger place every few years. Take for instance, the case of Ahmedabad city. Regulated wholesale market began functioning here in the year 1948. Annual trade was 0.05 million tons then. It grew ten-fold to 0.5 million tons, by 1995. This growth rate works out to 5.33% per year. In other words, volume doubled every 13 years. The Agriculture Produce Marketing Committee (APMC), the authority which regulates wholesale trade had to build a new market at Jamalpur in 1980. Built on a plot admeasuring 15,000 m^2, this too became highly congested within a few years. In 1996, a second market was built at Vasna named CJ Patel market. This is built on a plot twice as large. The cost of Jamalpur market was Rs. 9 million, that of CJP Market ten times as much, Rs. 90 million. Space is becoming increasingly scarce and expensive in big cities. It will not be easily possible to acquire bigger spaces in future.

Despite their importance, these have not received adequate research attention. Civil engineers view these markets only as civil structures. Buildings are designed to last fifty years or more. But their utility as market place diminishes much sooner, because of increased traffic. Passages get occupied with produce, movement of vehicles gets impeded and standards of cleanliness deteriorate.

Markets of future will need to be more compact, with speedier handling systems that do less damage to produce. Simulation models are extensively used for designing and operational management of manufacturing facilities [1,2]. Use of such models for vegetable markets is not common. We present in this paper a model of CJP Market, and illustrate how it can be useful in quantifying the congestion and guiding the program of modernisation. Operations of CJP Market are first described. Simulation model is then presented. Statistics on vehicle-borne congestion is generated and discussed.

2. CJP Market

This market is located on the outskirts of Ahmedabad city at Vasna. Trading in onion, potato and fruits has been shifted to this market in order to reduce congestion in the older Jamalpur market. Lay-out is shown in **figure 1**. There are 120 shops for general commission agents [3]. These are of equal size, 13.5 m x 6 m and arranged in two concentric circles with 78 in the outer and 42 in the inner. A 24 m wide paved road lies between the two circles.

Gate A is for entry of vehicles carrying onion and potato, Gate B for those carrying fruits. Presently gate B is not used. Exit is common through Gate C. One way traffic facilitates easy movement of vehicles.

Operations

Market is open round the clock for vehicles bringing produce for auction. These vehicles are referred to here as seller vehicles (SVs). Date, time of arrival, vehicle number, place of origin, commodity, quantity, commission agent and shop number are noted. An entry fee is charged and a gate pass given.

SVs then go to the shop of the particular commission agent for unloading. Unloading is done from 6 A.M. to 9 P.M. Vehicles arriving after 9 P.M. have to wait over night.

Figure 1: C.J. Patel Market Vasna - Layout

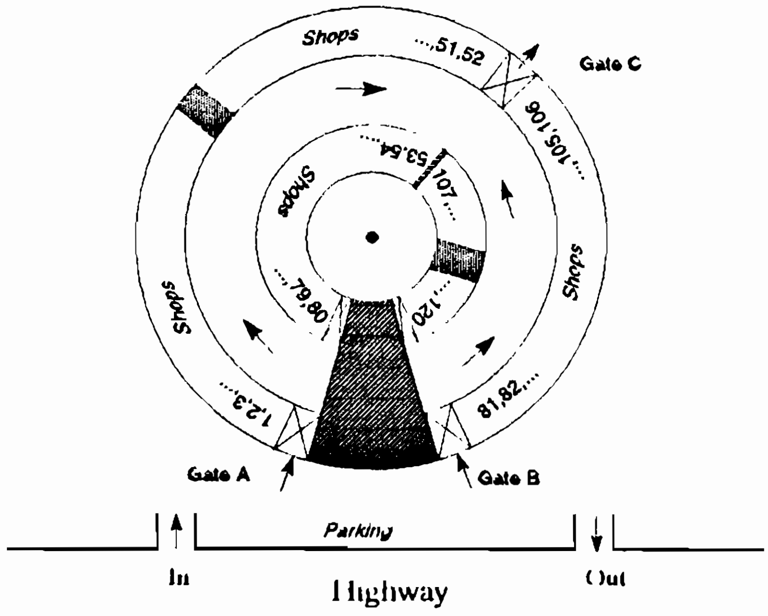
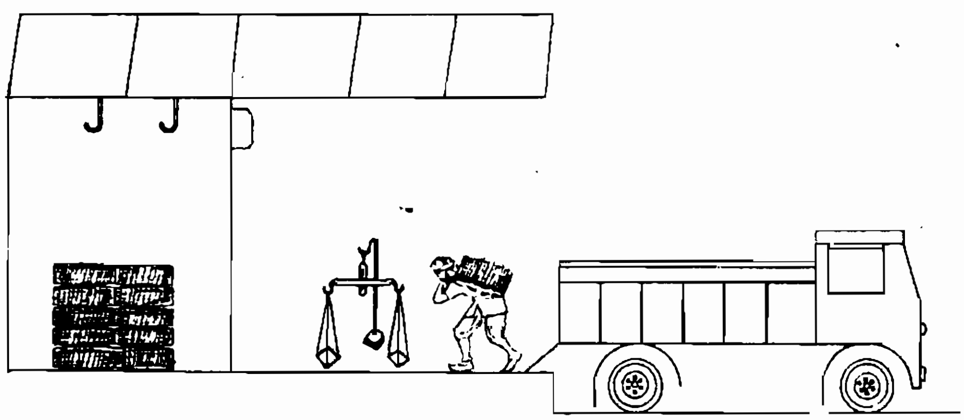


Figure 2 : Unloading by Hamal



Crew members generally spend more time in the market than it takes to service their vehicle. In the model, this is termed as `extra activity'.

Market opens for auction at 8 A.M. Buyers, who are sub-wholesalers and retailers, begin to arrive by about 7:30 A.M. Usually, buyers will browse around for a while before finalising a deal. When deal is made, the commission agents (sellers) issue an auction-slip to the buyers containing the details of the sale.

Buyers walk to the office at Gate A and obtain gate pass to bring their vehicle into the market for carting. Buyer vehicles (BVs) then enter. While buyers can enter or exit without communicating with the Gate, vehicles are required to do so. Most buyers arrange carting immediately. A small proportion takes a little time, perhaps going to town for some other work before returning to pick up the material. This has been termed `post-purchase activity'. Our observations showed that about 15 per cent of the buyers engage in post-purchase activity.

Loading and carting continues throughout the day. Weighing is done by market *tolats* (weight recorders and helpers), commonly on tripod balances. Bags are carried on backs by *hamals* (loaders) one at a time (**figure** 2). Regulations stipulate that auctioned goods be weighed before 5 P.M. and carted out by 7 P.M. the same day.

SVs are mostly 10 ton trucks. BVs include hand-carts, camel carts, rickshaws, matadors, and medium size trucks (**table** 1). All vehicles depart through Gate C, where gate pass and auction slip have to be returned. Vehicle may also be inspected occasionally.

Table 1
Vehicle related Statistics

Vehicles	Variety (%)	Pay-load (tons)	Capacity (bags)	Time to Service		Capacity (ton/m.sq)
				Load (sec/bag)	Unload (sec/bag)	
Seller Vehicles						
Large Trucks	95	10	125-160	14±6	11±5	1.0
Medium Trucks	5	3	40-50	18±6		0.5
Buyer Vehicles						
Medium Trucks	40	3	40-50	18±6		0.5
Matadors	40	1.5	20-25	18±6		0.4
Three-wheeler Carriers	15	0.75	10-12	34±13		0.3
Camel and Hand Carts etc.	5	<0.75	10-12	34±34		0.4

A special feature of fruit and vegetable markets is that whatever is brought into the market is sold the same day. It is rare to find inventories in the shops. Daily arrival of stock does vary seasonally, but within a narrow band. It averages to 650 tons, which can go up to 750 tons during peak month (January) and reduce to a low of 500 tons during lean month (July).

Let us recapitulate. All vehicles form a common queue and enter through Gate A on first-come-first-served (FCFS) basis. After gate formalities, this common queue, breaks into several parallel ones. These could be as many as the number of shops i.e.120. After being serviced (loaded/unloaded), vehicles again merge into a common queue at exit gate and depart after formalities which is again on FCFS basis.

3. Modelling Tasks

Modelling consisted of four stages--input pattern analysis, prototype model, its testing and refinement, and validation. Pattern underlying the following processes needs to be discovered. These are independent inputs.

1 Arrival of SVs,
2(a) Arrival of Buyers, browsing and buying
(b) Arrival of BVs

In addition, the following
3 Time to complete formalities at Gates A & C.
4 Time to load and unload vehicles
5 Relative market share of commission agents.

Data was acquired from CJP Market records as well as by direct observations. Discovering the underlying patterns typically involves examination of frequency diagram, selecting promising distribution and testing goodness of fit. For reason of space, we shall illustrate only one such analysis, inter-arrival density of SVs.

Inter-arrival Distribution of SVs

Seller Vehicle (SV) arrival data was acquired from records for seven consecutive days, September 1-7,1996. Number of arrivals at hourly interval is shown in **figure 3**. Although, arrivals occur round the clock, there are two peak periods. First is three hours long (5-8 hours) and the second about five hours (17-22 hours). It was decided therefore to divide the day in three parts--part one (5-8 hrs), part two (17-22 hrs), and the rest as part three. Analysis was done separately for each of these parts. The resulting distributions were used to generate arrivals on 24-hour days. The synthetic pattern was compared with the original and refinements made, as described below.

Time of arrival of each vehicle is available from gate records. However, records tend to be inaccurate due to two reasons. Only an approximate time of arrival is important to market management which it needs to determine the parking fee. Arrival and departure time need only be exact to an hour. Second, entry is made when the vehicle reaches the counter, ignoring the time it may have spent in queue. Thus, the records will include a random and unknown waiting time.

Figure 3

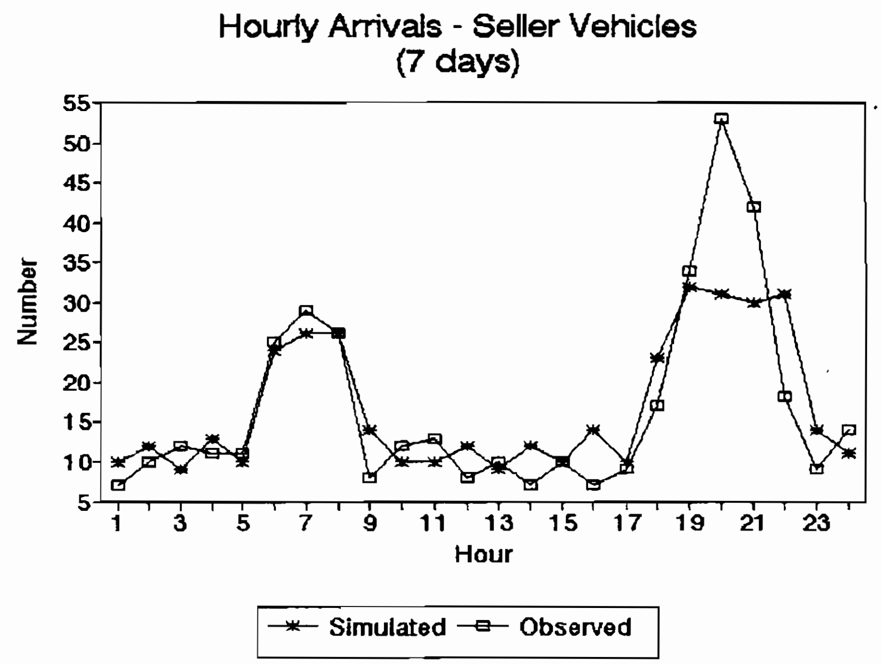
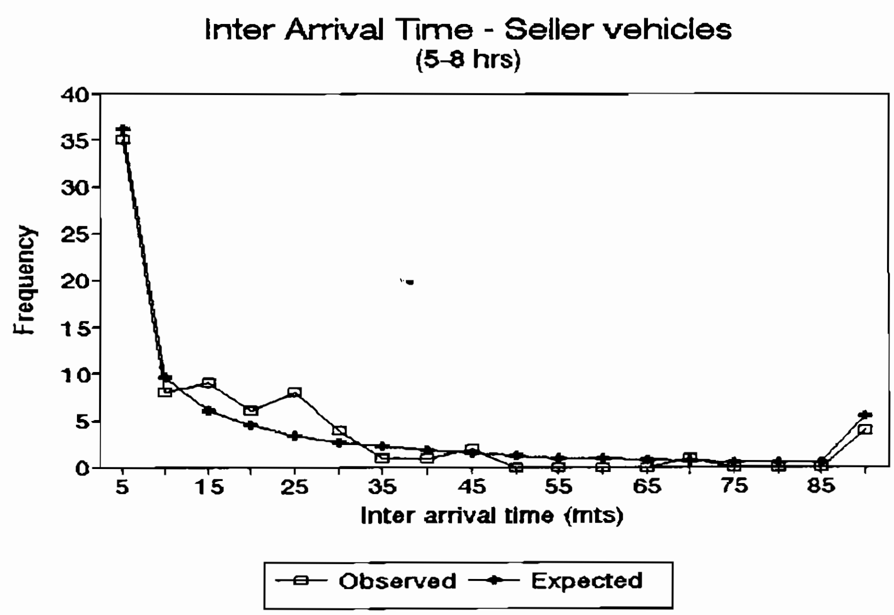


Figure 4



Inaccuracy is less at nights, when arrivals are fewer and queue mostly empty. We, therefore, made our own observations of inter arrival (IA) time during the day and relied on records for the nights.

Figure 4 shows the frequency diagram of inter-arrival time during the first period (5-8 hours). Similar patterns were also found in the other two periods. Visual inspection suggested the possibility of gamma being the underlying pattern. Accordingly, two-parameter gamma distribution was tried. The density is given by

$$f(x)=\frac{1}{\Gamma(\alpha)\beta^{\alpha}}\exp\left[-\frac{x}{\beta}\right]\ x^{\alpha-1}\ ;\ x>o \qquad (1)$$

where

$\hat{\beta}_i$ is scale and $\hat{\alpha}_i$ shape parameter;

σ_i^2 variance and $\bar{x}_i$ mean

i designates three periods of the day

Parameters, estimated using method of moments, are shown in **table 2**.

Table 2
Statistical Parameters

Time period	Mean (mts)	Variance	β_i	α_i	d.f.	χ^2 computed	χ^2 critical
05 - 08 hrs	16.48	765.82	46.467	0.355	4	9.811	11.143
17 - 22 hrs	13.99	762.86	54.514	0.257	4	21.382	11.143
Rest	37.47	1740.36	46.445	0.807	5	10.440	12.833

Fit was good for the first and the third time period but not the second. **Figure 4** shows the computed frequency diagram of first period for comparison. Data of period two was taken for further investigation.

It was found that one extreme observation of 260 minutes was lone outlier. All the other times did not exceed 140 minutes. Hence, a truncated gamma distribution using 140 minutes as the point of truncation was tried. The truncated density,

$$f(x)=\frac{\exp\left[-\frac{x}{\beta}\right]\ x^{\alpha-1}}{\int_0^{140}\exp\left[-\frac{x}{\beta}\right]\ x^{\alpha-1}}\ ;\ 0<x<140 \qquad (2)$$

This yielded a better fit with χ^2 (computed) being 6.191. Hourly arrivals were computed using the three gamma distributions and are shown in **figure 3**. Kolmogorov-Smirnov (K-S) test was used to check the goodness of fit. The K-S statistic works out to 0.053 against a tabulated value of 0.061 at 10% level of significance. Hence the fit is good. Visual examination shows that division of day in three periods did not distort the pattern of arrival. It does appear, however, that extremals generated for period two, tend to be lower than those observed. Parameters of truncated gamma are shown in the summary below.

Representations of other processes were similarly developed. These are summarized below.

Summary of Representations

	Parameter values are in minutes
Arrival of SVs	
	Gamma (0.355, 46.47); 5 to 8 hours
	Gamma (0.371, 33.77); 17 to 22 hours
	Gamma (0.807, 46.45); all other times
Gate formalities	U (0.25-1.25)
Unloading time	Empirical (**table 1**)
Extra activity time	U (60, 420)
Departure	
Arrival of buyers	
	Exponential (λ = 1.03); 0730 - 1330 hours
Time-to-browse	U (0 - 30 mts)
Time to get gate pass	U (0.25 - 1.25 mts)
Post-purchase activity	U (300, 420), in case of 15%
Arrival of BVs	
BVs enter when called by buyers with gate-pass	
Gate formalities	U (0.25 - 1.25 mts)
loading time	Empirical (**table 1**)
Extra activity	Exponential (λ = 15)
Departure	

To simplify the modelling task, we have assumed the following:

(a) All general commission agents, have an equal share of trade.

(b) Daily demand and daily supplies are nearly equal.

4. Simulation Model

A simulation model was built and coded in SLAM-II network module. **Figure 5** shows the flow diagram of simulation program. Source listing is available with the authors and also included in main report [4].

Prototype model was tested and refined. This was done by simulating the operations of the market for seven consecutive days and comparing the results with observations, specially collected for this purpose and not earlier used in model construction. This was done in the month of December (1996). Tests revealed the need to modify representation of buyer activity which was done. Satisfactory prototype model was completed in March 1997.

5. Validation

Systematic validation of began in April 1997 and will continue for a year. Each month we make observations over a 7 day period. On each day, number of vehicles in market, queue length at the gates are recorded at hourly interval from 8 AM to 6 PM. We also note the quantity of produce arriving for auction each day. In this paper, observations of the first month (April) are presented.

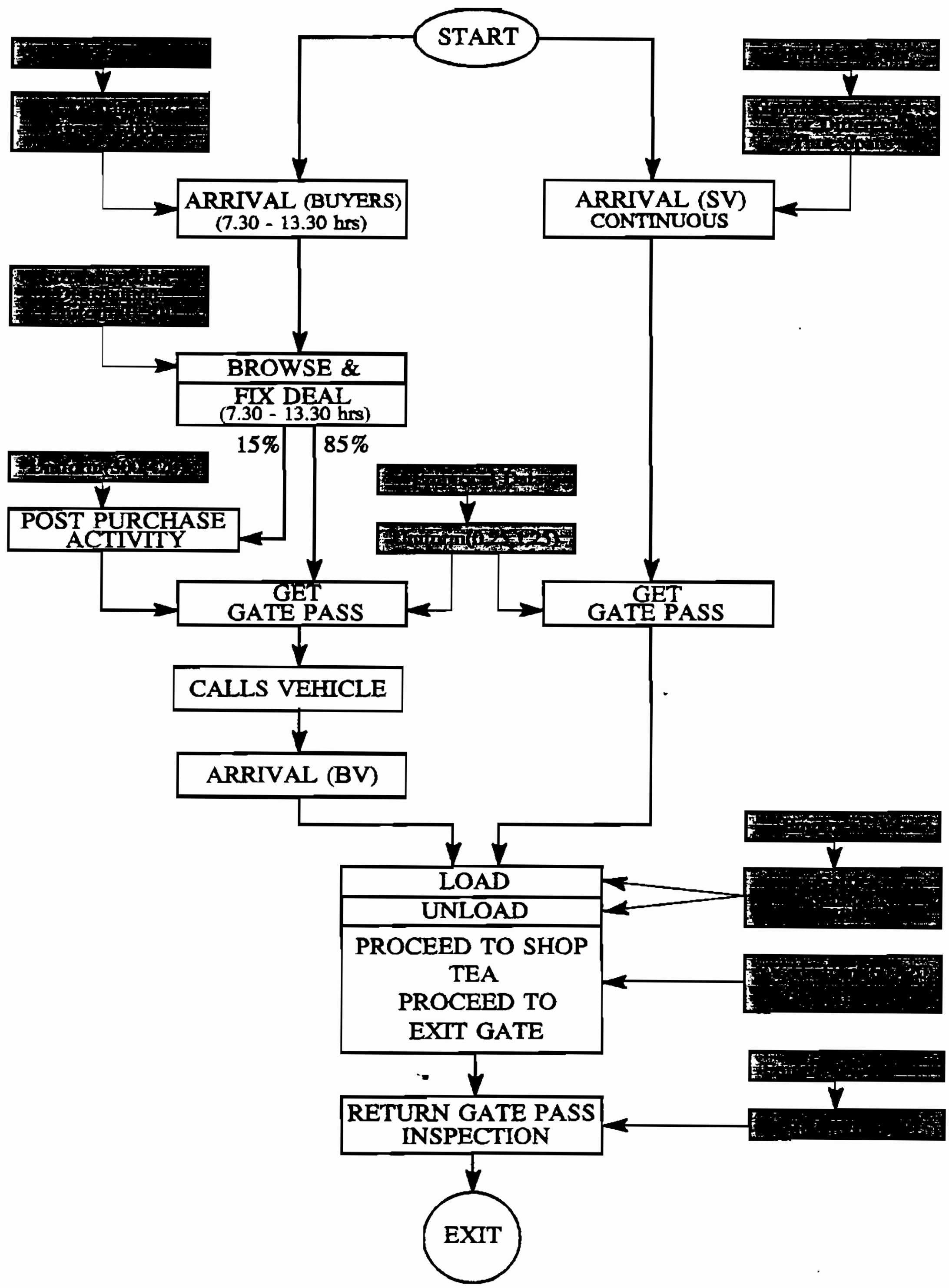
During the days of observation in April, arrivals averaged 750 tons/day. Model parameters were customised for this quantity. Simulation runs were made of 15 days at a time. Ten such replications were made. Each run started with empty market, at 6 AM on the first day. Results are given in **table 3**.

Number of vehicles (mean) in the market during the days is shown in **figure 6**. It can be seen that the pattern is similar and the magnitudes are also very close. It may be noted, however, from **table 3** that simulated extremals tend to be less than those observed. This aspect will be dealt with when validation data of subsequent months is also obtained and analysed. In anticipation of the model being found satisfactory when validation is completed, we will use it to study some operating characteristics, particularly the vehicle borne congestion.

Table 3
Number of Vehicles in Market

Hour of Day	Simulated (Arrival 750 tons/day)			Observations (April 1997)		
	Max	Min	Avg	Max	Min	Avg
7	37	6	33			
8	63	21	50	84	38	62
9	75	38	63	95	30	59
10	71	35	59	81	34	55
11	75	38	55	75	35	52
12	63	32	50	76	24	44
13	56	33	45	60	24	39
14	51	22	34	45	17	30
15	24	7	16	51	12	30
16	24	9	16	46	14	26
17	23	9	16	37	11	19
18	28	13	20	21	9	15
19	32	17	25			

Figure 5 Schematic Diagram of Simulation Program



6. Daily Arrival and Congestion

As stated, daily arrivals in CJP Market presently vary from about 500 to 750 tons/day. Given the fact that volume has risen by 5.33 per cent per year, it is likely that peak arrivals will grow to 1000 tons/day by year 2000 A.D., 1200 tons/day by 2005 and 1500 tons/day by about 2010. We customised the parameters for these levels and made runs as described earlier. **Table 4** shows the results for the first two levels.

Table 4
Vehicles in Market: Simulated Results

Hour of Day	Daily Arrival (1000 tons)			Daily Arrival (1250 tons)		
	Max	Min	Avg	Max	Min	Avg
7	37	8	31	31	9	25
8	65	30	53	59	29	50
9	78	44	67	72	46	63
10	82	45	64	71	48	61
11	75	47	61	68	48	58
12	70	45	57	69	46	57
13	66	43	51	68	44	54
14	60	36	48	63	40	52
15	61	33	47	58	43	51
16	60	16	34	63	42	51
17	45	14	23	60	40	50
18	40	20	28	70	31	53
19	46	25	33	72	34	47

Results are also shown graphically in **figure 7**. The figure has the graph also of daily arrivals of 500 tons/day which occurs in lean periods of the year. Effect of rising volume of trade on operational congestion can be discerned from this figure.

Buyers in the market are retailers who need to return to their own shops as early in the day as possible. With arrivals of 500 tons/day, the number of vehicles in the market begins to reduce sharply after 1:00 P.M. Same is true with arrivals of even 750 tons/day which can be seen in **figure 5**. But as arrivals rise further, the situation changes. It is seen that by 2:00 P.M., there will be on an average 48 vehicles in the market, at arrival of 1000 tons/day, and 52 at 1250 tons/day. By 7:00 P.M., the stipulated closing time for carting, as many as 33 and 47 vehicles are stranded respectively with the arrival of 1000 and 1250 tons/day. Simulation program identifies each vehicle. Most of these vehicles in the market at this time are buyer-vehicles (BVs), waiting for loading.

Most interesting aspect came to light when we tried to run the simulation at arrival of 1500 tons/day. Number of vehicles continued to rise with each successive day (**figure 8**). In other words, loading and unloading becomes so strained that arrivals of one day will get carried over to the next and the vehicles waiting for service will go on increasing. In fact this tendency begins to arise just above 1250 tons/day.

Figure 6

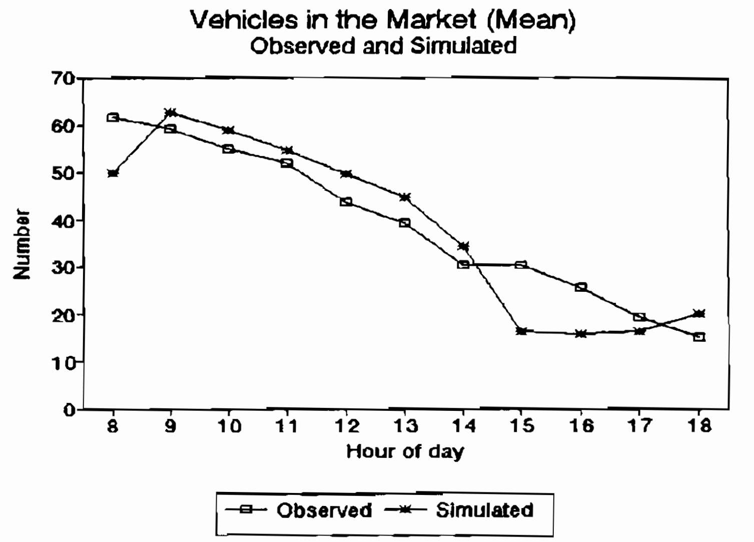
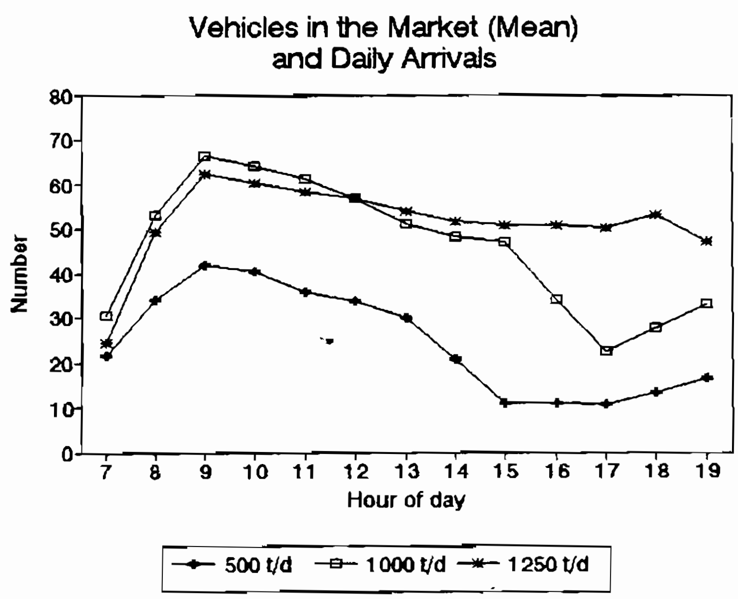
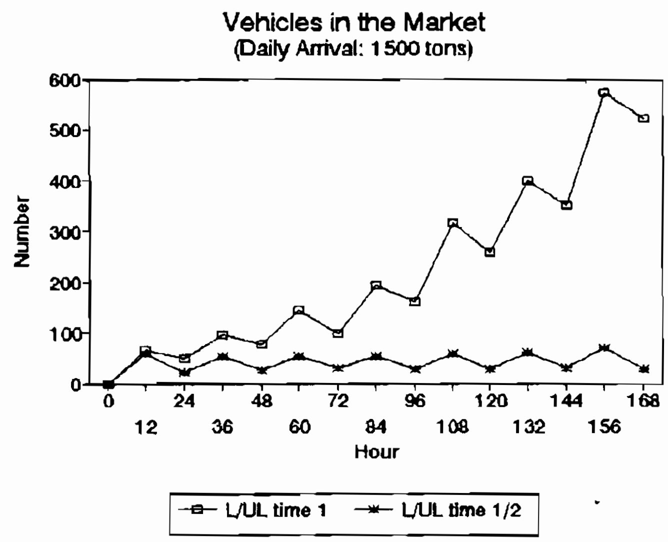


Figure 7



As stated, volume of this order can be expected in next 10 to 15 years. By that time the handling capacity of this market would be nearly saturated. It will become necessary to speed-up internal operations, by deploying suitable mechanical and other systems. Unlike manufacturing facilities, ways to control congestion in fresh produce markets such as this are limited. One of the ways is to mechanise loading, unloading operations. Simulation showed that instability can be removed by speeding up the loading and unloading operations. When we reduced the loading and unloading time to half the present values instability was completely removed, as can be seen in **figure 8.**

Figure 8



Vehicles, especially the ones brought in by the buyers also need attention. Buyers are small traders and retailers, who buy in lots of varying sizes. Consequently they employ vehicles of varied type and size. Some of these vehicles have carriages disproportionately large for the pay-load. Camel carts, for instance, have a flat wooden platform of 3 m x 1.6 m in size, with carrying capacity of 0.4 ton/m.sq. of carriage area. As compared to this, large trucks can carry 1 ton/m.sq.

Chain and beam weigh scales used are cumbersome, occupy a large space, and are slow in service. These also need to be replaced with modern electronic scales which have higher range and are compact.

7. Conclusions

Regulated wholesale markets in cities are vital nodes of post-harvest system of vegetables and fruits. In Ahmedabad, as also in most other places, these markets are marked with congestion, crowding, and litter. Such conditions lead to further deterioration in quality of produce before it reaches in consumer.

Management of these markets have hitherto solved the problem of congestion by moving out. This may still be possible in small towns. But in large cities like Ahmedabad, it could be increasingly infeasible due to high cost and scarcity of land.

Real solution lies in modernising the material handling systems and use of equipment to increase the productivity of space. The traditional view, that these markets are a complex of buildings and roads, needs to be altered. These are in reality complex, dynamic queuing systems.

CJP Market of Ahmedabad which began operations in 1996 was built to reduce congestion in the older main market. The new market is twice as large as the older one; but all other systems--loading, unloading, transfer, weighing etc.--are the same. Simulations--using the model of this market developed for the purpose--suggest that if the vegetable and fruit trade grows as it did in the past, this market will get so severely congested by the year 2010 A.D., that it may be necessary to move out again.

Operational congestion, non-existent presently, will in fact become real much before that. Peak arrivals could be 1000 to 1250 tons/day in next 5 to 10 years. Number of vehicles at peak hours would still be manageable. But carting and handling will extend further and further into afternoons. Buyers would find it unacceptable.

Speeding up loading, unloading and transfer operations by means of mechanical systems will be desirable. Examination of specific mechanical systems was not part of the objective in this work. But simulations showed that reduction in loading and unloading time had great effect on congestion. Vehicles used by buyers are quite a variety. Introduction of vehicles that carry more pay-load in smaller carriages offer another avenue of decongestion.

Models such as this can be useful in designing new fruit and vegetable wholesale markets. These can also be used to guide the program of modernization as well as operational management of the existing ones.

Acknowledgement

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