A SELECTION OF APPLICATIONS AT CANADA CUSTOMS

by

LAURA MUNRO

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Department of Commerce and Business Administration

The University of British Columbia
Vancouver, Canada

Date June 16/93

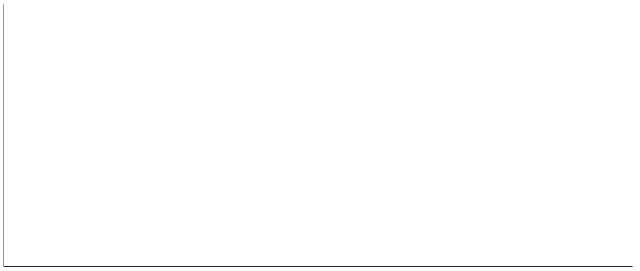
ABSTRACT

Canada Customs is currently faced with problems of overcrowding. This situation causes lost revenue and potential control problems, and detracts from its public image. Customs administration is interested in determining what changes, if any, can be made to help alleviate the problem. The goal of this paper is to analyze several alternatives which are available to customs officials, and to recommend changes which can be implemented to improve the current situation.

To achieve this goal, several applications of Management Science methods were performed. The first application involved a cost-benefit analysis of the Peace Arch Crossing Entry (PACE) Project. It was found that the PACE project has positive net benefits of approximately $9.5 million provided that it is supported by sufficient staff levels. Results of the cost-benefit analysis also indicate that the social benefits of having an extra staff member available far outweigh the costs involved.

In the second application performed, multiple regression techniques were used to analyze various characteristics of travellers which affect service time within the customs office. As a result, it is recommended that customs officials look into the possibility of keeping certain groups of individuals (whose processing times are relatively low) separate from the main flow of travellers, in order to save these travellers a great deal of time.

In the third application, simulation and animation were used to replicate the current situation in the Pacific Highway Customs Office. Experiments were then conducted to determine the optimal mix of regular terminals and Self Declaration System (SDS) terminals. It was found that implementing SDS was not as efficient as adding a new regular terminal. It is recommended that a study be conducted to determine by how much the times for SDS can be reduced. If significant reductions in time are not possible, it may be in the best interest of all concerned to revert the SDS terminals to regular terminals.



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1 INTRODUCTION TO CANADA CUSTOMS: THE PACIFIC HIGHWAY DISTRICT

Within the Pacific Highway District of Canada Customs and Immigration, there are five border crossing facilities, namely Boundary Bay, Douglas (Peace Arch), Pacific Highway, Aldergrove and Huntingdon. This study concentrates on the Douglas and Pacific Highway crossings. Section 1.1 details the site layout and activities of the Pacific Highway Crossing. Since the two crossings are very similar, the discussion of the Pacific Highway crossing can be generalized almost entirely to include the Douglas Crossing. For this reason, the discussion of the Douglas Crossing in section 1.2 is concerned only with the differences between the two crossings.

1.1 The Pacific Highway Crossing

The Pacific Highway Crossing is located at the corner of 0 Avenue and 176th Street, in South Surrey, British Columbia. The layout of the crossing is shown in Figure 1-1. The main building houses both the customs/immigration office and the administrative headquarters for the Pacific Highway District. On site there are facilities to accommodate both general customers and commercial customers (truckers). General customers are processed at the car booths on the western side of the main building, while commercial customers are handled at the truck booths on the eastern side. To the north of the main building there is a sheltered examination area, where cars are parked during searches.

During weekdays (Monday-Friday, 8:00am to midnight), commercial and general customers report to separate buildings. At all other times both commercial and general customers report to the same office, but the two are kept completely separate throughout the queuing and service process. There are congestion problems associated with both groups, but these problems generally occur during different time periods. For example, the traffic flow of general customers is usually quite heavy between 11:00am and 11:00pm on weekdays, and becomes even more intense during the weekend. In contrast, truck traffic is generally heaviest on Saturday afternoons and after midnight on weekdays. Of the two groups, the general customers have the more intense traffic flows and are of greater concern to the Pacific Highway District, and are thus the focus of this paper.

1.1.1 Booths and Primary Processing

As previously stated, general customers are processed at the car booths to the west of the customs building (see Figure 1-2). There are seven booths in total, although they may not all be open during a particular shift. Each shift is manned by a team of approximately 13 officers, although shifts overlap during peak periods. These officers are responsible for the entire crossing facility, including both the general and commercial customers. The decision on the maximum number of booths to open during a particular shift is made by the team superintendent on duty. The superintendent makes the decision based on the number of officers available to work in the booths and office. If traffic flows are

not sufficient to warrant opening the number of booths that has been calculated as the shift maximum, one or more officers will return inside to help with the customs desk and/or to perform administrative duties.

The activities that occur at the booths are referred to as *the primary*. The major responsibility of the primary officer is to determine the admissibility of people and goods into Canada. To make this decision, the officer questions individuals as to their citizenship, how long they have been absent from Canada (or, in the case of non-residents, how long they intend to stay in Canada), what goods they are taking across the border that need to be declared, and whether or not firearms are being transported. Border-crossers are required to report to the immigration desk if they are a resident of a country other than Canada or the United States. Regardless of citizenship, individuals crossing the border are required to report to the customs desk if they have declared goods for which duty must be paid and/or if the officer has reason to request a mandatory or selective search. Profiles are used to assist the primary officer in determining whether or not a search should be conducted. If an officer decides to send a border-crosser in to the customs/immigration office, this action is termed a secondary referral, and a referral card (called the E-67) is given to the border-crosser(s). Only one referral card is used for a single car, and the number of passengers in the car is recorded, along with each passenger's country of residence.

In addition to these duties, the primary officer is also responsible for filling out E-62 forms, which are used to tabulate the total number of cars and people that utilized the crossing during each hour. At the end of the hour, the officer returns inside and is replaced by another team member who has spent the past hour in the office.

1.1.2 Customs/Immigration Office and Secondary Processing

Once a referral card has been issued, the border-crossers enter the office and join the queue for either the immigration desk or the customs desk (see Figure 1-3 for office layout). All activities carried out in the office are referred to as *secondary activities*. These include immigration services, customs services, disclosures, duty payments, searches, forced payments and seizures. For explanations of these terms, see section 1.3. In addition to these activities, the office also handles general enquiries from travellers.

1.2 The Douglas Crossing

The Douglas Crossing is located on Highway 99/Route I-5, approximately one mile west of the Pacific Highway Crossing. The layout of this crossing is shown in Figure 1-4. Since the two crossings are in such close proximity, travellers are often indifferent as to which crossing to use. The crossings have only two major differences: 1) the Pacific Highway crossing houses the administrative offices for the district, while the Douglas crossing

is the base for the Interdiction and Intelligence Department; and 2) the Douglas Crossing does not have facilities for dealing with commercial travellers, but instead has the Peace Arch Crossing Entry (PACE) project.

The PACE project was first implemented on a trial basis in May of 1991. It began as a co-operative effort between the Canadian and American border agencies to provide better service to the travelling public. This "better service" can take the form of faster border crossing times, more frequent examinations, or any combination of the two. The PACE project has since been divided into two separate programs. The Canadian project involves an express lane at the Douglas (Peace Arch) border crossing, which can be used only by travellers who subscribe to the program and meet certain requirements designed to screen out all but the most trustworthy individuals.

PACE members are unsupervised as they fill out their declaration forms and drop them in a box on their way across the border. Duties and taxes are then charged automatically to their credit card. To encourage compliance, random checks are done on a regular basis. As a result of the program, PACE members enjoy almost non-existent queuing times in the vehicle lines when crossing the border, and they are not required to line up inside the Customs office to pay duties and taxes. In addition, congestion is reduced

at the regular vehicle lanes (assuming that the number of officers in the regular lanes is held fairly constant).

1.3 Definition of Terms

The terminology used by officers and administrators of the Pacific Highway District border crossings includes both formal terms and informal phrases. Those expressions which are relevant to this study can be explained as follows:

1) *Primary*- the process by which individuals are screened for acceptance across the border; those activities that occur at the border-crossing booths;
2) *Secondary*- the process by which individuals fulfil the necessary requirements prior to being allowed to cross the border; those activities that occur in the customs/immigration office and/or examination area;
3) *Returning Resident*- a resident of Canada who has been absent from the country and is now returning to Canada from (or by way of) the United States;
4) *Non-resident*- formally: a resident of any country other than Canada; informally: used to denote only those individuals who are residents of the United States and are visiting Canada;
5) *Passport Holder*- an individual who is a resident of any country other than Canada or the United States (often referred to simply as "passports");

6) *Referral or Secondary Referral*- the action performed by the primary officer when he or she instructs an individual to report to customs and/or immigration;

7) *Declaration*- formally: the act of providing a description of goods that an individual has acquired during a period of absence from Canada; informally: used almost exclusively to denote a written description of goods that an individual has acquired during an extended period of absence from Canada (7 days or more);

8) *Search or Examination*- when a vehicle and/or individual is searched for restricted or undeclared goods; a *mandatory search* occurs when the primary officer dictates that the vehicle must be searched, while a *selective search* leaves the decision up to the secondary officer;

9) *False Claim*- an incomplete or otherwise untruthful declaration of goods or materials;

10) *Forced Payment*- the action taken when a search uncovers a small amount of goods which are subject to duty but were not declared; the individual is recorded as a previous offender and must pay the duty owed on the undeclared goods;

11) *Seizure or Enforcement Action*- the strict disciplinary action taken when a search uncovers either illegal materials or a large amount of goods which are subject to duty but were not declared;

12) *Landing*- when an individual is moving into Canada and wishes to bring their goods across the border;
13) *Abandonment of goods*- when an individual decides to turn their goods over to the crown instead of paying the duties and taxes owing;

1.4 Classification of Border Crossers

Individuals crossing the border can be classified in a variety of ways depending on the criteria used to separate the groups. The methods of classification which are most relevant to the goal at hand are outlined below.

1.4.1 Classification by Country of Residence

The initial form of categorization used at the Pacific Highway Crossing is the division of individuals based on the country in which they reside. The three main classifications are returning residents (Canadian), non-residents (American), and passport holders (other). These groupings are recorded at the time when an individual is sent into the customs office. It is important to note that in most cases, passport holders are not required to report to the customs desk. They may instead report only to the immigration desk before continuing on their way.

1.4.2 Classification by Length of Absence/Stay

The second form of classification is by length of absence from Canada (in the case of returning residents), or expected length of stay in Canada (in the case of non-residents and passport holders). These facts are also recorded at the time of referral. The categories for length of absence/length of stay are as follows: A: less than 24 hours; B: 24-48 hours; C: greater than 48 hours and D: greater than 7 days. These groupings are used to determine limits of declarable goods in calculating the duty owed by each border-crosser.

1.4.3 Classification by Details of Primary (reason for being in the Customs office)

The decisions made by the officer in charge of the primary leads to another method of classification. These decisions include whether or not a referral is made, whether or not a mandatory search is ordered, and whether the border-crosser must report to customs, immigration, or both. Once the primary officer reaches his or her decision, the necessary information is written on the referral card, which is then given to the border-crosser, who in turn passes it to the officer at the service terminal.

1.4.4 Classification by Amount Declared

An additional method of grouping travellers is by the amount of goods they declare, either based on dollar value of the goods or the number of items declared. When border-crossers are processed at the terminal, the officer must manually enter each type of item which is being declared. Each item type requires one line to be entered into the computer. Thus, the procedure is driven by the number of different types of items declared rather than by the dollar value of the goods.

1.4.5 Classification by Number of People in Group

When the occupants of a car passing through the primary station are referred inside, only one referral card is issued. All occupants are covered by the same card until their terminal service is complete. Because of this, the carload of people remain together as they queue for the terminal, and while they are being served. Once served at the terminal, they are free to separate as they continue to the cash line, since processing at the cashier does not require the referral card. Thus the number of people on a single referral card may affect the time required for processing.

1.4.6 Classification by Outcome of Search

When an examination is conducted , several outcomes are possible, as follows: 1) no declarable goods may be present, in which case the individual is free to leave; 2) all goods may have been truthfully declared and the individual can then leave after paying the duty owed on the declared goods; 3) a false claim may have been made. If this occurs and there is only a small amount of undeclared goods, a forced payment results (the individual is subjected to additional processing at a separate terminal before being allowed to continue to the cashier). If a large amount of undeclared goods is found, enforcement action results, and the individual is removed from the office (and therefore also from the queuing and service system); 4) a seizure may occur, which also results in the perpetrator being removed from the system while enforcement action is taken.

1.4.7 Classification by Method of Payment

The cashiers at the Pacific Highway crossing accept cash, cheques and credit cards as methods of payment of duties and taxes. The length of time required to process an individual at the cashier's desk is greatly influenced by the method of payment used.

1.5 The Problem of Overcrowding

Canada Customs is currently facing problems due to space constraints. The situation is most severe at the Pacific Highway and Douglas crossings, therefore these two crossings were chosen as the focus of this series of applications. Traffic flow through the border-crossing facilities has seasonal trends, but in general it has increased steadily over the past five years, as shown in Figure 1-5. This pattern is expected to continue due to the following contributing factors: 1) the Canada/U.S. free trade agreements, which make cross-border shopping a desirable option for an increasing number of Canadians;[1] 2) drastically lower fuel prices in the U.S.; 3) rapid population growth of suburbs in close proximity to the border (e.g. White Rock, South Surrey, Langley, and Fraser Valley); 4) rapid increase in U.S. retail developments, which has resulted in greater selection and more competitive prices; and 5) increase in Canadian awareness of the merits of shopping in the U.S..

As the traffic flow intensifies at the border-crossing facilities, problems arise both outside at the primary, and inside at the secondary. During peak periods, queues as long as one-half mile form in the primary lanes, and travellers are forced to wait for long periods of time. At the same time, the customs/immigration offices become flooded with individuals who are required to report

[1] It should be noted that this situation will eventually lead to the need for fewer declarations, as more goods become duty-free.

to the customs and/or immigration desks. Once inside the offices, many travellers become confused due to the complicated layout of the offices. The results are often chaotic. Due to limitations in the amount of space available for queues, the offices are facing saturation problems. This situation is undesirable for a number of reasons: 1) crowding leads to poor public relations with those individuals who are crossing the border; 2) the long waiting periods may discourage non-residents from visiting Canada, thereby undermining the efforts of the Department of Tourism and Trade; and 3) large crowds lead to control problems, since it is impossible for the relatively small number of officers to watch all of the people at once.

In addition, while attempting to counteract the effects of intense traffic, customs officers in the primary booths become more lenient in their decision as to whether or not an individual with duty to pay must report to the customs office. In extremely busy periods, those persons with only a relatively small amount of duty to pay may be waved through, so that the office will have more room to accommodate those owing large amounts[2]. As this rate of secondary referral drops, small amounts of revenue are lost. If this situation occurs on a long-term basis (as is currently the case),

[2]This leniency does not, however, apply to immigrants or to those persons who fit a particular profile requiring a mandatory search.

the amount of lost revenue increases to the point where it is of major concern.

1.6 Management Science Applications

The combination of the above problems is leading to a difficult situation for customs officials. In the past, problems faced by the Pacific Highway District have been dealt with reactively, using intuition and common sense as guides. Administrators realize that this is a non-optimal solution, and they have expressed a desire to begin planning for the future and anticipating problems before their onset. They also require tools that will enable them to analyze various options in order to validate their decisions and gain confidence in the resulting changes. To help customs officials meet these goals, various Management Science methods were used to evaluate several alternatives and suggest beneficial changes. Application #1 of this paper outlines the methodologies and results of a cost-benefit analysis that was performed to determine the extent to which the PACE program promotes the efficient allocation of resources. Application #2 uses multiple regression techniques to determine which factors affect the length of time needed to process an individual at the terminals. Application #3 uses simulation and animation methods to model the current situation, and to analyze the newly implemented Self Declaration System.

2. APPLICATION #1: COST-BENEFIT ANALYSIS OF THE PEACE ARCH CROSSING ENTRY PROJECT

2.1 Introduction

Cost-benefit analysis (CBA), can be a very useful tool for evaluating various projects in the public sector. In order for a project to be deemed worthwhile from a cost-benefit viewpoint, it must promote the efficient allocation of resources. Efficient resource allocation occurs when the benefits gained from the project are great enough to cover any losses which are incurred. The major goal of this application is to evaluate the current PACE lane operation at the Douglas Border Crossing, through the use of interim Cost-Benefit Analysis. Results of this CBA can then be used to aid in the decision of whether or not the PACE project should be implemented at other border crossings.

2.2 Methodology of the PACE CBA

In order to examine the extent to which efficient allocation is being achieved by the PACE project, it is helpful to look at the marginal costs and benefits generated by the project. The border crossings at Douglas (Peace Arch) and Pacific Highway were both included in the study (by combining the two border crossings into one fictional crossing). Since the two are very close together and frequent switching occurs between the two, impacts of the PACE program are relevant to both crossings. By combining the two crossings into one during the analysis, we are assuming that traffic flows and resources are divided evenly between the Douglas

and Pacific Highway Crossings. At the present time, traffic is not always evenly divided, largely due to a lack of public awareness of the Pacific Highway Crossing. This situation is inefficient since large line-ups may build at one crossing while the other crossing is relatively idle. In order to avoid these inefficiencies, customs officials should attempt to distribute the traffic more evenly by better educating the travelling public and providing clearer signage.

When calculating the applicable costs and benefits, several factors were of great importance:

1. The only goal of the PACE project is allocative efficiency; therefore membership fees and duties and taxes are considered transfers.

2. The standing of the CBA is assumed to be global (i.e. the benefits of all travellers are included, not just those who are residents of British Columbia) since the residents of many different provinces and states use the border crossings at Douglas and Pacific Highway, and receive benefits from the PACE project. This situation is expected to continue.

3. The PACE project is evaluated over an eight year period. Since the project development phase began in 1990-91, this interim study is effectively being performed at the beginning of year 3 of the project (Canada Customs' operating year starts in April). The choice of the eight-year time frame was based largely on the fact that traffic flow levels are expected to grow quite rapidly over the next few years. If the present situation continues, it is very likely that capacity will become a problem in the near future, and that changes will be necessary in order to deal with the traffic flow. When operating methods are changed, the costs and benefits associated with the PACE project will be drastically altered in ways which are not predictable at this time. Since no reliable estimates can be made further than the eight year period, the PACE project is not evaluated past this point. No residual value is assigned to PACE, since the program did not add any real assets to Canada Customs. The only benefits associated with the program are those that occur as a result of its use. If the project were discontinued in the future, the PACE lane could very easily be converted back to a regular lane.

4. A nominal social discount rate of 7.89% is used. Assuming inflation at 2%, this translates to a real rate of 5.77%.

2.3 Calculation of Marginal Costs

Table 2-1 summarizes the relevant costs incurred as a result of the PACE project. These costs are explained below.

TABLE 2-1: COST CATEGORIES OF THE PACE PROJECT

Construction and maintenance	0
Signage (one-time)	$15,000
Administration Costs	$3,067,580
Set-up Costs (one-time)	$628,111
Advertising Costs	$189,449
Membership fees	transfer
Time required by individual to fill out forms (15 min)	$213,445
TOTAL COSTS	$4,113,585

2.3.1 Construction and Maintenance Costs

These costs were considered to be zero since the lane and booth were already in place as a regular lane which was used only during peak periods. The PACE project does not cause any additional construction or maintenance costs to be incurred.

2.3.2 Signage Costs

This figure was based on actual costs incurred at the Douglas crossing. A one-time cost of $15,000 was incurred in year 0. Maintenance costs were reported as negligible.

2.3.3 Administration Costs

This number was also based on actual figures. This cost category includes computer systems costs, costs of labour, operating and maintenance costs, and capital and replacement costs. These "hard" costs totalled $462,800 annually, as reported by an audit performed at the beginning of year 2.

Total discounted administration costs= $3,067,580

2.3.4 Set-up Costs

These costs occurred in years zero and one (1990-91 and 1991-92). The year 2 audit reported these costs at $392,600 in year 0, and $249,100 in year 1.

Total discounted set-up costs= $ 628,111

2.3.5 Advertising Costs

Since only word of mouth advertising was used, advertising costs were zero in years 0 to 2. In future years, however, Customs officials plan to advertise in local papers. An advertising budget of $50,000 per year is expected for years 3 to 7.

Total discounted advertising costs= $ 189,449

2.3.6 Time Required by Applicants to Fill Out Forms

This figure was based on an estimated fill-out time of 15 minutes/applicant, which was then multiplied by the average number of applicants/year, recorded at approximately 18,000. Monetary values were based on 40% of the average wage rate in British Columbia in 1990[3], as reported by Statistics Canada.

Total time spent= 0.25 hrs/applicant x 18000 applicants

= 4500 hrs/year

Value of time spent= 4500 hrs/yr x .40 x $17.89/hr[4]

= $32,202/yr

Total discounted value of time spent= $213,445

The number of applicants per year is assumed to remain constant over future years, despite the planned increase in advertising. This assumption is made since the current target market (commuters and retired travellers) is finite and will soon become saturated. Thus, the number of applicants per month should soon start to decrease. At the same time, the advertising campaign will attempt to increase the number of applicants by generating new markets. Thus, the two forces will tend to offset each other.

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[3] This decision was based on the advice of Dr. W. G. Waters II, in a conversation on May 12,1993.

[4] Average annual income for B.C. in 1990, as reported by Statistics Canada equals $34,886. Assuming 37.5 hours per work week and 52 weeks per year, the average wage rate can be calculated at $17.89 per hour.

2.4 Calculation of Marginal Benefits

The benefits directly associated with the project are summarized in Table 2-2. These benefits are discussed below.

TABLE 2-2: BENEFIT CATEGORIES OF THE PACE PROJECT

Time saved by PACE members (primary)	$4,658,730
Time saved by PACE members (secondary)	$5,086,938
Flexibility received by PACE members	+
Time Saved/Spent by Regular Travellers	$4,532,948
TOTAL BENEFITS	14,278,616

2.4.1) Time saved by PACE members:

A) Time saved at the primary:

PACE members enjoy large time savings at the primary processing for two reasons: 1) PACE members do not have to join the regular queues which can be very lengthy; and 2) the service times at the PACE booth are approximately 1/6th of those at the regular booths. Calculations of these benefits will be explained in section 2.4.4.

B) Time saved at the secondary:

Secondary processing includes both examinations and processing in the customs office (i.e. paying duties and taxes). Although PACE members are subject to examinations as often as are the regular travellers, they are not required to enter the customs office (unless, of course, a search is resultant). Instead, they need

only to pause as they pass through the PACE booth so that the traveller can deposit his/her pre-completed PACE card, and so that the officer can view their PACE decal. Since PACE members are generally not required to enter the office, large time savings result. The calculations of this benefit will be discussed in section 2.4.5.

2.4.2 Flexibility of PACE Members

Since PACE members are not affected by the regular traffic flow, they do not have to schedule their trips to avoid the peak periods. This results in a good deal of flexibility for the PACE members. This benefit could not be monetized, due to lack of accurate data on the travellers' willingness to pay for the benefits of the program. For this reason, the flexibility received by PACE members is included in the CBA as an unknown positive number (+).

2.4.3 Time Saved (or Lost) to Regular Travellers

When the PACE program is implemented, it reduces the number of lanes available to regular traffic by one. If the PACE lane is processing only a small amount of traffic, the average throughput times of the regular traffic will increase, since a larger number of cars will arrive at each of the regular lanes remaining (after one has been lost to PACE). If, however, the PACE lane processes as many (or more) cars as the average regular lane, the average throughput times of the regular traffic will decrease. Thus, in the early years of the PACE program, we would expect to see the

PACE lane inflicting a cost on the regular traffic, while in the later years, as PACE membership grows, the PACE lane should provide a benefit to the regular traffic. These benefits will be calculated along with the throughput time savings for PACE members in the following section.

2.4.4 Calculations of Throughput Time Savings and Costs

In order to monetize the throughput time savings and costs of the regular travellers and the PACE members, the following steps were followed:

1) the value per hour of time saved (or extra time spent) was calculated;

2) the average number of trips/year for PACE members and regular travellers were determined;

3) the average time saved (or extra time spent) per trip was determined;

4) the following equation was used to calculate the yearly benefits of time saved (or cost of extra time spent) for PACE members and regular travellers:

Benefit of time saved = value/hour of time saved
x number of trips/year
x avg time saved/trip

and finally, 5) the yearly benefits and costs were discounted.

1) Value per Hour of Travel Time Saved/Spent (VTTS)

To determine the monetary value of the travel time saved/spent by regular travellers, this study uses the estimated values of travel time saved/spent obtained from the B.C. Ministry of Transportation and Highways, Planning Services Branch (BC MOTH,[5]). The Ministry of Transport estimated values of time spent in transit for various classifications of drivers. The classifications of interest to this study (based on 1991 dollars) are as follows:

Value of Travel Time Saved

Category:
Passenger cars and light trucks

Sub-category:
Adult driver (work) : $17.66/hr
Adult driver (non-work) : $5.89/hr
Retired driver : $4.12/hr

Adult passenger (work) : $17.66/hr
Adult passenger (non-work) : $4.12/hr
Retired passenger : $2.94/hr

In addition, information was drawn from a marketing study recently performed by a group of U.B.C. students (Araujo et al.,[1]). Results of their survey indicated the following numbers:

Percentage of PACE members crossing for business= 16%
Percentage of PACE members who are commuters= 11%
Percentage of PACE members who are over 65= 27%
Other (assumed to be travelling for non-work purposes)= 46%

The value per hour of time spent to be used in this study was determined based on the following assumptions:

-all people over 65 were assumed to be retired;
-commuters were assumed to value their travel time at a point half-way between that of those who are travelling for work purposes and those who are not.

TABLE 2-3: AVERAGE VALUE PER HOUR OF TRAVEL TIME SAVED/SPENT

CLASS	% OF PACE MEMBERS IN CLASS	V.T.T.S.* DRIVER	V.T.T.S.* PASSENGER	TOTAL CONTRIBUTION TO V.T.T.S.**
Adult (work)	16%	$17.66	$17.66	$4.24
Commuter	11%	$11.76	$10.89	$1.89
Adult (non-work)	46%	$5.89	$4.12	$3.66
Retired	27%	$4.12	$2.94	$1.51
TOTAL V.T.T.S.				$11.30

*V.T.T.S.: value of travel time saved/spent per hour
** based on an average of 1 driver and 0.5 passengers/car

Thus, the value of travel time spent in transit is estimated at $11.30 per hour.

2) Number of Trips Made Per Year By Travellers

An attempt was made to forecast traffic levels through the use of time series analysis, but a suitable model could not be found within a reasonable time frame, due to the great number of underlying factors which affect traffic flows. The results of time series forecasting are shown in Appendix A, part 3.

Instead of using time series methods, estimates of growth rates for total traffic flows were obtained from Customs administration. These growth estimates were then applied to current traffic levels in order to calculate reasonable forecasts of future traffic flows. Customs administration also provided predictions of the percentage of total trips across the border that will be made by PACE members. These percentages were then multiplied by the total number of expected trips to obtain forecasts of the number of PACE trips that will be made in future years.

The following table summarizes the resulting forecasts of traffic flow for regular travellers and PACE members:

TABLE 2-4: FORECASTED TRAFFIC FLOW

		TOTAL TRAFFIC		PACE		REGULAR
YEAR		EST. GROWTH	NUMBER OF TRIPS*	EST. %**	NUMBER OF TRIPS*	NUMBER OF TRIPS*
0	90/91	-	4,562,943		0	4,562,943
1	91/92	-	4,836,577	5.0	241,829	4,594,748
2	92/93	-	4,508,548	12.0	541,026	3,967,522
3	93/94	3%	4,643,804	15.0	696,571	3,947,233
4	94/95	3%	4,783,119	16.5	789,215	3,993,904
5	95/96	3%	4,926,612	18.0	886,790	4,039,822
6	96/97	5%	5,172,943	19.5	1,008,724	4,164,219
7	97/98	5%	5,431,590	21.0	1,140,634	4,290,956

* Years 0 to 2 were based on actual observed values.
** This figure represents the estimated percentage of cars crossing the border (per year) that are PACE members.

3) Amount of Time Saved (or lost) per Trip as a Result of PACE

These figures were determined by comparing the expected throughput times when the PACE program is in operation with similarly calculated throughput times that would occur without the PACE program. This was done separately for PACE members and for regular travellers. Expected times were computed based on queuing theory formulae. Queuing theory can be very helpful in dealing with queuing systems when 1) arrivals appear to have a random pattern; and 2) many individuals can be processed quite quickly, while some others require much longer times . The formulae used analyze

steady state queuing systems, based on Poisson arrivals and exponential service times.

The queuing system for PACE traffic at Canada Customs is a single-server, single-queue system, while the regular traffic system has multiple servers and multiple queues. It is possible to think of a system with multiple servers and queues as having only one queue which feeds all of the servers, but this assumption is generally valid only if free "jockeying" or lane switching is possible. At customs, some jockeying may be possible during non-peak hours, but in general, most travellers find their cars boxed in, thus removing the possibility of jockeying. For this reason, the multiple-server, single-queue system was not considered. Instead, an average regular server and queue was used to estimate throughput times for regular travellers, and these results were compared with those of the PACE system.

To perform the analysis, information was needed regarding the hourly arrival rates and service rates per lane. Arrival rates were computed based on expected annual traffic flows, assuming an average of 6 lanes open (including the PACE lane when applicable). These arrival rates change each year as a result of changes in traffic levels and increases in the level of PACE membership, as shown in Table 2-5. The service rates used are based on the

TABLE 2–5: AVERAGE ARRIVAL RATES

YEAR	PACE %	YEARLY ARRIVALS	HOURLY ARRIVALS (TOTAL)	HOURLY ARRIVALS (REGULAR)	HOURLY ARRIVALS (PACE)
1 91/92	0.05	4836577	552.12	524.51	27.61
2 92/93	0.12	4508548	514.67	452.91	61.76
3 93/94	0.15	4643804	530.11	450.60	79.52
4 94/95	0.165	4783119	546.02	455.93	90.09
5 95/96	0.18	4926612	562.40	461.17	101.23
6 96/97	0.195	5172943	590.52	475.37	115.15
7 97/98	0.21	5431590	620.04	489.84	130.21

TABLE 2–6: AVERAGE THROUGHPUT TIMES BASED ON QUEUING THEORY RESULTS

A: AVERAGE TIME THROUGH SYSTEM FOR PACE MEMBERS

YEAR	HOURLY ARRIVALS (PACE)	TIME THROUGH SYSTEM (SEC.)
1 91/92	27.61	5.42
2 92/93	61.76	5.71
3 93/94	79.52	5.88
4 94/95	90.09	5.98
5 95/96	101.23	6.09
6 96/97	115.15	6.24
7 97/98	130.21	6.41

B: AVERAGE TIME THROUGH SYSTEM FOR REGULAR TRAVELLERS (WITH PACE OPEN)

YEAR	HOURLY ARRIVALS (TOTAL)	HOURLY ARRIVALS (/LANE)	TIME THROUGH SYSTEM (SEC.)
1 91/92	524.51	104.90	1386.18
2 92/93	452.91	90.58	212.80
3 93/94	450.60	90.12	207.13
4 94/95	455.93	91.19	220.66
5 95/96	461.17	92.23	235.81
6 96/97	475.37	95.07	289.70
7 97/98	489.84	97.97	377.64

C: AVERAGE TIME THROUGH SYSTEM FOR REGULAR TRAVELLERS (WITH PACE CLOSED)

YEAR	HOURLY ARRIVALS (TOTAL)	HOURLY ARRIVALS (/LANE)	TIME THROUGH SYSTEM (SEC.)
1 91/92	552.12	92.02	232.56
2 92/93	514.67	85.78	165.74
3 93/94	530.11	88.35	188.01
4 94/95	546.02	91.00	218.22
5 95/96	562.40	93.73	261.50
6 96/97	590.52	98.42	396.47
7 97/98	620.04	103.34	865.54

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TABLE 2-7: BENEFITS/COSTS OF TIME SAVED/LOST

A: SAVINGS TO PACE MEMBERS (FROM PRIMARY)

YEAR	TIME SAVED (/TRIP)	#TRIPS PER YR	TIME SAVED/YR (IN HOURS)	VALUE OF TIME SAVED	DISC. VALUE
1 91/92	227.14	241829	15258.15	172417	$163,011
2 92/93	160.03	541026	24049.59	271760	$242,919
3 93/94	182.14	696571	35241.78	398232	$336,549
4 94/95	212.24	789215	46528.77	525775	$420,097
5 95/96	255.40	886790	62913.60	710924	$537,045
6 96/97	390.22	1008724	109341.42	1235558	$882,446
7 97/98	859.13	1140634	272210.16	3075975	$2,077,042
			TOTAL DISCOUNTED VALUE=		$4,659,109

B: SAVINGS/COSTS TO REGULAR TRAFFIC

YEAR	TIME SAVED (/TRIP)	#TRIPS PER YR	TIME SAVED/YR (IN HOURS)	VALUE OF TIME SAVED	DISC. VALUE
1 91/92	-1153.61	4594748	-1472381	-2E+07	($15,730,271)
2 92/93	-47.0611	3967522	-51866	-586081	($523,881)
3 93/94	-19.1150	3947233	-20959	-236834	($200,150)
4 94/95	-2.43443	3993904	-2701	-30519	($24,385)
5 95/96	25.68836	4039822	28827	325743	$246,072
6 96/97	106.7622	4164219	123495	1395492	$996,672
7 97/98	487.9044	4290956	581549	6571504	$4,437,386
			TOTAL DISCOUNTED VALUE=		($10,798,557)

TABLE 2–8: REVISED THROUGHPUT TIMES WITH INCREASED # LANES

A: AVERAGE TIME THROUGH SYSTEM FOR REGULAR TRAVELLERS (WITH PACE OPEN)

YEAR	HOURLY ARRIVALS (TOTAL)	HOURLY ARRIVALS (/LANE)	TIME THROUGH SYSTEM (SEC.)	
1 91/92	524.51	93.66	260.12	with an additional 0.6
2 92/93	452.91	90.58	212.80	lanes open.
3 93/94	450.60	90.12	207.13	
4 94/95	455.93	91.19	220.66	
5 95/96	461.17	92.23	235.81	
6 96/97	475.37	95.07	289.70	
7 97/98	489.84	97.97	377.64	

B: AVERAGE TIME THROUGH SYSTEM FOR REGULAR TRAVELLERS (WITH PACE CLOSED)

YEAR	HOURLY ARRIVALS (TOTAL)	HOURLY ARRIVALS (/LANE)	TIME THROUGH SYSTEM (SEC.)
1 91/92	552.12	92.02	232.56
2 92/93	514.67	85.78	165.74
3 93/94	530.11	88.35	188.01
4 94/95	546.02	91.00	218.22
5 95/96	562.40	93.73	261.50
6 96/97	590.52	98.42	396.47
7 97/98	620.04	103.34	865.38

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TABLE 2–9: REVISED BENEFITS/COSTS OF TIME SAVED/LOST

A: SAVINGS TO PACE MEMBERS (FROM PRIMARY)

YEAR	TIME SAVED (/TRIP)	#TRIPS PER YR	TIME SAVED/YR (IN HOURS)	VALUE OF TIME SAVED	DISC. VALUE
1 91/92	227.14	241829	15258.15	172417	$163,011
2 92/93	160.03	541026	24049.59	271760	$242,919
3 93/94	182.14	696571	35241.78	398232	$336,549
4 94/95	212.24	789215	46528.77	525775	$420,097
5 95/96	255.40	886790	62913.60	710924	$537,045
6 96/97	390.22	1008724	109341.42	1235558	$882,446
7 97/98	858.98	1140634	272160.49	3075414	$2,076,663

TOTAL DISCOUNTED VALUE= $4,658,730

observed average of 107.5 cars/hour[5] at the regular lane and 692 at the PACE lane.

The arrival and service rates calculated lead to the average times through the system shown in Table 2-6. Once estimates of throughput times were calculated for both PACE and regular traffic, differences in throughput times could then be computed (see Table 2-7).

4) The differences in throughput times were then monetized as previously explained: the time differences/trip were multiplied by the expected number of trips to get total time saved/year; the time saved/year was then monetized at a rate of $11.30/hour; and finally, the values were discounted. The resulting costs and benefits are presented in Table 2-7.

The results of this section of the analysis indicate that the expected relationships between throughput times (discussed in sections 2.4.1 and 2.4.3) are correct. For example, PACE members save a great deal of time per trip (between 227 and 428 seconds), since if PACE had not been implemented, they would have had to join the regular lanes. For regular travellers, the PACE lane originally increases their throughput time while membership is small, then decreases their times as PACE membership grows.

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[5] During non-peak hours, the observed service rate was approximately 105 cars/hour, while during peak periods, the service rate averaged just over 115 cars/hour. This illustrates the natural tendency to speed up service when long queues are present.

A severe problem arises in the first year, as the increase in throughput time is over 24 times larger than in other years, leading to an extremely large social cost ($15 mill.). This shockingly large cost provides a good illustration of the way in which queues (and thus waiting times) grow exponentially when server utilization is high (in this case utilization is 98%). This large throughput time would not be acceptable to Canada Customs, due to the reaction of the public. For the remainder of the analysis, it is assumed that customs officials would wish to reduce the throughput time to the mean throughput time. This can be done by increasing the average number of servers in year 1 by 0.6, thereby stopping utilization from growing too large. Since staff has been added, marginal labour costs must be included in the analysis, based on an estimate of $36,000/officer per year (including benefits). When the analysis of throughput times is rerun, the unreasonably large throughput time does not occur, as shown in Table 2-8. The benefits of time saved to PACE and non-PACE members combined (net of additional labour costs) is large and positive, as presented in Table 2-9.

The results of this analysis provide an excellent argument for keeping staff levels high enough to avoid over-utilization. As illustrated in this analysis, if server utilization becomes too large, greatly increased queues and waiting times result. Thus, customs officials should take care to keep utilization under

B: SAVINGS/COSTS TO REGULAR TRAFFIC

YEAR	TIME SAVED (/TRIP)	#TRIPS PER YR	TIME SAVED/YR (IN HOURS)	VALUE OF TIME SAVED	DISC. VALUE
1 91/92	−27.5558	4594748	−35170.00	−397421.	($375,741)
2 92/93	−47.0611	3967522	−51865.58	−586081.	($523,881)
3 93/94	−19.1150	3947233	−20958.73	−236833.	($200,150)
4 94/95	−2.43443	3993904	−2700.803	−30519.0	($24,385)
5 95/96	25.68836	4039822	28826.782	325742.6	$246,072
6 96/97	106.7622	4164219	123494.86	1395491.	$996,672
7 97/98	487.7476	4290956	581362.18	6569392.	$4,435,961

TOTAL DISCOUNTED VALUE= $4,554,548
COST OF ADDITIONAL LABOUR= $21,600

TOTAL DISCOUNTED VALUE INCLUDING
COST OF ADDITIONAL LABOUR= $4,532,948

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TABLE 2–10: SAVINGS TO PACE MEMBERS (FROM SECONDARY)

YEAR	TIME SAVED (/TRIP)	#TRIPS PER YR	TIME SAVED/YR (IN HOURS)	VALUE OF TIME SAVED	DISC. VALUE
1 91/92	396.04	241829	26603.860	300624	$284,224
2 92/93	396.04	541026	59518.844	672563	$601,185
3 93/94	396.04	696571	76630.505	865925	$731,800
4 94/95	396.04	789215	86822.378	981093	$783,899
5 95/96	396.04	886790	97556.770	1102392	$832,767
6 96/97	396.04	1008724	110970.83	1253970	$895,596
7 97/98	396.04	1140634	125482.40	1417951	$957,467

TOTAL DISCOUNTED VALUE= $5,086,938

control, especially since the cost of labour is so small compared to the social costs avoided.

2.4.5 Time Saved to PACE Members at the Secondary

The average time that an individual spends in secondary processing was found to be approximately 396 seconds (from the results of the simulation in Section 4 of this paper). This corresponds to the time saved per trip by PACE members. The time saved per trip was multiplied by the expected number of trips per year, then monetized based on a VTTS of $11.30 (as in Section 2.4.4). Results are shown in Table 2-10.

2.5 Impacts not Included in the CBA

In addition to the major classifications of costs and benefits outlined above, several other potential impacts were also investigated, but discarded. These include the following:

2.5.1 Impacts Associated with Differences in Compliance Behaviour when an Individual Becomes a PACE Member

If an individual changed his/her compliance behaviour upon becoming a PACE member, we would expect to see a change in enforcement levels shortly after PACE was introduced. However, statistical testing gives no evidence that the introduction of the PACE program has significantly affected the levels of enforcement (seizures and forced payments) that have occurred since the beginning of the project. Test results are shown in Appendix A, part 2.

2.5.2 Impacts Associated with an Increase in Traffic Flows and/or Cross-border Shopping as a Result of the PACE Program

Time series analysis was used to predict what would have happened to traffic flows had the PACE program not been implemented. These predictions were then compared with the actual traffic flows observed, to determine whether the PACE program has generated new traffic flow or has just transferred traffic from the regular lanes to the PACE lanes (see Appendix A part 3). Results were clouded by economic factors and public attitudes, but there was some indication that the PACE program is not generating new traffic, and is rather just transferring traffic from the regular lanes. These results are intuitively sound, since the majority of PACE members are commuters, business people, and retirees, whose travel habits are less dependent on waiting times.

2.6 Results and Conclusions of the PACE CBA

Findings of the cost-benefit analysis are summarized below:

TABLE 2-11: RESULTS OF PACE CBA

TOTAL BENEFITS	$14,278,616
TOTAL COSTS	$4,758,271
TOTAL NET BENEFITS	$9,520,345

These results indicate that the benefits of the PACE project outweigh the costs provided that server utilization factors in regular lanes are kept within reasonable limits. This provides strong evidence that the PACE project can be of significant value

to Canada Customs, but it is imperative that the project be supported by a sufficient staff level, especially during the early periods. If staff levels are not sufficient, the project is not likely to succeed. If, however, customs administration is suitably committed to the project, the PACE project will be of great benefit in providing a higher level of service to the travelling public by better coping with the increasing traffic levels.

Based on these results, it is highly recommended that the PACE project be continued, and that every effort be made to minimize the necessary waiting times of travellers in the regular lanes by keeping utilization factors at a reasonable level (under 95%). Furthermore, it is strongly advised that the number of officers available for work in the primary booths be increased if at all possible, since the social benefits of increasing the throughput at the regular lanes far outweighs the cost of additional staffing.

3 APPLICATION #2: MULTIPLE REGRESSION OF SERVICE TIME FACTORS

3.1 Introduction

In order to determine what changes can be made to alleviate the overcrowding in the customs offices, it is necessary to discover the underlying causes of the problem. From observing the flow of travellers in the customs office, it is apparent that a large portion of a traveller's required processing time is spent queuing for, and being served at, the customs office terminals. In order to better understand the process, it would be beneficial to determine which characteristics of border crossers have the greatest effect on the amount of time needed to process an individual at the terminals. The goal of this section of the paper is to use multiple regression techniques to examine the relationship between various personal characteristics of border crossers and the length of service time needed. If it is found that the level of service time is directly related to one or more of the characteristics studied, it may be possible to restructure the office to reflect these relationships (for example, those who require the longest time may be separated from the general flow).

3.2 Data Collection

Data for this study was collected personally at the Pacific Highway Border Crossing, during time periods which appeared average in terms of both traffic flow and types of travellers. A sample size of 100 data points was used, with one point discarded due to its

large influence on the regression. For each traveller, information was collected on the seven variables outlined below.

3.3 Summary of Variables

1) loa: this variable represents a traveller's length of absence or length of stay. It is broken down into three separate variables, and values are assigned as follows:

LENGTH OF ABSENCE/STAY	VARIABLE NAME		
	LOA1	LOA2	LOA3
less than 24 hrs	0	0	0
24 to 48 hrs	1	0	0
48 hrs to 7 days	0	1	0
greater than 7 days	0	0	1

2) sonly: this variable is coded 1 for those who have no goods declared and are in the office only to be searched, and 0 otherwise. These people will be referred to in the future as the "searched only" group. It should be noted that this group does not include all travellers that are searched. Some travellers who declare goods are also searched, to verify their declaration. These people will be referred to in future sections of this paper as the "search and declare" group.

3) rootline: this variable represents the square root of the number of lines that the officer needs to enter into the computer in order to complete processing. It was found that the square root of the

value lead to a better model than could be attained by using the raw data. This is caused by the fact that after one line has been entered into the computer, the time required to enter the second line is not as great (since the individuals name, address etc. must be entered as part of the first line).

4) info: this variable is coded 1 if the individual is at the office for a landing, an abandonment, or information; and 0 otherwise.

Other variables studied which do not appear in the final model are:

6) people: this variable represents the number of occupants of a car who are referred to the customs office.

7) dec: this variable is coded 1 if the border crosser is there to make a declaration (meaning that the traveller has been out of the country for more than 7 days and is claiming their once-per-year $300 exemption).

3.4 Statistical Methods

Several multiple regression models were evaluated based on R^2-adjusted values and residual analysis. In order to meet normality assumptions, the service time data was transformed by taking logarithms. The final model chosen is shown below.

The regression equation is:

logtime = 3.74 + 0.130 loa1 + 0.817 loa2 + 0.139 loa3
- 1.10 sonly + 0.562 rootline + 1.89 info

88 cases used 12 cases contain missing values

Predictor	Coef.	Stdev.	t-ratio	p
Constant	3.7396	0.2379	15.72	0.000
loa1	0.1304	0.4971	0.26	0.794
loa2	0.8166	0.2792	2.92	0.004
loa3	0.1394	0.2706	0.52	0.608
sonly	-1.1001	0.3617	-3.04	0.003
rootline	0.5619	0.1712	3.28	0.002
info	1.8910	0.4647	4.07	0.000

s = 0.6915 R-sq = 45.0% R-sq(adj) = 41.0%

Analysis of Variance

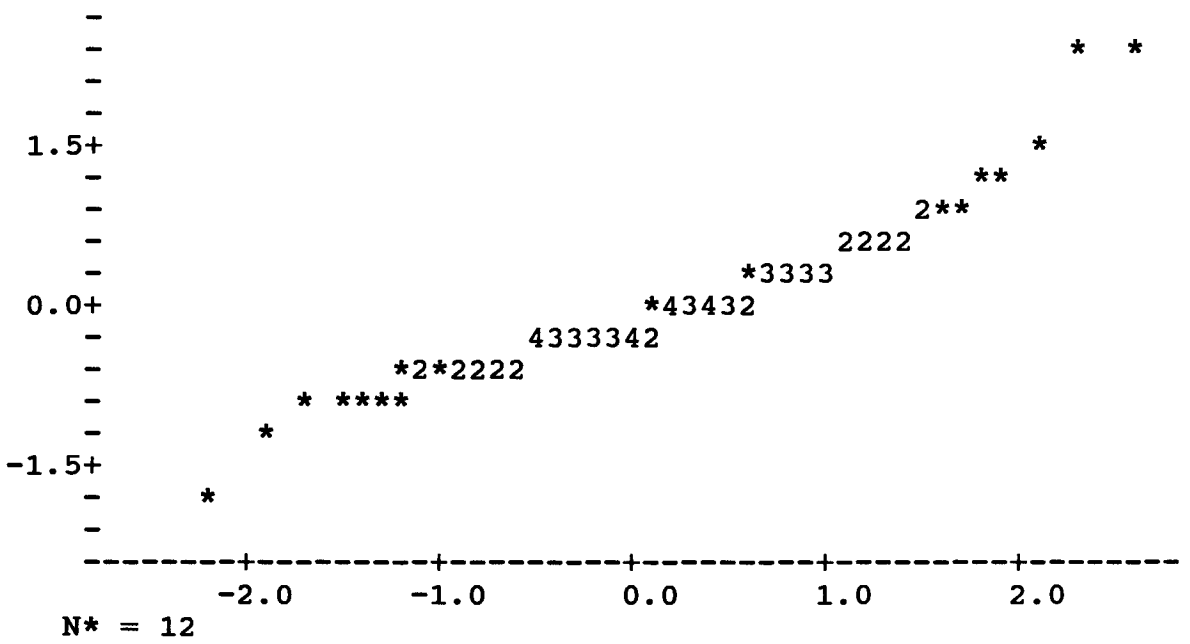
SOURCE	DF	SS	MS	F	p
Regression	6	31.7292	5.2882	11.06	0.000
Error	81	38.7352	0.4782		
Total	87	70.4643			

The results of the regression model provide strong evidence that the factors used in the model significantly affect the amount of time required to process a traveller. Although the variables loa1 and loa3 are not significant, they are included in the model for explanatory reasons, so that the group of variables representing the traveller's length of absence/stay is not broken up. To

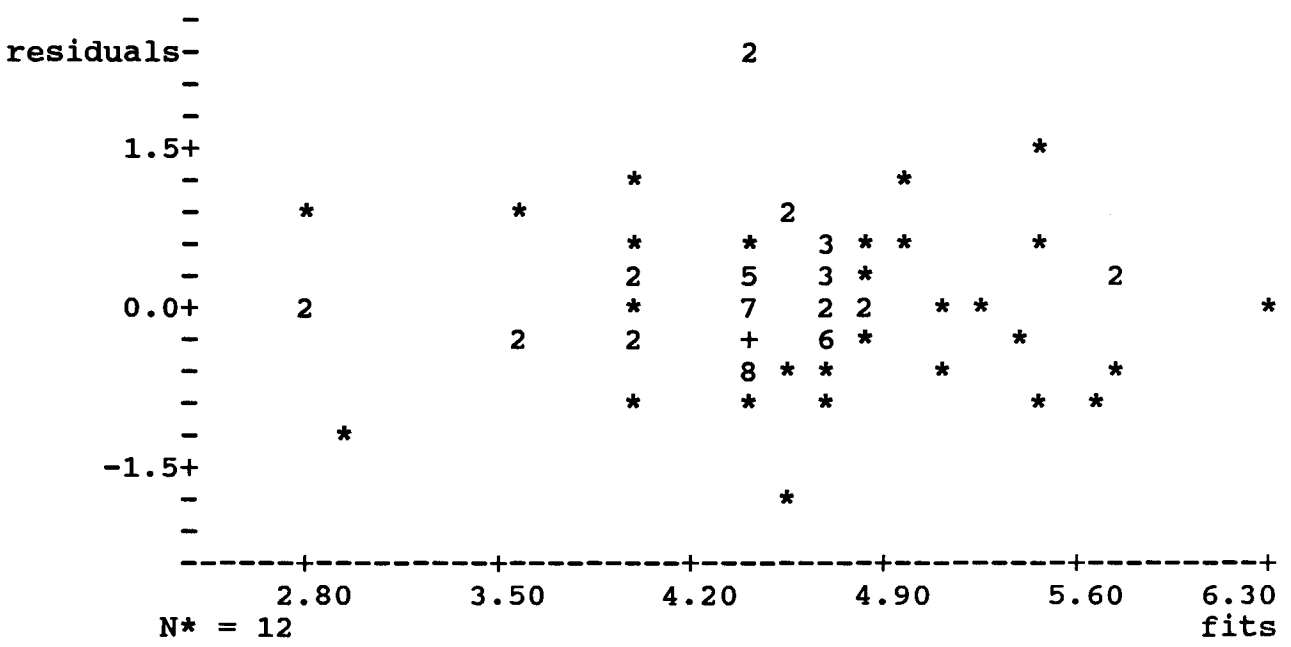
include one of the three "loa" variables without the others would not provide enough information.

To verify that the residuals are normal, a scatterplot and a normal probability plot were graphed. These graphs indicate that the assumptions were fairly well met.

Normal Probability Plot



Plot of Residuals vs Fits



3.5 Results and Conclusions

The results of the analysis indicate that there is a significant relationship between the above variables and the amount of service time needed at the terminal in order to complete an individual's processing.

In general, we can conclude that after adjusting for the effects of all other variables:

1) those who have been away from Canada (or are planning to be visiting Canada) for between 48 hours and seven days need longer amounts of time for processing;

2) as the number of computer lines needed to be entered by the officer increases, so does the service time required;
3) travellers in the "searched only" group (i.e. those who have not declared goods, and are referred into the customs office only to be searched) generally require less processing time; and
4) those who are present at the customs office for a landing, abandonment, or information require greater amounts of time to process than do others.

While this study has helped to explain several factors related to service time, there are still large variations in service times which are not explained. It suspected that this situation may be caused by differences in the degree of difficulty between entries. Some items that a border crosser may be bringing with him/her are very difficult to classify, and are therefore difficult to enter into the computer. This causes large differences in the service times of two individuals that seem otherwise very similar.

3.6 Recommendations

The following recommendations can be made based on the results obtained:

1) It may be beneficial to separate those individuals who require relatively longer processing times from the regular flow of travellers, since the these people create large bottlenecks and lead to even greater congestion in the office.

2) It may also be advantageous to keep separate travellers in the "searched only" group, since these people can be processed quite quickly. This course of action may also be wise since it will increase security measures by ensuring that those individuals who are under suspicion are not able to disappear easily into the general crowd.

3) It is further recommended that an effort be made to standardize the time needed to complete one line of an entry, so that better analysis and planning can be accomplished. It may be possible to achieve this by improving the resources available to the officers while entries are being done (e.g. an expanded database).

4 APPLICATION #3: SIMULATION AND ANIMATION OF THE PACIFIC HIGHWAY OFFICE

4.1 Introduction

The purpose of this application is to evaluate the current situation in the Pacific Highway Customs Office, and to determine if the Self Declaration System (SDS) can be used to improve processing efficiency. Customs officials want a method to cope with periods of high traffic flow without causing a loss of control or creating poor public relations. Traffic flow in the customs office is dependent on the level of demand at the primary and on the referral rate in effect. When a low referral rate is in effect, potential revenue is lost. If the referral rate can be increased, this problem is lessened. Thus, the higher the level of traffic flow that can be handled efficiently in the office, the higher the referral rate that can be enforced, and the lower the level of lost revenue.

The simulation and animation study is comprised of three parts: 1) the current queuing system of the Pacific Highway Crossing is modelled using the simulation language GPSS/H; 2) it is animated using PROOF; and 3) the simulation is then altered to include the SDS, and experiments are conducted to find the most efficient combination of SDS terminals and regular terminals. The results of these experiments can be used to aid customs administration in their decision-making.

4.2 Choice of Modelling Techniques

The queuing process in the customs office is comprised of a number of separate events, including the arrival of border crossers, the initiation/completion of service at the terminals, and the initiation/completion of service at the cashier. To model this system, simulation and animation were used. The simulation language chosen was GPSS/H, while the animation was completed through the use of PROOF Animation Software. Justification for choosing these techniques is provided in Appendix D.

4.3 Effects of Classification Methods

When designing a model to simulate the Pacific Highway office, it is essential that the analyst have a good understanding of the paths followed by travellers as they are routed through the customs office, and of the service times involved. To gain this understanding, we refer back to the discussion of classification methods of travellers that was presented in section 1.4 of this paper. To summarize, the seven classification methods discussed are as follows:

1) Classification by Country of Residence
2) Classification by Length of Absence/Stay
3) Classification by Details of Primary (reason for being in the Customs office)
4) Classification by Amount Declared
5) Classification by Number of People in Group
6) Classification by Outcome of Search
7) Classification by Method of Payment

Each classification method has the potential to affect a traveller's path and/or service time. These effects are discussed below.

4.3.1. Effects of Classification Methods on Path Followed

The effect that each classification method has on the path followed by an individual during processing was determined through observation. Upon examination of the entire group of classification criteria, it becomes apparent that the first factor to affect the path taken by a specific border crosser is his/her country of residence. A traveller's country of residence will determine whether they are referred to customs, immigration, or both. The system being simulated, however, does not include the immigration desk, since immigration is a completely separate system. It was found that in almost all cases, travellers entering the customs terminal queue were Canadian residents. As a result, very little information was available on non-residents or passport holders. For this reason, the simulation model does not distinguish between the three groups.

Two other important factors which may significantly affect the path a traveller follows during processing are 1) whether or not they are searched and, 2) if so, whether a release, forced payment, or seizure results. These factors are dealt with directly in the GPSS/H model. Figures 4-1, 4-2, and 4-3 trace the paths followed by each grouping of border crossers as they are segregated initially by country of residence, secondly by details of the primary (searched or not searched), and finally by outcomes of the search (non-resultant, forced payment, or seizure). For the purpose of this study, Figure 4-1 is of great importance, while Figures 4-2 and 4-3 are provided for completeness.

4.3.2 Effects of Classification Methods on Service Times

Cashier Service Times:

The amount of time that is required for the cashier to process an individual varies greatly according to method of payment chosen (see Appendix B, part 1 for an analysis of cashier service times). Payments by cheque and credit card require the greatest amount of processing time, while cash payments require much less time. Cash payments are faster to process than credit card payments by between 4.9 and 71.4 seconds, while payments by cheque are between 34.5 and 62.5 seconds slower than cash. However, no significant difference in service times could be detected between cheque payments and credit card payments. For this reason, the GPSS/H model divides border crossers based on whether they make a cash or non-cash payment.

Terminal Service Times:

In designing the terminal service section of the simulation, the results of the multiple regression study conducted in Application #2 of this paper were applied. To review, the final regression model included four significant predictors of service time, as follows:

1) length of absence/stay (in general, those away for 48 hours to seven days required the longest time);

2) number of lines that the officer has to enter into the computer in order to process an individual (generally speaking, a larger number of lines results in a longer service time);

3) whether an individual has declared nothing and has been referred only to be searched (since these people are only entered into the computer if the search is resultant, these people have shorter service times);

4) whether an individual is in the office only to get information (in general, these people took longer than most others).

Factors three and four are of particular interest in the simulation study, since they can divide the population of travellers into definite groups as follows: 1) "information seekers"; 2) "searched only"; and 3)"general". The first two factors do not offer this possibility, since they overlap considerably. One-way analysis of variance was used to determine if the above groups were significantly different from each other in terms of service times (see Appendix B, part 2). It was found that the service times of the "searched only" group were significantly less than those of the other two groups. No difference could be established, however, between the service times of the "information seekers" and those of the "general" group. Although the group of travellers who fit in the "searched only" category is relatively small (approximately 7%), it is beneficial to split the population of border crossers on this basis because of the clear difference in service times. For this reason, the GPSS/H model separates the two groups.

4.4 Data Collection and Analysis

The GPSS/H model contains several functions and parameters which guide the movement of the travellers being processed. In order to specify functions which closely resemble the actual situation, it was necessary to analyze data regarding the percentage of border

crossers in each class, inter-arrival times of travellers, and service times at the terminals and cashiers.

In general, data was collected through a three-part process. Firstly, data that had been previously collected by the Pacific Highway District was used to examine levels of traffic flows through the customs office. The Pacific Highway administration had gathered information on the number of entries processed at the cashier on an hourly basis, between Wednesday, April 8th and Sunday, April 19th of 1992. Since the number of entries completed by the cashier depends directly on the number of border crossers that are referred to the customs office, any trends in the number of cashier entries can be generalized into trends in the traffic flow through the office. Thus, if the level of cashier entries was high during a particular hour, this could only be caused by a high level of traffic flow in the customs office during that hour. By using this data it was possible to choose time slots on different days that were relatively similar in terms of traffic flow. These time slots could then be studied to determine inter-arrival and service times.

The second component of the data collection process involved the use of video cameras and stopwatches to observe and record the activities in the customs office. The time slots which were chosen to be studied were of moderate traffic levels, since it was not possible to accurately record the activities when the office was extremely busy. In addition, time slots were chosen that would

coincide with the schedule of one particular team of officers who, in the interest of accuracy, had been involved in the study from its onset.

The final element of the data collection process was the collection of the E-67 forms (referral cards) and summary reports corresponding to the time slots being studied. The E-67 forms are handed to the border crosser at the time of referral, and show information on the individuals in the car, including country of residence, length of absence/stay, amount of goods declared, and what action the secondary officer should take. The summary reports provide details on traffic flows, numbers referred, and information concerning the computer entries.

The resulting data set was a sample of size 214. The sample that was examined in Application #2 was a smaller sample (n=100), for which more information was available. This smaller data set was used in the simulation study when sufficient information was not available from the larger sample. Chi-squared testing showed strong evidence (see Appendix B, part 4) that the two samples were from the same population.

4.4.1 Percentage of Border Crossers in Each Class

Information on the percentage of border crossers that made up each classification was extracted from various reports provided by the superintendents at the Pacific Highway crossing, and by summing values on the E-67 forms. The resulting percentages are summarized in Appendix B, part 3. From this we can see that approximately 88% of all payments were made in cash, and that very few cheques were accepted. This is consistent with the office policy: cheques are to be discouraged if at all possible. In addition, we can see that almost 13% of all referrals are examined, and that approximately 17% of all searches result in a forced payment or seizure.

4.4.2 Inter-arrival Times

Inter-arrival times were studied by using the videotapes of the customs office. In each of the time slots studied, the arrival times of the border-crossers were recorded, and the inter-arrival times were computed. Goodness-of-fit testing was then done through the use of the computer program UBC FREQ, in order to determine the appropriate distribution. The results of the goodness-of-fit tests indicate that the observed inter-arrival times follow the exponential distribution, since tests done at the .05 level showed no significant differences between the observed and expected distributions. The goodness-of-fit test results are summarized in Table 4-1.

TABLE 4-1: CHI-SQUARE TEST FOR GOODNESS OF FIT

CLASS	CLASS BOUNDS	OBSERVED	EXPECTED	POOLED CLASS
1	0.0 - 99.0	170	158.51	1
2	100.0 - 199.0	44	47.34	2
3	200.0 - 299.0	8	14.14	3
4	300.0 - 399.0	2	4.22	4
5	400.0 - 499.0	2	1.80	4
	TOTAL	226	226	

CHI-SQUARE= 4.40839 CHI-PROB= .11034 DEGREES OF FREEDOM= 2

*** CHI-SQUARE= 4.41 < 5.99

KOLMOGOROV-SMIRNOV TEST FOR GOODNESS OF FIT (N=226)
D= 0.05084 KS(.05)= 0.09047
LILLIEFORS CORRECTED KS VALUE: KS(.05)= 0.07051

*** D= 0.05 < 0.07051 < 0.09047

DO NOT REJECT Ho: observed data is from the exponential distribution
PARAMETER THETA= 82.7433

4.4.3 Service Times

The distributions of service times at the terminals were ascertained in much the same manner as the inter-arrival times. For each border-crosser in each time slot, the beginning and completion of service time was recorded, and this information was analyzed. This was done separately for the terminals and the cashier.

A. Terminals

Goodness-of-fit testing was applied to the terminal service time data through the use of UBC FREQ. The results indicated that the service times observed were not representative of known distributions. For this reason, the empirical distributions of terminal service times are used in the GPSS/H simulation model, for both the travellers who are in the "searched only" group and for those in the main group. Appendix B, part 5 shows the cumulative probabilities upon which the GPSS/H functions for determining terminal service times are based.

B. Cashiers

Goodness-of-fit testing was applied to the service times at the cashier's desk, for both cash and non-cash payments. The results of this analysis showed that cashier service times for both cash and non-cash payments did not fit well with theoretical distributions. Therefore, the empirical distributions were once again used in the simulation model. Appendix B, part 6 shows the cumulative probabilities upon which the GPSS/H functions for determining cashier service times are based.

4.5 The GPSS/H Model

4.5.1 Explanation of the Model

The simulation model of the Pacific Highway Customs Office replicates the flow of travellers through the office. Figure 4-4 provides a flowchart of the model segments and their interaction. The full model is listed in Appendix C, part 1.

Model segment 1 controls the arrival of travellers to the customs office. The system is initialized by placing 16 travellers in the customs terminal queue at the beginning of the simulation run. As travellers enter the system, they join the terminal queue and walk through the "maze". When they reach the front of the queue, they wait for a terminal to become available before proceeding.

Model segment 2 allows the traveller at the front of the line to choose the first available server. Once an available server has been chosen, the traveller walks to the terminal and processing begins. If the traveller belongs to the "searched only" group, they are immediately transferred to Model segment 6. This will be detailed later. If the traveller is in the "search and declare" group (i.e. the traveller declared goods and is to be searched), their initial processing is done at this time. Once initial processing is complete, the traveller is transferred to Model segment 6. If a traveller is not to be searched, they are processed fully at this time. Upon completion of processing, they continue to the cashiers desk (Model segment 3).

Model segment 3 controls the travellers as they approach the cashier(s). As was previously mentioned, all of the occupants of a car who are referred to the customs office are dealt with on one referral card. Once they have been processed at the terminals, they are free to split apart. This occurs during the first part of Model segment 3. After this splitting has occurred, the travellers join the queue for the cashier(s), and wait for a cashier to become available. Cash payments are handled in this segment, while non-cash payments are dealt with in Model segment 4. After the payment has been completed, the traveller exits the system.

Model segment 4 controls the non-cash payments separately from the cash payments, due to differences in processing time. The traveller is then sent back to segment 3, where they exit the system.

Model segment 5 is not directly linked to the rest of the program. Although there are two cashier terminals in the office, the second cashier is usually only open when an extreme queue builds up. This section of the model opens the second cashier at the beginning of the simulation run, and then shuts it down part way through.

Model segment 6 controls the service of the "searched only" group. Members of this group are separated from the rest of the travellers because their initial service times are generally shorter, since no lines can be entered into the terminal unless the examination is

resultant. In addition, this segment handles examinations of both the "searched only" group and the "search and declare" group. When a traveller leaves the office to be searched, the officer also leaves and meets them outside. At this point, the terminal that was used shuts down temporarily, until another officer takes over (or the officer performing the search returns). Travellers exit this segment of the model based on the results of their search. Those who have made truthful declarations and must make a payment are transferred back to segment 3. Those who are free to leave are sent to segment 7. In the case of a false payment or seizure, the traveller is sent to segment 8 or 9 respectively.

Model segment 7 is used to remove travellers with non-resultant searches from the system once they are free to leave.

Model segment 8 deals with forced payments in the case of a false claim. The traveller returns to the terminal and additional processing time is needed while their declaration is updated. After this step is completed, the traveller is transferred back to segment 3 to join the cashier queue.

Model segment 9 deals with any seizures which occur. The offender is removed from the system and enforcement action is taken.

4.5.2 Validation of the Model

Several methods were used to validate the GPSS/H model of the Pacific Highway office. Firstly, small segments of the model were run separately to ensure that they were working correctly, and that the logic being followed by GPSS/H matched with the logic followed in the customs office.

Next, thirty replications of the completed model were run, and figures obtained from these replications were compared with the data collected at the office. Several parameters were compared, including the number of arrivals to the office, the number of travellers served in an hour, the number of payments received, and average times through various parts of the system. It was found that in all cases, the observed values were within two standard deviations of the mean of the simulated data. Further results of the comparison are shown in Appendix C, part 2.

Thirdly, the model was validated by varying several parameters or holding them constant, to ensure that the model reacted as expected. During one such test it was found that if the inter-arrival time was reduced by one third (i.e. the rate of arrivals was increased), the system becomes too crowded to operate.

As a final form of validation, the resulting statistics were presented to customs administration for their approval.

4.6 The PROOF Animation Model

PROOF animation provides a visual compliment to the simulation. This is beneficial, since it allows the analyst to highlight important features and events. In addition, animation is easier to understand than the output of a simulation run, since it does not require a technical background to view the results. Furthermore, animation encourages confidence in the results, since "seeing is believing".

The PROOF animation is created by using two files: 1) the *layout file*, which is used to define the layout of the office and the paths to be followed by travellers; and 2) the *animation trace file* (atf) which controls the movement of the travellers. The animation trace file is an output file of the simulation software GPSS/H. In the model (shown in Appendix C, part 1), text which follows a BPUTPIC block (written on the far left-hand side) provides GPSS/H with the instructions for creating the trace file.

In the animation, travellers flow through the customs office and change colours as they change states. When a traveller first enters the office, he/she is red. If they are being searched, they will appear on the screen as blue. Any seizures which occur are shown in pink. Travellers in the cash line[6] are yellow, and once their processing is complete, they turn green and exit the system. Summary statistics are gathered by GPSS/H, and are included in the

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[6] As travellers enter the cash line and change from red (or blue) to yellow, the observer will see travellers "split apart", as was explained in section 4.5.1, under Model Segment #3.

animation as relevant. During the animation, messages will appear indicating to the viewer the number of travellers which have been processed and the number of seizures which have occurred. Once the animation run is complete, messages concerning the average time that the travellers spent in queues and the average total time spent in the system will appear. These statistics help the viewer compare the results of various simulation runs.

4.7 Including the Self Declaration System (SDS)

4.7.1 Introduction to SDS

By revising the original simulation model, it is possible to examine the most likely effects that would occur as a result of adding the Self Declaration System. SDS was introduced early in the fall of 1992, and is generally open daily from noon to 2000 hrs. Travellers who have a fairly straightforward declaration have the option of using this system. SDS involves a computerized question form where travellers supply information concerning the amounts of each type of declarable good that they are bringing into Canada. This form is then taken to the SDS terminal, where it is fed into a card reader. The amount of duties and taxes owing is automatically calculated by the computer, and the traveller's payment is processed immediately. It is not necessary for the traveller to proceed to the cashier. Many travellers are willing to participate in this program, but advertising and signage are poor. As a result, virtually no travellers will participate unless a "point officer" is present. This officer is responsible for

informing travellers who have fairly simple declarations that they have the option of using SDS.

4.7.2 Setting Up the Experiments

The Pacific Highway Customs Office uses a system called the Traveller Entry Processing System (TEPS). The terminals are multipurpose so that each terminal in the office can be used as a regular terminal, an SDS terminal or a cashier terminal. A total of seven linked work stations are available for use (excluding the terminal(s) used by the cashier(s)), but due to staffing constraints, it is unlikely that more than five or six of the terminals could be used at any given time. As previously mentioned, data was collected during moderately busy periods. During these periods, no more than 4 regular terminals were open. Thus, customs officials could conceivably open one or two additional terminals in order to deal with an increase in traffic. The important question is how many SDS terminals and how many regular terminals should be opened.

A total of six experiments were run in order to compare different combinations of SDS and regular terminals, as listed below:

1) the base case: 4 regular terminals and no SDS terminals (R4-S0);
2) 4 regular terminals and 1 SDS terminal (R4-S1);
3) 4 regular terminals and 2 SDS terminals (R4-S2);
4) 5 regular terminals and no SDS terminals (R5-S0);
5) 5 regular terminals and 1 SDS terminal (R5-S1);
6) 6 regular terminals and 0 SDS terminals (R6-S0).

These combinations were compared based on differences in the average time in the system between the regular travellers and SDS participants. These differences are most apparent during periods of fairly high traffic, since during lower traffic periods, long queues do not form at the regular terminals. For this reason, the GPSS/H model was altered so that only the first half-hour of the simulation would be used, rather than the hour-long run that was used for validation purposes. The first half hour of the simulation is busier than the second half-hour because the model is initialized with 16 people in line for the terminals. This creates a "front-loaded" simulation. As the simulation continues, the rush of traffic is brought under control, and the office is not quite as busy. This situation was observed frequently at the customs office. Focusing on the busiest section of the simulation shows time differences much more clearly than including the calmer section.

Several assumptions were needed in order to perform the experiments. The assumptions made are based on information from customs officials, and are listed below:

1) SDS users are searched as frequently as regular travellers;

2) the officer manning the SDS terminal does not leave his/her station to perform examinations (another officer is called over);

3) the point officer does not leave his/her post; the percentage of travellers using SDS stays relatively constant throughout the experiment.

4.7.3 Data Collection and Analysis

In order to include SDS in the GPSS/H program, information on the following values was needed:

1) The length of time needed to complete the SDS form: no information was available on this topic, therefore, data was collected by timing travellers. Results indicate that, on average, it takes 116 seconds to complete the SDS form (see Appendix C, part 3 for cumulative distribution).

2) The percentage of travellers who use SDS: this information was available in the summary reports printed each morning in the office. It was found that if a point officer is on duty and does not leave his/her post, the percentage of travellers which use the SDS can reach as high as 50%. If the point officer is called away frequently, this level is drastically reduced. On average, the percentage of travellers using SDS is currently at approximately

28% (see Appendix C, part 4). The simulation model assumes that 30% of all travellers will use SDS.

3) The length of service time for SDS users: this information was also available in summary reports. Appendix C, part 5 shows the cumulative distribution of service times for travellers using SDS.

4.8 Results and Recommendations

It was originally thought that since the service time for an SDS transaction was, on average, less than the sum of the terminal service time and cashier service time of a regular TEPS transaction, SDS should save the traveller quite a bit of time. In reality, however, it was found that the time required to fill out the SDS form was fairly large. When the form completion time was added to the SDS service time, the result was actually larger than the service time and cashier time required by a traveller at the regular terminals by approximately 75 seconds. This represents nearly 30% of the total form completion and service time. As a result, SDS is operating less efficiently than the regular terminals. This situation lead to the results of the six experiments that are shown in Tables 4-2, 4-3, and 4-4 on the following page[7]. To get these results, the various combinations of SDS and regular terminals were compared based on the average time

[7] Appendix C, part 6 outlines the tests used to determine if differences in various service times were significant.

required for a traveller to pass through the system. In order to keep all of the combinations on equal footing, a weighted average time through the system for regular travellers and SDS participants was used. The improvement over the base case was then calculated for each combination. This figure represents the amount of time that is saved by each traveller in a half-hour period. In each case, the amount of time saved was multiplied by the average number of people served, and the total time saved was valued (as before) at $11.30/hr. It was then necessary to subtract off the marginal cost associated with opening an additional (SDS or regular) terminal. Because all of the terminals in the office are multipurpose, there is essentially no cost in switching from one type of terminal to another. Thus, the only significant cost is that of labour. Each additional regular terminal requires an officer, while each SDS terminal can be operated by a cashier. In addition, if one or more SDS terminals is opened, a point officer must also be stationed. After subtracting off these marginal labour costs, the net benefits of opening one or more additional terminals is obtained.

The results in Tables 4-2, 4-3 and 4-4 show that negative net benefits result when SDS terminals are opened. Thus, with the current form completion and service times, SDS is not operating efficiently. When one additional regular terminal is opened, the net benefit is positive, yet when two are opened, negative net benefits once again occur. This indicates that at the current (simulated) level of traffic, one additional regular terminal

TABLE 4–2: AVERAGE TIMES THROUGH THE SYSTEM (IN SECONDS)

MIX	REGULAR TERMINALS	SDS TERMINALS	WEIGHTED AVERAGE**	IMPROVEMENT OVER BASE CASE
4R 0S*	435.80	--	435.80	0
4R 1S	357.50	658.00	447.65	-11.85
4R 2S	330.20	294.00	319.34	116.46
5R 0S	348.80	--	348.80	87
5R 1S	294.60	622.80	294.60	141.2
6R 0S	302.39	--	302.39	133.41

* base case
** based on 70% regular terminal use and 30% SDS use

TABLE 4–3: BREAKDOWN OF TIME THROUGH SYSTEM

	REGULAR TERMINALS		SDS TERMINALS:		
MIX	AVG WAIT	AVG SERVICE	AVG WAIT	AVG SERVICE	FILL–OUT & SERVICE
4R 0S*	277.53	158.28	--	--	--
4R 1S	174.92	182.62	414.07	127.83	243.93
4R 2S	147.70	182.50	38.81	139.09	255.19
5R 0S	183.67	165.23	--	--	--
5R 1S	103.70	190.90	374.41	132.29	248.39
6R 0S	136.13	166.26	--	--	--

* base case

TABLE 4–4: COSTS AND BENEFITS OF VARIOUS MIXES:

MIX	AVG TIME SAVED (seconds)	AVG # SERVED (/ half hr)	TOTAL TIME SAVED (hrs)	BENEFIT OF TIME SAVED* ($)	MARG.COST OF STAFF** ($/half hr)	NET BENEFIT ($/hr)
4R 0S	0.00	40.40	--	--	--	0.00
4R 1S	-11.85	36.50	-0.12	-1.36	15.71	-34.14
4R 2S	116.46	39.90	1.29	14.59	22.51	-15.85
5R 0S	87.00	40.83	0.99	11.15	8.91	4.48
5R 1S	141.20	37.10	1.46	16.44	24.62	-16.35
6R 0S	133.41	40.07	1.48	16.78	17.81	-2.06

* based on $11.30 per hour saved
** avg cost of an additional cashier = $13.60/hr
avg cost of an additional officer = $17.81/hr

Note: adding an SDS terminal requires 1 cashier and one point officer
adding a regular terminal requires one officer

should be opened, but two additional terminals are not warranted. If traffic levels increase, however, the benefits of having six regular terminals open could well outweigh the costs. Based on these results, it is recommended that the SDS be examined to determine if the times involved with the program can be significantly reduced. Since the program is fairly new it is likely that the times can be reduced by adopting a higher level of commitment to the program, and by better informing the officers and the travelling public. It should be kept in mind, however, that SDS will not operate efficiently unless times can be reduced by approximately 30%. If this significant time reduction is not possible, it is recommended that the SDS program be discontinued, and that the SDS terminal be reverted to a regular TEPS terminal.

5. SUMMARY OF FINDINGS

The findings of the applications outlined in this paper can be summarized as follows:

1) The PACE lane promotes the efficient allocation of resources and provides net social benefits in the range of $9.5 million over an eight-year period. The success of the program depends, however, on the availability of sufficient staff, so that high server utilization does not result. It is recommended that the program be continued, and that customs administration focus on maintaining or, if possible, increasing current staff levels.

2) The amount of time needed to process an individual at the service terminal in the customs office is affected by the following factors:

a) those who have been away from Canada (or are planning to be visiting Canada) for between 48 hours and seven days need longer amounts of time for processing;

b) as the number of computer lines needed to be entered by the officer increases, so does the service time required;

c) travellers in the "searched only" group (i.e. those who have not declared goods, and are referred into the customs office only to be searched) generally require less processing time; and

d) those who are present at the customs office for a landing, abandonment, or information require greater amounts of time to process than do others.

It is recommended that customs officials look into the possibility of keeping groups who require much longer or shorter times than average separate from the general flow of traffic. Emphasis should be placed on separating the "searched only" group, since this policy also provides security benefits. In addition, efforts should be made to standardize the time needed to classify various categories of declarable goods, perhaps by using an expanded database.

3) The Self Declaration System is currently not operating efficiently, mainly due to large form-completion times. It is recommended that customs officials examine the process to determine to what extent times can be reduced. If significant reductions (greater than 30%) are not possible, the program should be disbanded, and the work stations returned to regular TEPS terminals. Those travellers who are currently using SDS should be encouraged to join the PACE program, since it is similar in nature and provides greater benefits.

REFERENCES

[1] Araujo, Rosemary et al., students of U.B.C. *PACE Project Marketing Plan*, 1993.

[2] Bales, W.J., J.R. Johnson and J.T. Sommerfeld. "Use of a Queuing Simulator in Design of a Batch Chemical Production System." *Production and Inventory Management Journal*, 2nd quarter,1988.

[3] Bratley, P., B.L. Fox and L.E. Schrage. *A Guide to Simulation (2nd Edition)*, New York: Springer-Verlag, 1987.

[4] Brunner, D.T., N.J. Earle and J.O. Henriksen. *PROOF Animation: The General Purpose Animator,* Proceedings of the Winter Simulation Conference, 1991.

[5] British Columbia Ministry of Transportation and Highways: Planning Services Branch. *Economic Analysis Guidebook*, Version 1.1; April 23,1992 (p B26).

[6] Crain, R.C. and D.T. Brunner. *Modelling Efficiently with GPSS/H,* Proceedings of the Winter Simulation Conference, 1990.

[7] Graybeal, W.J. and I.W. Pooch. *Simulation: Principles and Methods*. Cambridge: Winthrop Publishers Inc., 1980.

[8] Harpell, J.L., M.S. Lane and A.H. Mansour. *Operations Research in Practice: A Longitudinal Study*. Interfaces 19:3 (pp 65-74), 1989.

[9] Kreutzer, Wolfgang. *System Simulation Programming Styles and Languages,* Don Mills: Addison-Wesley Publishers Ltd., 1986.

[10] Lau, H.S and A. Zaki. *The Sensitivity of Queueing Models Simulation to Time Discretization*. Winter Simulation Conference Proceedings, 1981.

[11] Law, A.M. and W.D. Kelton. *Simulation Modelling and Analysis (2nd edition),* Montreal: McGraw-Hill Inc., 1991

[12] Revenue Canada, Customs and Excise: Audit and Evaluation Branch. *Evaluation Study of the Peace Arch Crossing Entry Project;* May,1992 (pp 7-10).

[13] Sadowski, R.P. *Avoiding the Problems and Pitfalls in Simulation*. Proceedings of the Winter Simulation Conference, 1991.

[14] Schriber, T.J. *An Introduction to Simulation Using GPSS/H,* New York: Wiley, 1991.

[15] Solomon, S.L. *Simulation of Waiting-line Systems,* New Jersey: Prentice-Hall Inc., 1983.

[16] Thomas, G. and J. DaCosta. *A Sample Survey of Corporate Operations Research*. Interfaces 9:4, pp102-111, 1979.

Figure 1-1:

PACIFIC HIGHWAY CROSSING

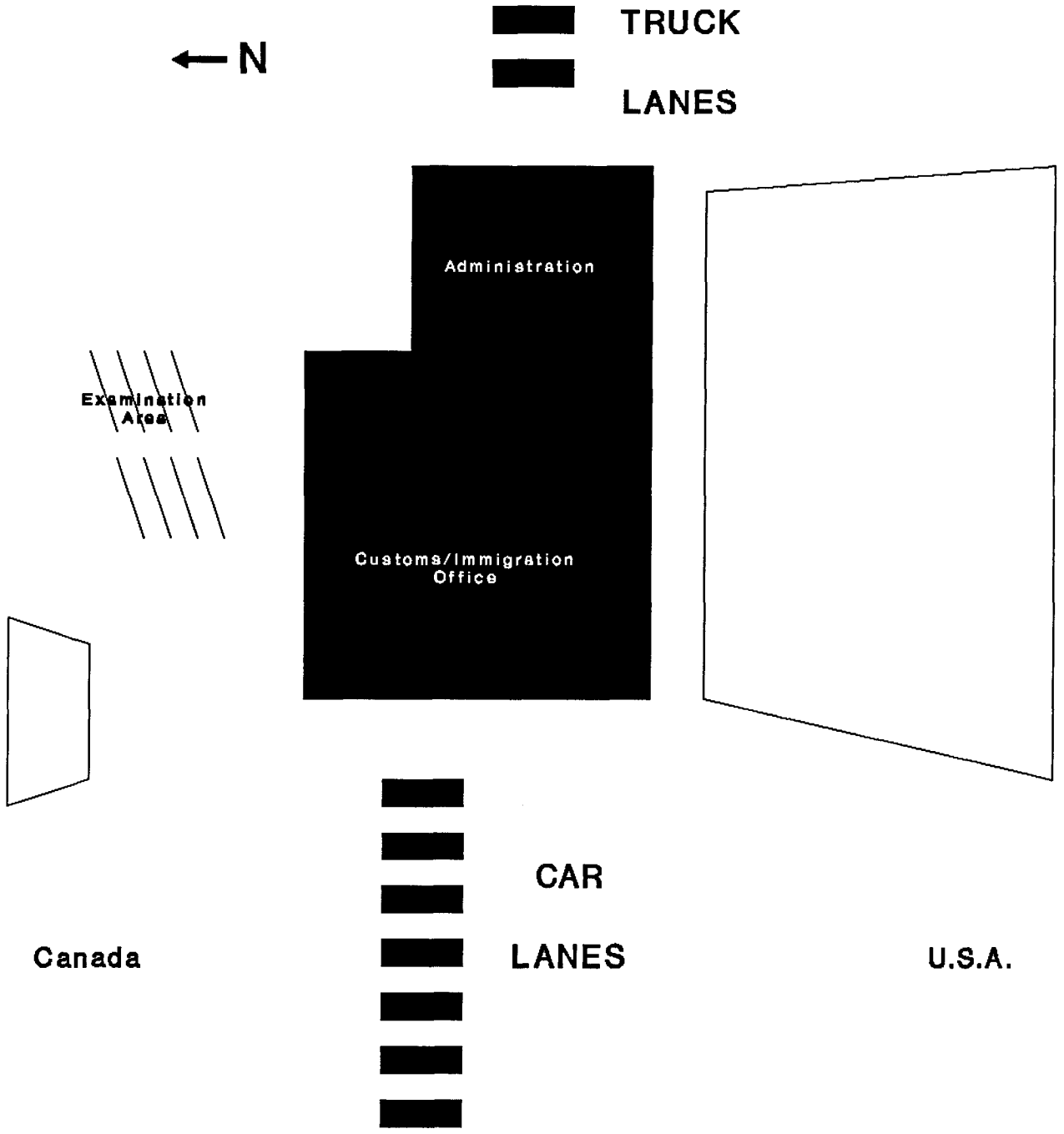


Figure 1-2:

BOOTHS AND PRIMARY PROCESSING

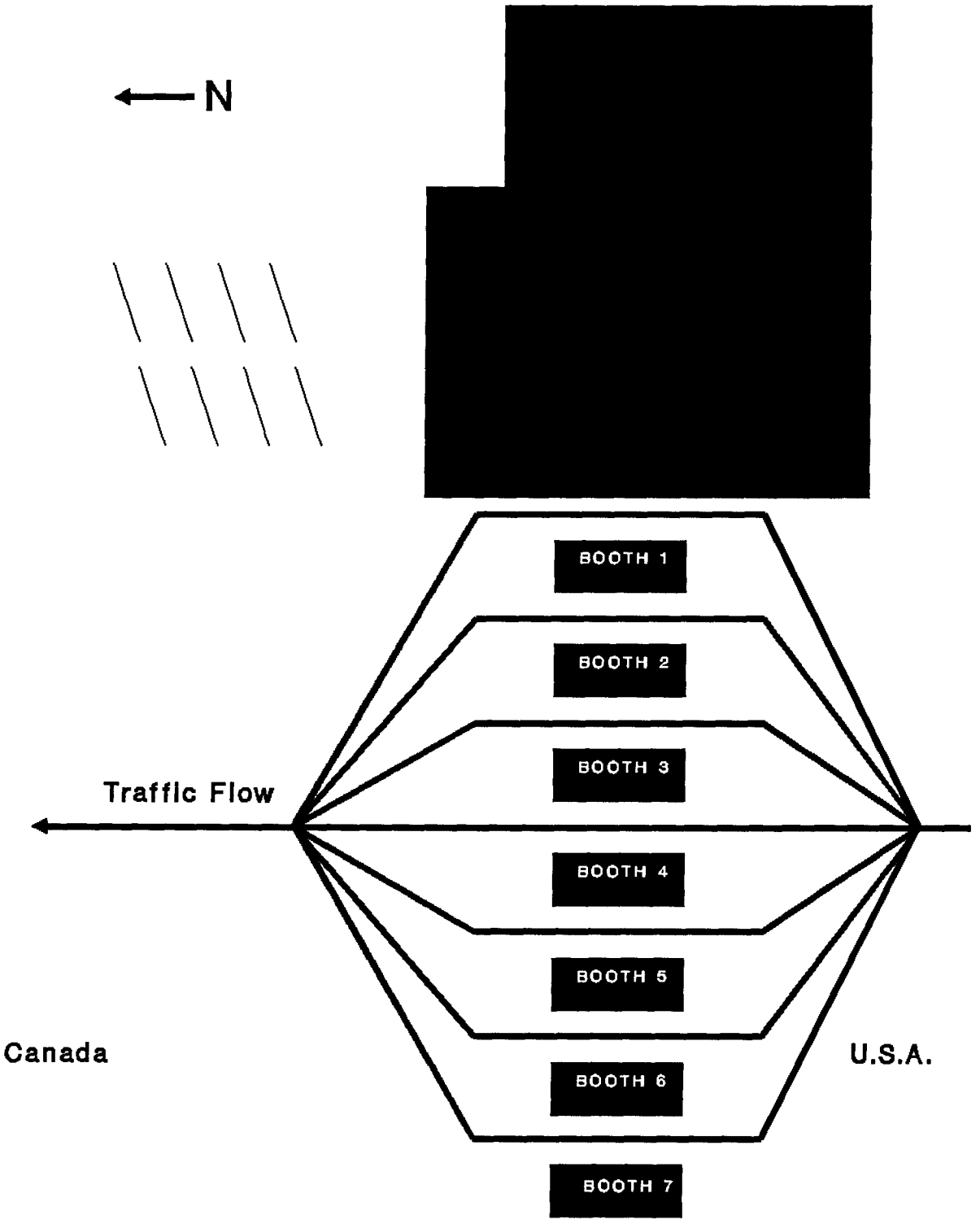


Figure 1-3:

CUSTOMS OFFICE AND SECONDARY PROCESSING

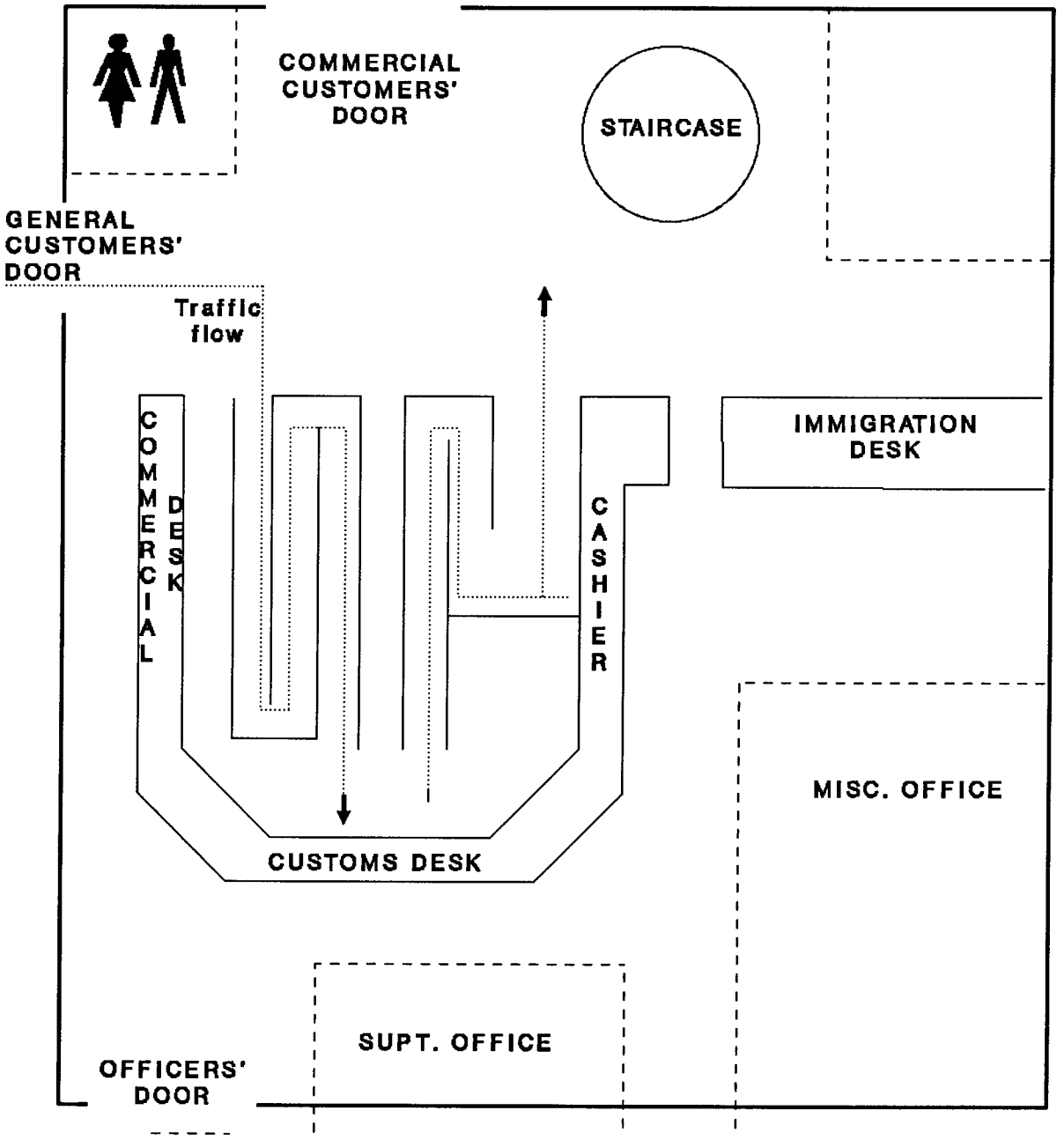


Figure 1-4:

DOUGLAS (PEACE ARCH) CROSSING LAYOUT

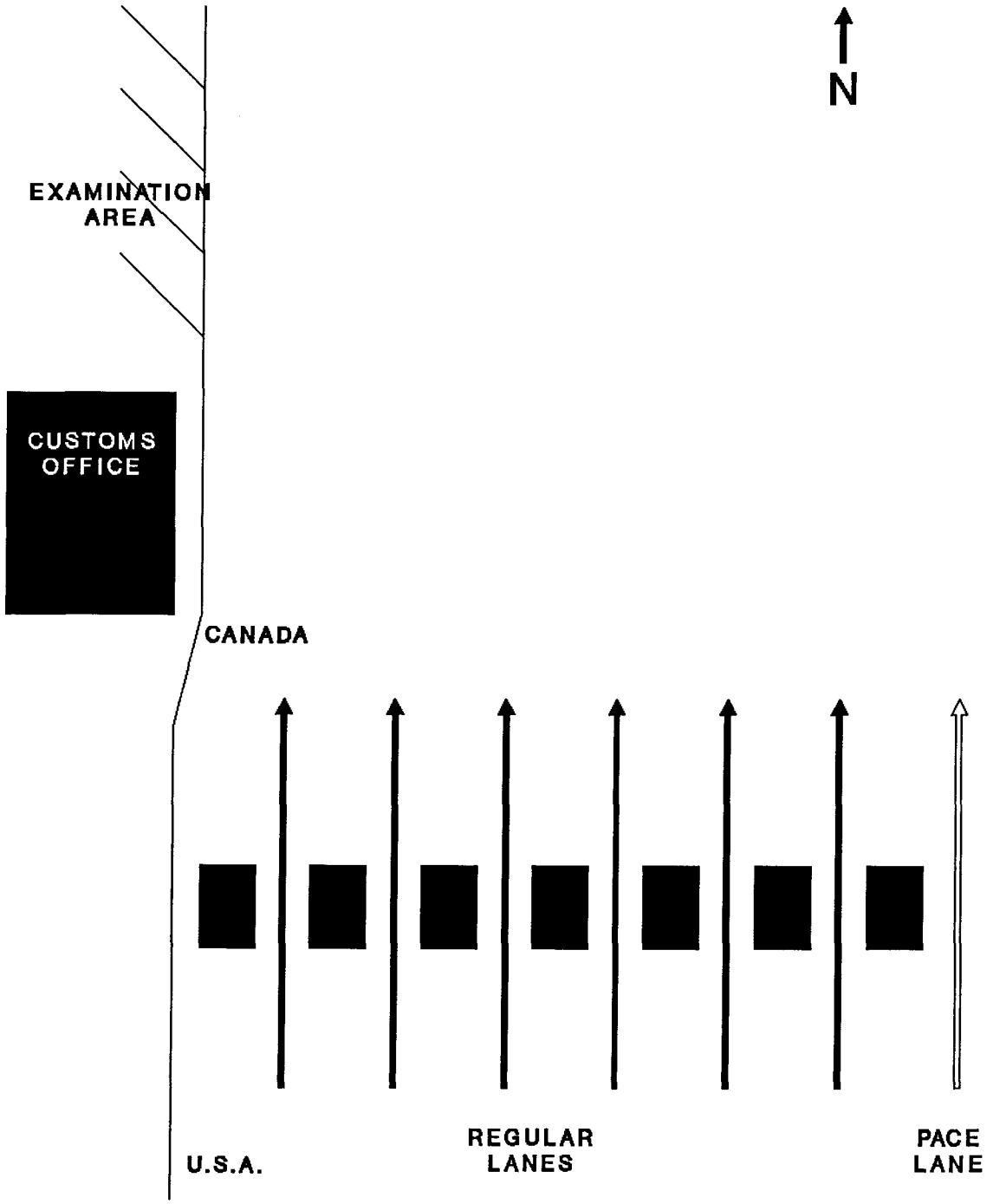


Figure 1-5: Monthly Traffic Flows

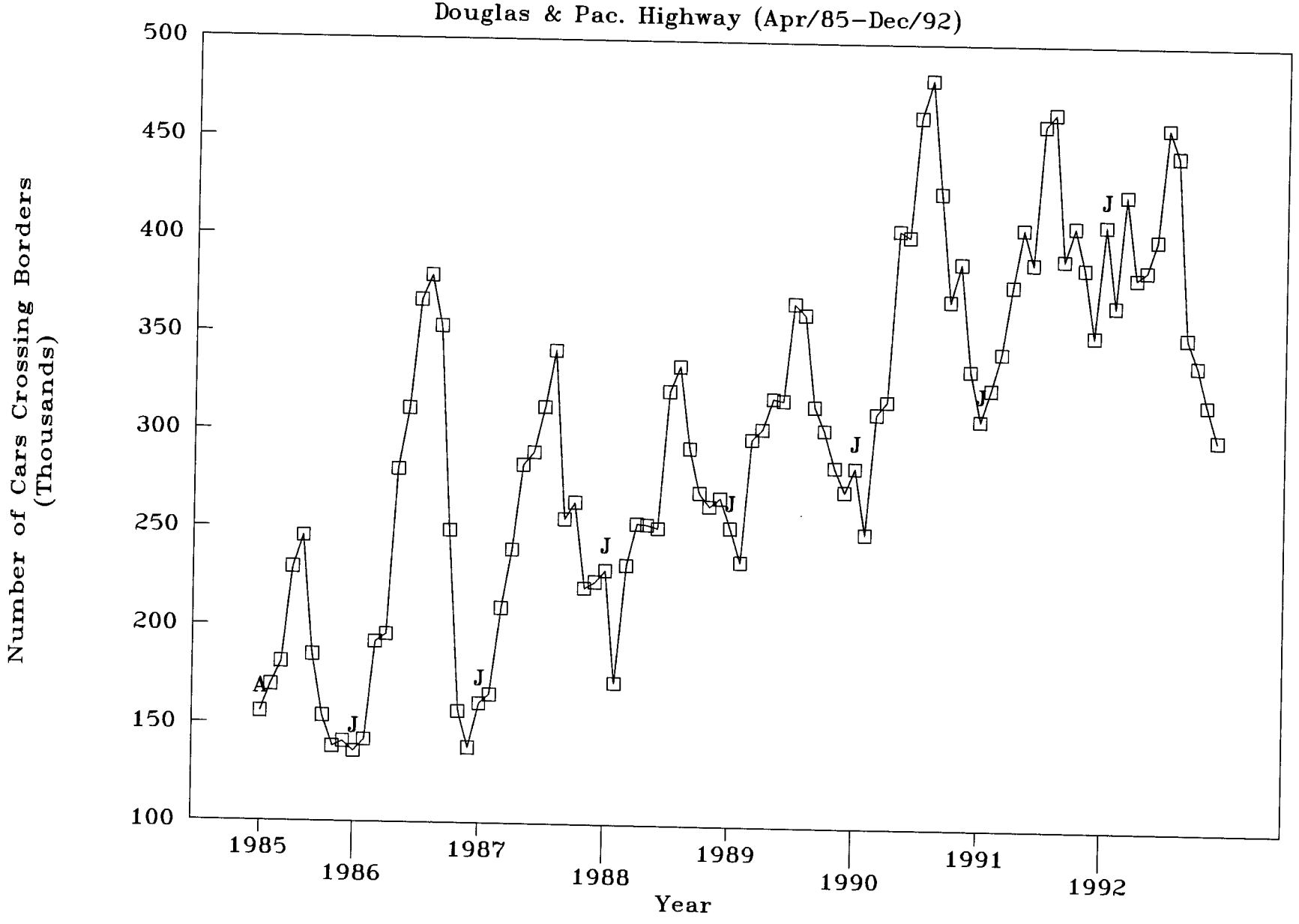


Figure 4-1:

FLOW OF BORDER-CROSSERS BY CLASSIFICATION: RETURNING RESIDENTS

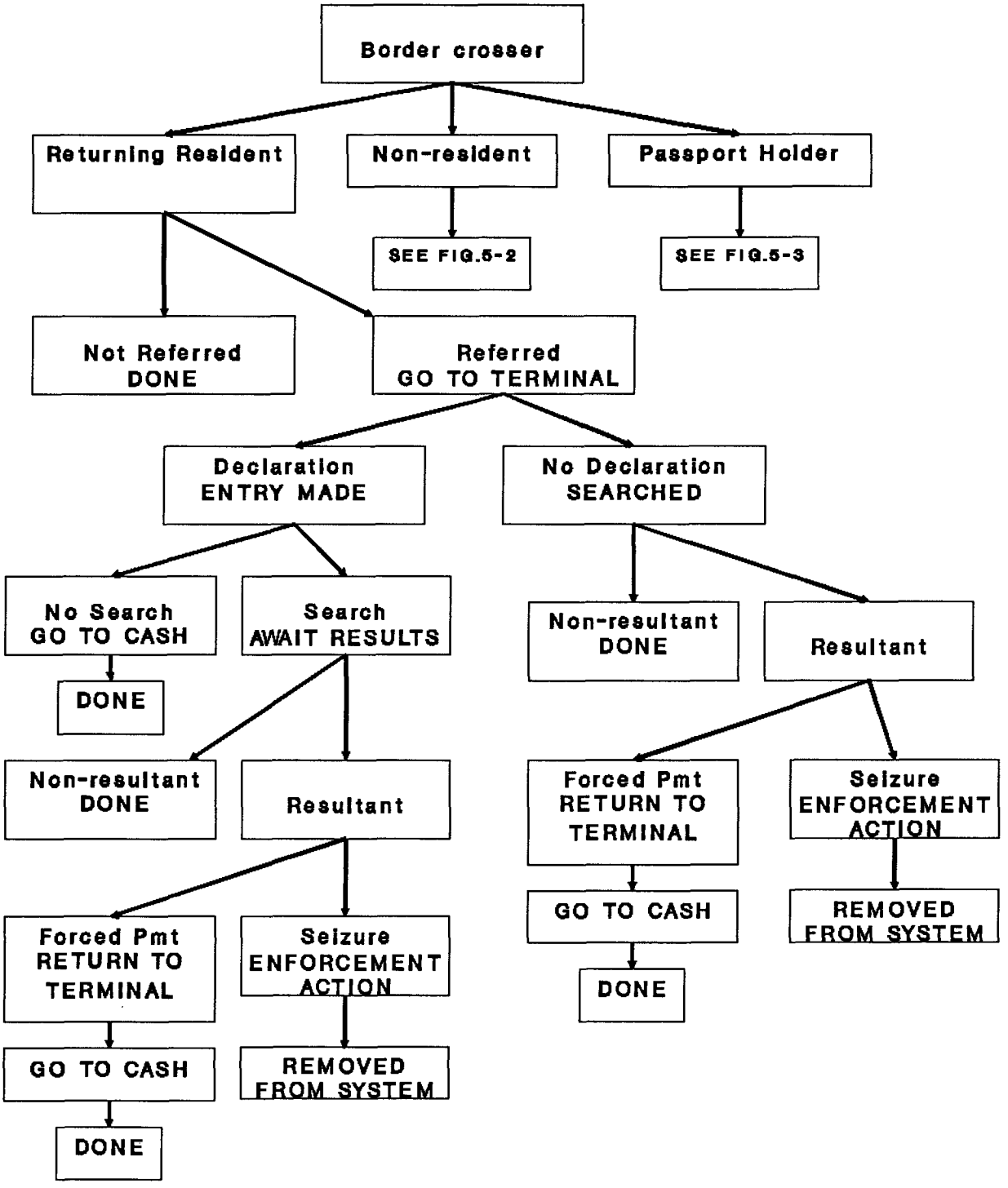


Figure 4-2:

FLOW OF BORDER-CROSSERS BY CLASSIFICATION: NON-RESIDENTS

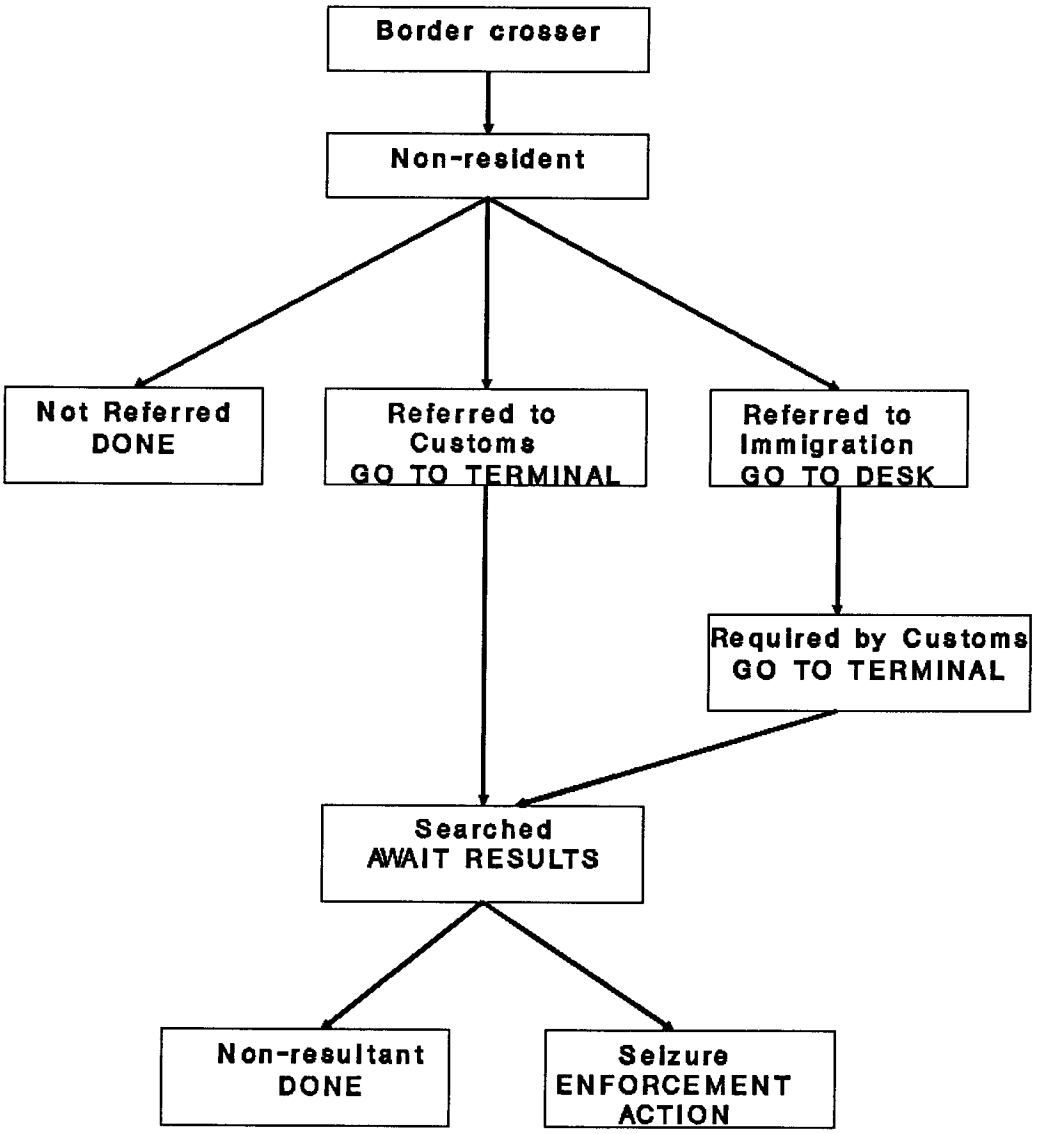


Figure 4-3:

FLOW OF BORDER-CROSSERS BY CLASSIFICATION: PASSPORT HOLDERS

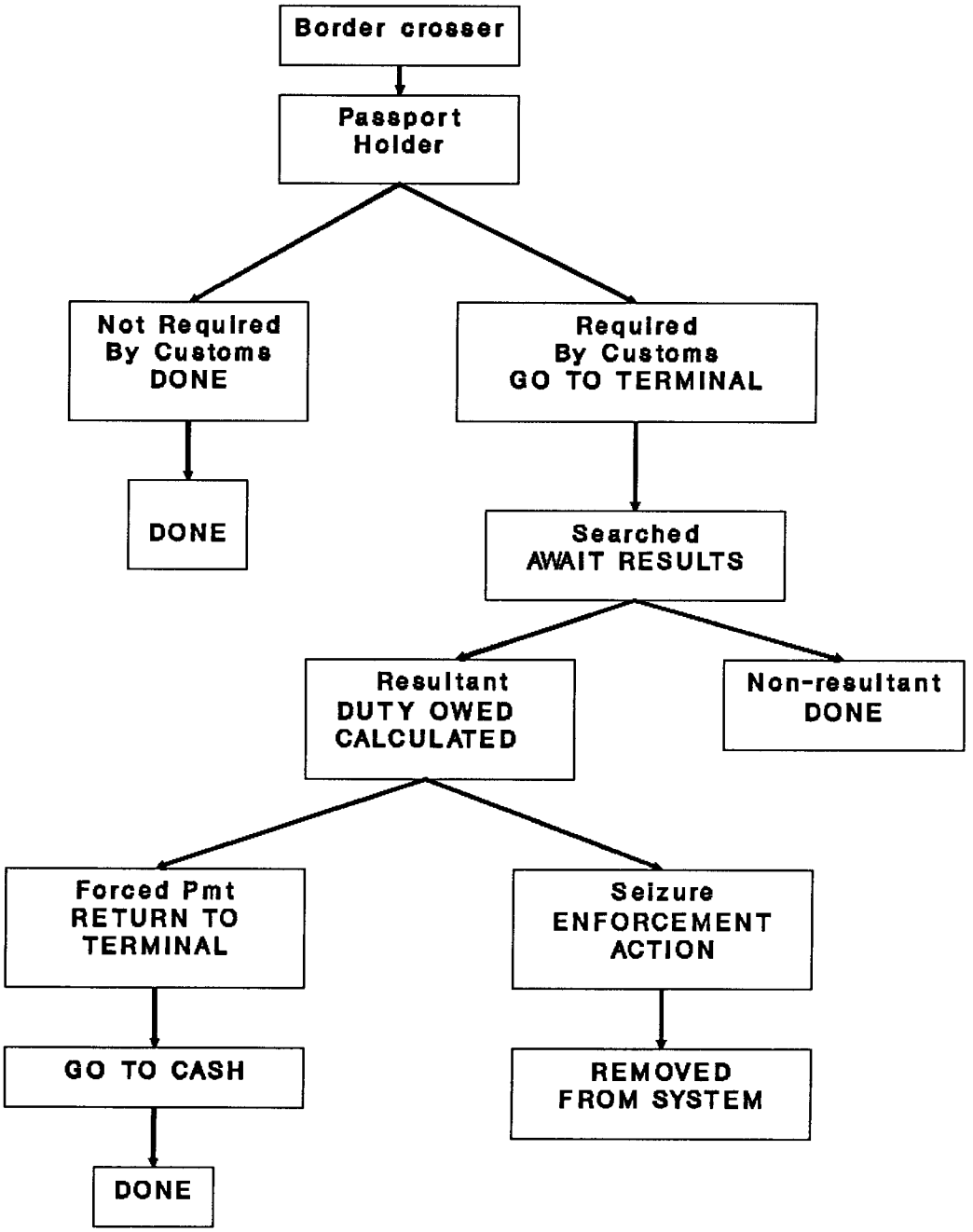
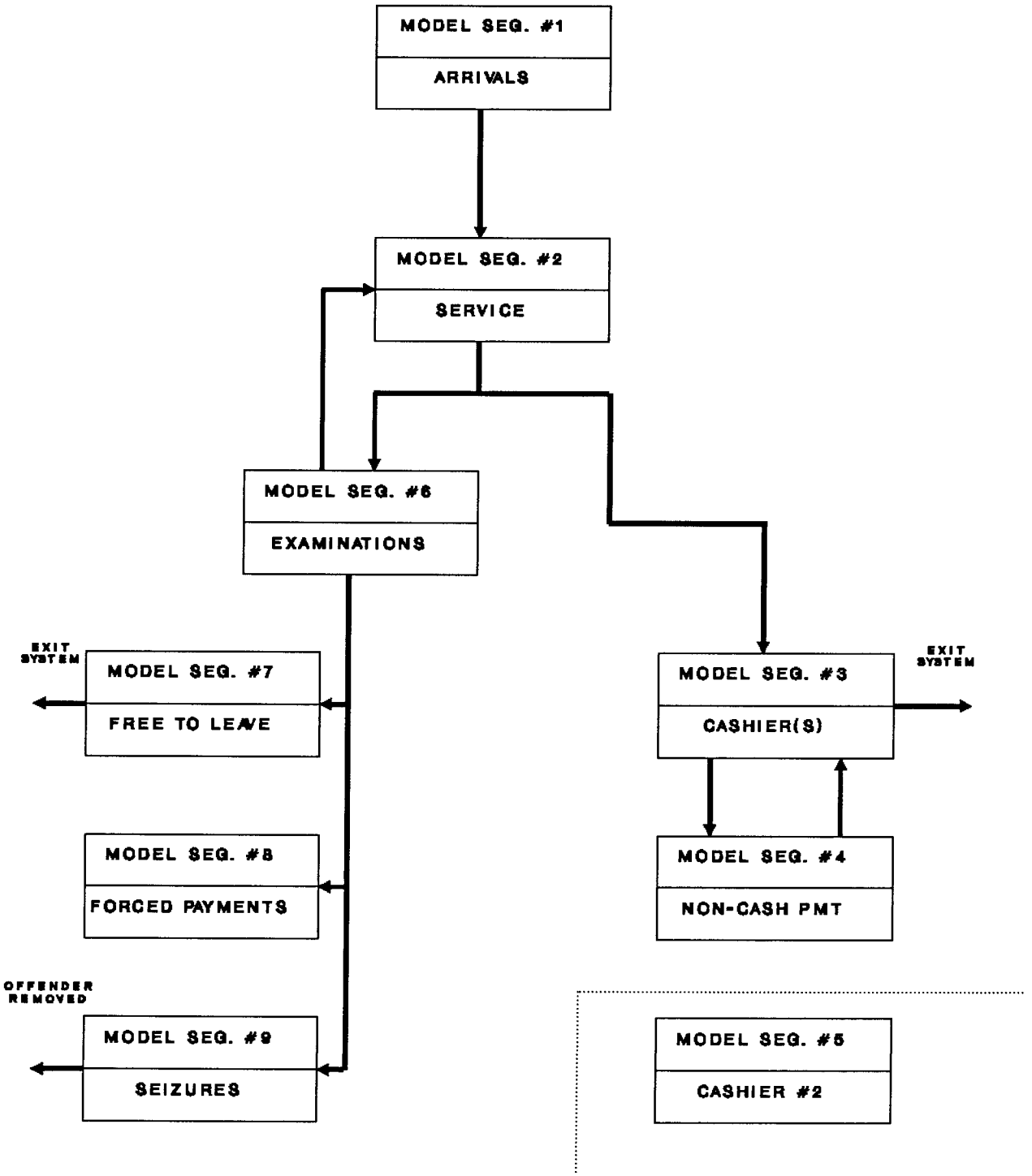


Figure 4-4:

DETAILS OF THE GPSS/H MODEL SEGMENTS



APPENDIX A: STATISTICAL TESTS TO VALIDATE ASSUMPTIONS USED IN THE PACE CBA

Part 1) Forecasting the Expected Number of Seizures

To forecast the expected number of seizures, an ARIMA (1 1 0) model was used. The model was accepted based on chi-squared testing ($p>0.45$) and validated based on residual analysis. Results are as follows:

Final Estimates of Parameters

Type		Estimate	St. Dev.	t-ratio
AR	1	0.7073	0.1803	3.92
MA	1	0.8913	0.1067	8.35

Forecasted Number of seizures

Year	
0(actual)	1798
1(actual)	3172
2(actual)	3457
3	3088
4-9	3135

Part 2) Was there a significant change in the number of seizures (k19's) and enforcement actions when PACE was introduced?

Implication: if level increased, it may indicate that PACE members are complying less than they were before;

The total number of seizures and forced payments have been increasing steadily over recent years. To examine the effect of the PACE program on enforcement, it is necessary to remove the data's natural trend. This is done by taking the first differences of the data. One-way analysis of variance is then used to assess the effects on enforcement that can be attributed to PACE.

Ho: there is no difference in enforcement levels before and after the introduction of the PACE project.
Ha: there is a difference in enforcement levels.

ANALYSIS OF VARIANCE ON FIRST DIFFERENCES OF DATA

SOURCE	DF	SS	MS	F	p
bef/aft	1	478	478	0.06	0.806
ERROR	66	516671	7828		
TOTAL	67	517149			

LEVEL	N	MEAN	STDEV	INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV
1	48	5.17	89.16	(---------*---------)
2	20	-0.65	86.76	(---------------*---------------)
POOLED STDEV =		88.48		-25 0 25

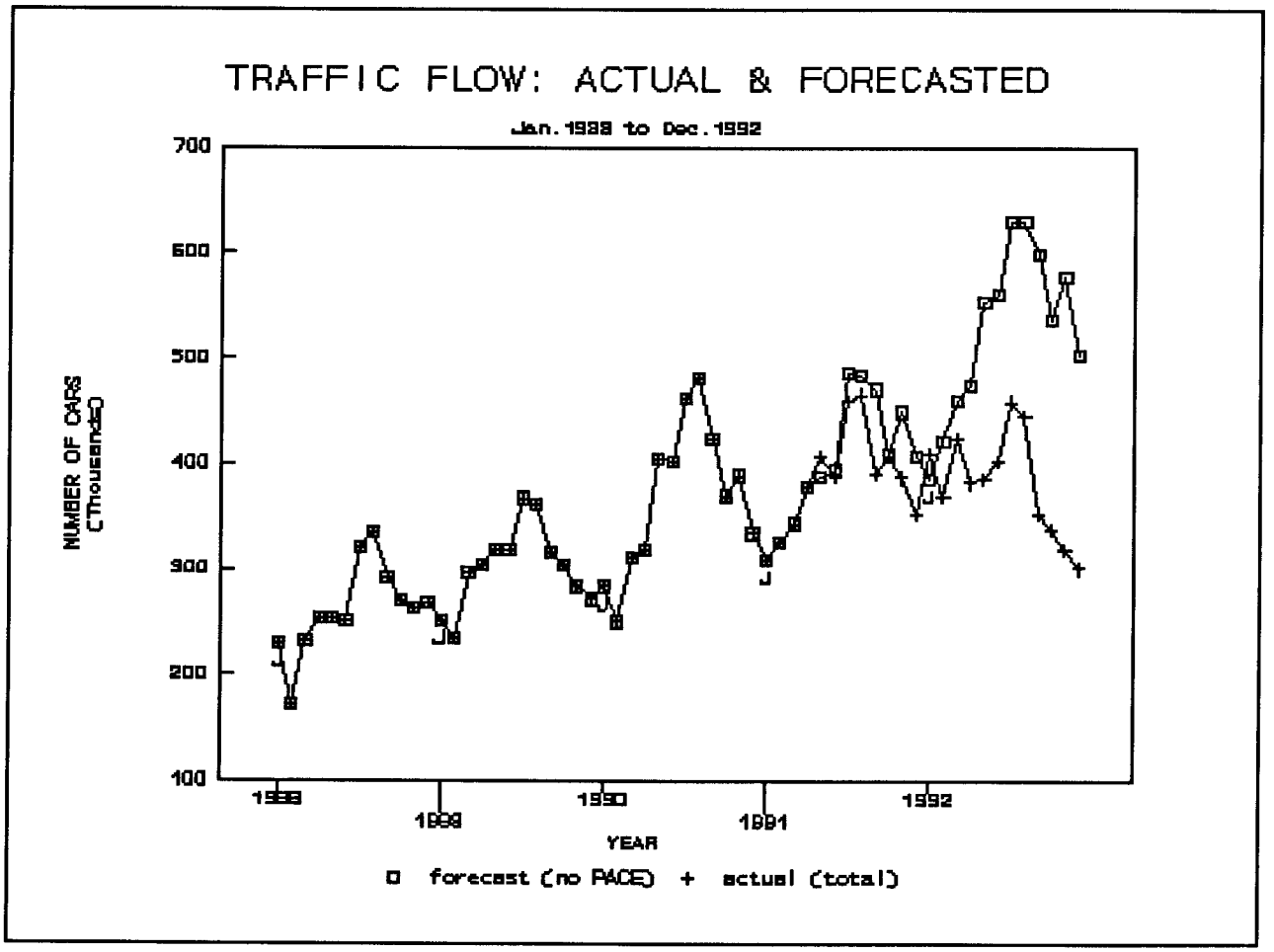
Level 1 represents the period prior to the introduction of PACE. Level 2 represents the period after the program's introduction. Based on the low F-value, the high p-value and the overlapping confidence intervals, we do not reject the null hypothesis.

Therefore we conclude that PACE has not significantly affected enforcement levels.

Note: residuals tested for normality through histograms, normal probability plots and scatterplots.

Part 3) Has the PACE program generated new traffic, or is traffic just being transferred from the regular lanes to the PACE lane?

Time series methods were used to forecast what traffic levels would have been if PACE had not been introduced. The graph below shows the predicted vs actual values. Clearly, traffic flows are down (as a result of various economic and public attitude factors), thus we cannot assume that the PACE program has generated new traffic.



APPENDIX B: DATA ANALYSIS FOR SIMULATION MODEL

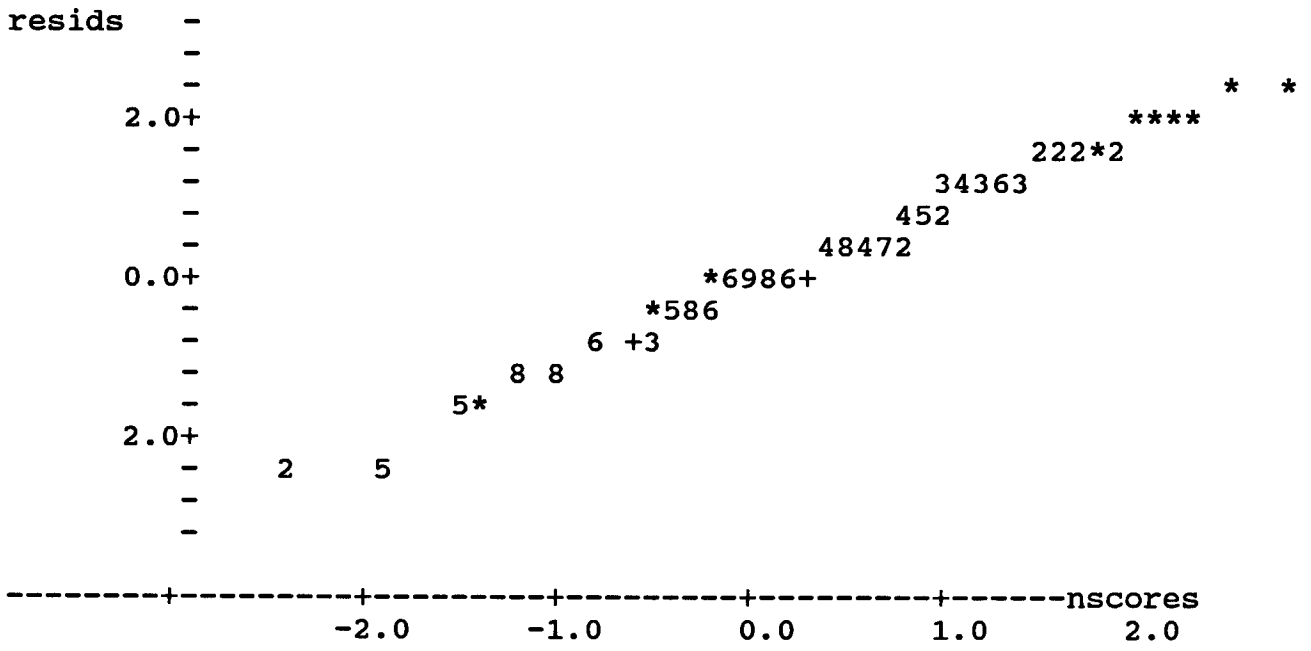
Part 1) Analysis of Cashier Service Times

The method of payment chosen by the individual has a significant impact on the length of time required for service at the cashier's desk. A one-way analysis of variance was run, using transformed data in order to meet normality assumptions. The corresponding histogram and normal probability plot for the transformation based on the negative inverse of cashier service times are shown below.

Histogram of Residuals N = 183

Midpoint	Count	
-0.025	2	**
-0.020	5	*****
-0.015	6	******
-0.010	22	**********
-0.005	37	**********
0.000	43	**********
0.005	28	**********
0.010	16	**********
0.015	16	**********
0.020	7	*******
0.025	1	*

Normal Probability Plot of Residuals



Correlation of resids and nscore = 0.996

ANALYSIS OF VARIANCE ON CASHIER SERVICE TIMES (TRANSFORMED DATA)

ANALYSIS OF VARIANCE ON neginv

SOURCE	DF	SS	MS	F	p
level	2	0.0122579	0.0061289	62.05	0.000
ERROR	180	0.0177791	0.0000988		
TOTAL	182	0.0300370			

LEVEL	N	MEAN	STDEV	INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV
1	144	-3.3E-02	0.011003	(-*-)
2	26	-1.5E-02	0.003850	(----*----)
3	13	-1.1E-02	0.002820	(------*-----)

POOLED STDEV = 0.009938

-0.0320 -0.0240 -0.0160 -0.0080

TUKEY'S multiple comparison procedure

```
         Nominal level = 0.0500
     Family error rate = 0.0500
 Individual error rate = 0.0192

 Critical value = 3.34

 Intervals for (mean of column group) - (mean of row group)

              1         2

     2 -2.4E-02
       -1.4E-02

     3 -2.9E-02 -1.2E-02
       -1.6E-02 0.004121
```

Conclusions: Based on a p-value of 0.0, we conclude that the method of payment has a significant effect on the length of cashier service time. The results of the Tukey test indicate that cash payments are significantly shorter than both cheque payments and credit card payments. There is no evidence, however, to indicate that there is any significant difference between the cashier service time of a cheque payment and that of a credit card payment.

Part 2) Analysis of Groups for Section 4.3.2:

Groups: 1) information seekers 2) searched only 3) general

Q: Are the three groups significantly different?

In order to meet the assumptions of normally distributed residuals and constant variance, the data was transformed based on the natural logarithms.

Results of Oneway ANOVA

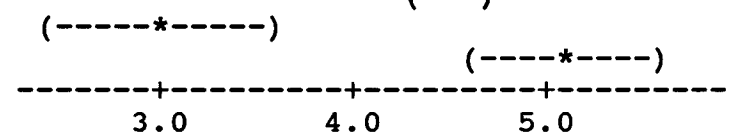
ANALYSIS OF VARIANCE ON logset2

SOURCE	DF	SS	MS	F	p
code	2	19.178	9.589	14.08	0.000
ERROR	97	66.050	0.681		
TOTAL	99	85.229			

LEVEL	N	MEAN	STDEV
1	82	4.4705	0.8040
2	7	3.0094	0.8904
3	11	5.0990	0.9455

POOLED STDEV = 0.8252

INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV



Fisher's pairwise comparisons

Family error rate = 0.0436
Individual error rate = 0.0167

Critical value = 2.436

Intervals for (column level mean) - (row level mean)

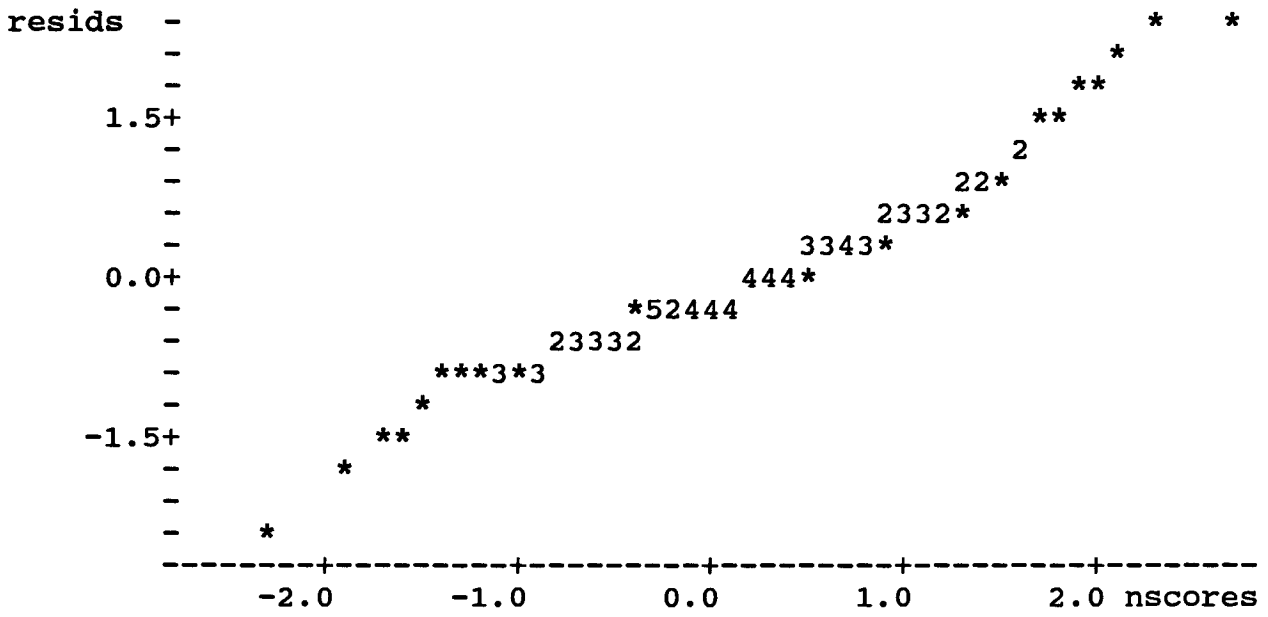
	1	2
2	0.6695 2.2526	
3	-1.2739 0.0170	-3.0615 -1.1177

1=general
2=searched only
3=information seekers

Conclusion: Since p-value of the ANOVA < 0.001, we will reject the hypothesis that the groups are all the same. From Fisher's pairwise comparisons, we can see that there is a significant difference between the "searched only" group and the other two groups, but there is no

significant difference between the "information seekers" group and the "general" group.

Normal Probability Plot



The normal probability plot of the residuals shows that the residuals are fairly normal.

Part 3) Classification Proportions

Part A: At the Cashier(s)

Method of Payment	Number	Percentage of Total
Cash	551	88.16%
VISA	40	6.40%
M/C	23	3.68%
Cheque	11	1.76%
TOTAL	625	100.00%

Note 1: Credit card payments totalled 10.08% of all transactions.
Note 2: Non-cash payments totalled 11.84% of all transactions.

Part B: Examinations

Total Number Referred= 536

	Number	Percentage
Examined	69	12.87%
Not Examined	467	87.13%
TOTALS	536	100.00%

Part C: Search Results

Total Searches= 69

Breakdown of Results	Number	Percent
Done	26	37.68%
To Cash	31	44.93%
Forced Pmt	6	8.70%
Seizure	6	8.70%
TOTAL	69	100.00%

Part 4: Comparison of Large Sample used in Simulation
with Smaller Sample used in Multiple Regression.

CLASS	RANGE	# SET1	# SET2	P SET1	P SET2
1	0–100	116	61	54.21%	61.00%
2	101–200	59	24	27.57%	24.00%
3	201–300	24	5	11.21%	5.00%
4	301–400	9	4	4.21%	4.00%
5	401–1000	6	6	2.80%	6.00%
TOTALS		214	100	1	1

				$(SAM-EXP1)^2$ / EXP	$(SAM-EXP2)^2$ / EXP
CLASS	RANGE	E SET1	E SET2		
1	0–100	120.6	56.4	0.18	0.38
2	101–200	56.6	26.4	0.10	0.22
3	201–300	19.8	9.2	0.91	1.94
4	301–400	8.9	4.1	0.00	0.00
5	401–1000	8.2	3.8	0.58	1.24
TOTALS		214	100	1.77	3.79
			$CHI^2=$	5.57	
			D.F.=	4	

$0.20 < P-VALUE < 0.25$ Therefore we do not reject the null hypothesis.

Accept Ho: The two data sets are from the same population.

General Group:

Time (sec.)	Number of Obs.	Cum. Obs.	Cumulative Probability
15	1	1	1.08%
16	1	2	2.15%
20	1	3	3.23%
24	1	4	4.30%
32	1	5	5.38%
33	1	6	6.45%
35	1	7	7.53%
36	2	9	9.68%
38	1	10	10.75%
40	3	13	13.98%
46	2	15	16.13%
47	1	16	17.20%
50	3	19	20.43%
51	3	22	23.66%
52	1	23	24.73%
54	1	24	25.81%
56	2	26	27.96%
60	3	29	31.18%
61	2	31	33.33%
62	1	32	34.41%
63	1	33	35.48%
64	1	34	36.56%
66	1	35	37.63%
69	2	37	39.78%
70	1	38	40.86%
71	1	39	41.94%
72	1	40	43.01%
74	2	42	45.16%
80	1	43	46.24%
81	3	46	49.46%
82	1	47	50.54%
86	1	48	51.61%
90	2	50	53.76%
92	1	51	54.84%
93	1	52	55.91%
97	1	53	56.99%
98	1	54	58.06%
102	1	55	59.14%
106	2	57	61.29%
112	1	58	62.37%
113	1	59	63.44%
114	1	60	64.52%
115	2	62	66.67%
117	1	63	67.74%

"Searched only" Group:

Time (sec.)	Number of Obs.	Cum. Obs.	Cumulative Probability
5	1	1	14.29%
13	2	3	42.86%
21	1	4	57.14%
27	1	5	71.43%
35	1	6	85.71%
84	1	7	100.00%

118	1	64	68.82%
123	1	65	69.89%
130	1	66	70.97%
133	1	67	72.04%
144	1	68	73.12%
151	1	69	74.19%
155	1	70	75.27%
160	2	72	77.42%
161	1	73	78.49%
162	1	74	79.57%
169	1	75	80.65%
175	2	77	82.80%
180	1	78	83.87%
207	2	80	86.02%
233	1	81	87.10%
246	1	82	88.17%
294	1	83	89.25%
329	1	84	90.32%
349	1	85	91.40%
355	1	86	92.47%
395	1	87	93.55%
480	1	88	94.62%
482	1	89	95.70%
514	1	90	96.77%
767	1	91	97.85%
860	1	92	98.92%
972	1	93	100.00%

Cash Payments:

Time (sec.)	Number of Obs.	Cumulative Probability
17	2	1.39%
18	6	4.86%
20	5	8.33%
21	1	9.03%
22	8	14.58%
23	8	20.14%
24	5	23.61%
25	13	33.33%
26	5	36.81%
27	6	40.97%
28	3	43.06%
29	4	45.83%
30	9	52.08%
31	2	53.47%
32	7	58.33%
33	8	63.89%
34	3	65.97%
35	4	68.75%
36	1	69.44%
37	2	70.83%
38	2	72.22%
40	3	74.31%
41	1	75.00%
42	2	76.39%
43	3	78.47%
44	3	80.56%
45	1	81.25%
48	3	83.33%
50	6	87.50%
51	3	89.59%
52	2	90.97%
54	1	91.67%
55	1	92.36%
58	2	93.75%
60	1	94.44%
64	2	95.83%
66	1	96.53%
73	1	97.22%
75	1	97.92%
78	1	98.61%
90	1	99.31%
132	1	100.00%

Non–cash Payments:

Time (sec.)	Number of Obs.	Cumulative Probability
45	1	2.56%
48	2	7.69%
49	1	10.26%
56	2	15.38%
57	1	17.95%
60	1	20.51%
62	1	23.08%
63	1	25.64%
68	1	28.21%
70	5	41.03%
71	1	43.59%
72	1	46.15%
74	1	48.72%
77	1	51.28%
78	1	53.85%
79	1	56.41%
80	2	61.54%
81	1	64.10%
94	2	69.23%
100	2	74.36%
104	2	79.49%
105	1	82.05%
110	1	84.62%
111	1	87.18%
115	1	89.74%
122	1	92.31%
124	1	94.87%
132	1	97.44%
133	1	100.00%

APPENDIX C: THE GPSS/H MODEL AND ITS VALIDATION

PART 1: THE GPSS/H MODEL

```
************************************************************************
* THESIS: CUSTOMS OFFICE MODEL  ( all times are in seconds)
************************************************************************
            SIMULATE
*
            INTEGER    &I                        do-loop index
*
ATF         FILEDEF    'BC.ATF'
************************************************************************
* CONTROL STATEMENTS (Functions) AND EXPLANATION OF PARAMETERS
************************************************************************
 SERVTIME   FUNCTION   RN1,C8                    general flow service
*                                                 time
0.0,10/.05,32/.49,81/.70,123/.84,180/.90,329/.98,514/1,1000
*
 SRESULT    FUNCTION   RN1,D4                    results of search
.38,DONE/.83,CONTINUE/.915,FCLAIM/1,CSEIZE
*
 SOSTIME    FUNCTION   RN1,C5                    "searched only" group
0,0/.43,13/.71,27/.86,35/1,100                    service time
*
 PAIDCASH   FUNCTION   RN1,C6                    cashier service time:
0,15/.09,21/.33,25/.69,35/.91,52/1,90             cash payment
*
 NONCASH    FUNCTION   RN1,C6                    cashier service time:
0,44/.28,68/.64,81/.69,91/.9,115/1,133            non-cash payment
*
*FULLWORD PARAMETERS:
* TEPS          number of the terminal chosen
* BACKPATH      path from the terminal to the cash queue
* CN1           cashier chosen
* LEAVING       path to leave system
* CHNG          PROOF object to change color
*
*FLOATING POINT PARAMETERS:
* EQ1           empty queue travel time (terminal queue)
* EQ2           empty queue travel time (cashier queue)
*
************************************************************************
* MODEL SEGMENT 1: ENTERING THE CUSTOMS OFFICE
************************************************************************
            GENE        1,,,16,,5PF,2PL         put 16 people in line
            QUEUE       LINEAB
            QUEUE       LINEAC
            ASSIGN      EQ1,20,PL
            BPUTPIC     FILE=ATF,LINES=4,(AC1,XID1,XID1,XID1,PL(EQ1))
TIME *.*
CREATE CROSSER *
```

```
PLACE * ON PATHT
SET * TRAVEL *
            TRANS       ,JOIN
*
            GENE        RVEXPO(1,73.94),,,,,5PF,2PL   interarrivals *
            QUEUE       LINEAB                  gather stats
            QUEUE       LINEAC                      "
            ASSIGN      EQ1,ABS(RVNORM(1,20,3.2)),PL
* ATF statement to put person on main path
            BPUTPIC     FILE=ATF,LINES=4,(AC1,XID1,XID1,XID1,PL(EQ1))
TIME *.*
CREATE CROSSER *
PLACE * ON PATHT
SET * TRAVEL *
 JOIN       ADVA        PL(EQ1)                 empty queue travel
*****************************************************************
* MODEL SEGMENT 2: CHOOSING A SERVER
*****************************************************************
            TEST GE     FS1+FS2+FS3+FS4,1       see if a terminal is
*                                                 available
            SELECT FS   TEPS$PF,1,4             choose available
*                                                 server
 SERVICE    SEIZE       PF(TEPS)                seize terminal
            DEPA        LINEAB                  leave first queue
*
            BPUTPIC     FILE=ATF,LINES=2,(AC1,XID1,PF(TEPS))
TIME *.*
PLACE * ON PATH*
            BPUTPIC     FILE=ATF,LINES=2,(AC1,XID1,PF(TEPS)+1)
TIME *.*
SET * TRAVEL *
*
            ADVA        (PF(TEPS)+1)            walk to counter
            ASSIGN      CHNG,(PF(TEPS)+3),PF
            TRANS       .07,,SONLY              some cars searched
*                                                 only
            TRANS       .05,,SEARCH             search and declaration
            ADVA        FN(SERVTIME)            general service time
            TRANS       ,GOON
 SEARCH     PRIORITY    1
            ADVA        FN(SERVTIME)            search and declaration
            SPLIT       1,TERMDWN1               service time
            RELE        PF(TEPS)
            PRIORITY    0
            DEPA        LINEAC
            TRANS       ,STIME                  go to be searched
TERMDWN1    FUNAVAIL    PF(TEPS)                officer leaves;
*                                                 terminal
* ATF statement to change color of terminal      temporarily down
            BPUTPIC     FILE=ATF,LINES=2,(AC1,PF(CHNG))
TIME *.*
```

```
SET * COLOR LAYOUT
            ADVA        RVEXPO(1,236.7)
            FAVAIL      PF(TEPS)
* ATF statement to return terminal to blue
            BPUTPIC     FILE=ATF,LINES=2,(AC1,PF(CHNG))
TIME *.*
SET * COLOR BLUE
            TERM        0
 GOON       RELE        PF(TEPS)                leave terminal
            DEPA        LINEAC                  stats gathering
            ASSIGN    BACKPATH,(PF(TEPS)*10),PF   to assign PROOF path

*
* Atf statement to return crosser to beginning of cash line
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,PF(BACKPATH),XID1)
TIME *.*
PLACE * ON PATH*
SET * TRAVEL 3
            TRANS       ,CONTINUE
*****************************************************************
* MODEL SEGMENT 3: GOING TO THE CASHIER
*****************************************************************
 CONTINUE   ADVA        3                       get back to cash line
*
            TRANS       .10,,THREE              1 in 10 splits into 3
            TRANS       .333,,TWO               3 in 10 split into 2
            TRANS       ,ONE                    other 6 don't split
 THREE      SPLIT       2,CRCLONE
            TRANS       ,ONE
 TWO        SPLIT       1,CRCLONE
            TRANS       ,ONE
 CRCLONE    BPUTPIC     FILE=ATF,LINES=2,(AC1,XID1)
TIME *.*
CREATE CROSSER *
*
 ONE        ADVA        0
            SEIZE       CQSTART                 dummy facility to
            ADVA        1                        smooth animation
            RELE        CQSTART
            QUEUE       LINECD                  join cash line/get
*                                                stats
            QUEUE       LINECE
*
            ASSIGN      EQ2,ABS(RVNORM(1,5,0.8)),PL empty queue
*                                                    travel
* ATF statement to put crosser on path for cashier
            BPUTPIC     FILE=ATF,LINES=4,(AC1,XID1,XID1,PL(EQ2),XID1)
TIME *.*
PLACE * ON PATHC
SET * TRAVEL *
SET * COLOR YELLOW
```

```
*
            ADVA        PL(EQ2)                  empty queue travel
*                                                 time
            TEST GE     FS5+FS6,1                is a cashier seizable?
            SELECT FS   CN1$PF,5,6               choose the cashier
            SEIZE       PF(CN1)                  seize the cashier
* ATF statement to go to cashier chosen
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,PF(CN1),XID1)
TIME *.*
PLACE * ON PATH*
SET * TRAVEL 2
            DEPA        LINECD
            ADVA        2                        dummy advance
            TRAN        .12,,NOTCASH             pay by cheque/credit
*                                                 card
            ADVA        FN(PAIDCASH)             cash payment time
 FINISH     RELE        PF(CN1)
            DEPA        LINECE
*
* ATF statement to put crossers on the leaving path
            ASSIGN    LEAVING,(PF(CN1)*10),PF    to assign PROOF path

            BPUTPIC  FILE=ATF,LINES=4(AC1,XID1,PF(LEAVING),XID1,XID1)
TIME *.*
PLACE * ON PATH*
SET * COLOR GREEN
SET * TRAVEL 5
*
            ADVA        5                        watch crossers leave
* ATF statement to destroy crosser
Y           BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,N72+N116+N126)
TIME *.*
DESTROY *
WRITE NUMBER Number of travellers processed = *
            TERM        0
*****************************************************************
* MODEL SEGMENT 4: NON-CASH PAYMENTS
*****************************************************************
 NOTCASH    ADVA        FN(NONCASH)              non-cash pmt. time
            TRANS       ,FINISH                  rejoin group
*****************************************************************
* MODEL SEGMENT 5: CONTROL OF TEPS TERMINALS AND CASHIER #2
*****************************************************************
            GENE        0,,,1
* ATF statement to create cashier #2
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
CREATE CASHIER *
PLACE * ON PATHCASH
*
            ADVA        1500                     after 1500 seconds,
```

```
*                                                    shut down cashier #2
            TEST E      F6,0                         if it is empty
            FUNAVAIL    6
* ATF statement to change color of cashier #2
            BPUTPIC     FILE=ATF,LINES=2,(AC1,XID1)
TIME *.*
SET * COLOR LAYOUT
            TERM        0
*
            GENE        0,,,1
* ATF statement to create terminal #1
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
CREATE TEPS *
PLACE * ON TP1
            TERM        0
*
            GENE        0,,,1
* ATF statement to create terminal #2
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
CREATE TEPS *
PLACE * ON TP2
            TERM        0
*
            GENE        0,,,1
* ATF statement to create terminal #3
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
CREATE TEPS *
PLACE * ON TP3
            TERM        0
*
            GENE        0,,,1
* ATF statement to create terminal #4
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
CREATE TEPS *
PLACE * ON TP4
            TERM        0
*****************************************************************
* MODEL SEGMENT 6: CARS THAT ARE REFERRED ONLY TO BE SEARCHED
*                      ("SEARCHED ONLY" GROUP)
*****************************************************************
 SONLY      PRIORITY    1
            ADVA        FN(SOSTIME)              time at terminal
            SPLIT       1,TERMDWN2
            RELE        PF(TEPS)                 terminal released
            PRIORITY    0
            TRANS       ,CSGEN
 TERMDWN2   FUNAVAIL    PF(TEPS)                 officer leaves,
```

```
* ATF statement to change color of terminal
            BPUTPIC     FILE=ATF,LINES=2,(AC1,PF(CHNG))
TIME *.*
SET * COLOR LAYOUT
            ADVA        RVEXPO(1,236.7)
            FAVAIL      PF(TEPS)
* ATF statement to return terminal to blue
            BPUTPIC     FILE=ATF,LINES=2,(AC1,PF(CHNG))
TIME *.*
SET * COLOR BLUE
            TERM        0
*
 CSGEN      DEPA        LINEAC
* ATF statement to temporarily leave system
 STIME      BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
PLACE * ON PATHS
SET * COLOR BLUE
            ADVA        ABS(RVNORM(1,228,87))  time for search
            TRAN        ,FN(SRESULT)           results of search


*****************************************************************
* MODEL SEGMENT 7: SEARCHED CARS THAT ARE FREE TO LEAVE
*****************************************************************
 DONE       ADVA        0
* ATF statement to leave system
            BPUTPIC     FILE=ATF,LINES=4,(AC1,XID1,XID1,XID1)
TIME *.*
PLACE * ON PATHLS
SET * TRAVEL 5
SET * COLOR GREEN
            ADVA        5                      dummy to watch
*                                               them leave
            BPUTPIC     FILE=ATF,LINES=2,(AC1,XID1)
TIME *.*
DESTROY *
 YZ         TERM          0
*****************************************************************
* MODEL SEGMENT 8: SEARCHED CARS THAT RETURN TO TERMINAL
*****************************************************************
* ATF statement to bring them back in
 FCLAIM     SEIZE       SPAREWIC               use unoccupied
*                                               terminal
            BPUTPIC     FILE=ATF,LINES=3,(AC1,XID1,XID1)
TIME *.*
PLACE * ON PATHFP
SET * TRAVEL 5
            ADVA        FN(SERVTIME)           added time at terminal
            RELE        SPAREWIC
            TRAN        ,CONTINUE              rejoin main flow
```

```
*****************************************************************
* MODEL SEGMENT 9: SEIZURES
*****************************************************************
 CSEIZE    ADVA       0
*ATF statement to turn seizure pink
           BPUTPIC    FILE=ATF,LINES=4,(AC1,XID1,XID1,N(CSEIZE))
TIME *.*
PLACE * ON PATHSZ
SET * COLOR PINK
WRITE SEIZURES Number of seizures = *
           ADVA       5
           BPUTPIC    FILE=ATF,LINES=2,(AC1,XID1)
TIME *.*
DESTROY *
*
 Z         TERM       0                          remove offender
*****************************************************************
* RUN CONTROL XACT
*****************************************************************
*
           GENE       1
           TERM       1
*
           DO         &I=1,30,1                  number of replications
              START     3600                     1 hr run
*
           PUTPIC    FILE=ATF,LINES=2,(AC1,QT(LINEAC)+QT(LINECE))
TIME *.*
WRITE TOTAL Average total time through office = * seconds.
           PUTPIC    FILE=ATF,LINES=3,(AC1,QT(LINEAB)+QT(LINECD))
TIME *.*
WRITE WAIT Average time spent in queues = * seconds.
END
              CLEAR
*
           ENDDO
*
           END
```

A) ARRIVALS, SERVICE, AND PAYMENTS

FROM SIMULATION:

Rep.#	Number of Arrivals	Number Served	Number of Payments	# Cash Payments	% Cash
1	49	64	84	72	85.71%
2	48	62	77	61	79.22%
3	46	62	91	82	90.11%
4	44	60	75	70	93.33%
5	47	63	92	84	91.30%
6	49	65	82	67	81.71%
7	49	65	87	79	90.80%
8	41	57	78	69	88.46%
9	56	71	97	86	88.66%
10	57	72	99	88	88.89%
11	43	59	81	77	95.06%
12	48	64	88	77	87.50%
13	46	61	76	71	93.42%
14	53	69	99	88	88.89%
15	46	62	79	69	87.34%
16	45	61	72	65	90.28%
17	47	63	86	72	83.72%
18	45	60	88	73	82.95%
19	45	61	80	72	90.00%
20	37	53	67	60	89.55%
21	51	67	88	73	82.95%
22	68	83	93	83	89.25%
23	48	63	79	72	91.14%
24	44	60	79	67	84.81%
25	48	64	83	76	91.57%
26	52	68	95	86	90.53%
27*	50	65	83	74	89.16%
28	62	77	98	84	85.71%
29	48	64	93	84	90.32%
30	40	56	77	67	87.01%
Mean	48.40	64.03	84.87	74.93	88.31%
St.Dev.	6.12	5.90	8.30	7.81	3.59%
Mean − 2StD	36.15	52.23	68.26	59.30	81.13%
Mean + 2StD	60.65	75.84	101.47	90.56	95.50%

FROM OBSERVATION (Average of Three Hours):

	46.25	60.00	75.67	66.74	88.20%

In all cases, observed results are within two standard deviations of the mean.

B) SEARCHES AND RESULTS

Rep.#	Number of Searches	Percentage Searched	Number of Seizures	% Resulting in Seizures
1	8	12.50%	1	12.50%
2	8	12.90%	0	0.00%
3	5	8.06%	0	0.00%
4	7	11.67%	0	0.00%
5	6	9.52%	0	0.00%
6	12	18.46%	1	8.33%
7	8	12.31%	0	0.00%
8	6	10.53%	0	0.00%
9	9	12.68%	2	22.22%
10	4	5.56%	0	0.00%
11	8	13.56%	0	0.00%
12	13	20.31%	1	7.69%
13	7	11.48%	0	0.00%
14	4	5.80%	1	25.00%
15	8	12.90%	1	12.50%
16	7	11.48%	0	0.00%
17	6	9.52%	1	16.67%
18	10	16.67%	0	0.00%
19	3	4.92%	0	0.00%
20	4	7.55%	0	0.00%
21	5	7.46%	0	0.00%
22	11	13.25%	1	9.09%
23	8	12.70%	0	0.00%
24	6	10.00%	1	16.67%
25	7	10.94%	0	0.00%
26	12	17.65%	1	8.33%
27	6	9.23%	2	33.33%
28	9	11.69%	1	11.11%
29	5	7.81%	1	20.00%
30	10	17.86%	2	20.00%
Mean	7.40	11.57%	0.57	7.45%
St.Dev.	2.84	4.32%	0.67	9.42%
Mean + 1StD	4.56	7.25%	−0.10	−1.97%
Mean − 1StD	10.24	15.88%	1.24	16.87%
From Observations:				
		12.90%		8.70%

In both cases, observed results are within one standard deviation of the mean.

Point A: Traveller enters queue for TEPS terminal
Point B: Traveller leaves queue and reaches service desk
Point C: Traveller leaves service desk and joins queue for cash
Point D: Traveller leaves cash queue and reaches cashier
Point E: Traveller leaves cashier

Rep.#	Ave. Time A – B	Ave. Time A – C	Ave. Time C – D	Ave. Time C – E
1	117.97	237.52	160.51	203.84
2	294.13	423.35	226.14	267.37
3	123.72	249.65	92.47	132.80
4	111.94	238.90	53.25	87.45
5	113.40	232.78	66.26	104.88
6	154.39	245.45	64.93	107.92
7	69.19	217.34	133.16	168.46
8	73.09	191.51	81.04	123.07
9	272.03	386.61	174.56	212.19
10	140.82	256.44	91.09	128.97
11	235.93	408.99	80.32	117.65
12	239.67	374.06	135.81	178.62
13	87.07	199.15	73.81	113.17
14	78.43	212.69	125.56	164.49
15	154.79	266.74	44.78	84.61
16	79.21	194.08	27.54	67.28
17	96.75	210.30	67.62	110.58
18	102.58	225.64	30.22	69.03
19	117.03	284.57	109.91	152.24
20	139.23	294.80	45.68	84.44
21	164.70	301.16	205.53	245.38
22	109.09	209.63	71.61	110.02
23	105.11	212.43	32.79	71.98
24	201.15	349.53	79.44	125.93
25	83.29	224.08	68.35	105.52
26	88.28	182.40	79.07	118.22
27	141.72	256.60	80.91	121.17
28	134.36	266.83	174.59	212.06
29	122.24	260.80	130.48	169.21
30	102.05	208.28	59.17	100.37
Mean	135.11	260.74	95.55	135.30
St.Dev.	57.75	65.01	50.93	51.12
Mean + 1StD	77.36	195.73	44.63	84.17
Mean – 1StD	192.86	325.75	146.48	186.42

RAW DATA:

#	A	B	C	D	E
1	93	764	786		786
2	99	791	849		849
3	272	805	868		868
4	320	854	903	929	987
5	546	874	947	991	1064
6	569	907	1005	1070	1104
7	638	949	1054	1110	1137
8	669	976	1030		1030
9	773	1011	1104	1164	1213
10	781	1034	1177	1348	1512
11	812	1063	1223	1366	1428
12	819	1108	1164	1215	1346
13	912	1169	1202	1516	1545
14	954	1179	1566	1589	1708
15	1010	1206	1978	2005	2050
16	1153	1368	1424		1424
17	1193	1428	1503	1552	1587
18	1230	1508	1740		1740
19	1345	1515	1537		1537
20	1490	1569	1735		1735
21	1499	1744	1803	1817	1918
22	1561	1806	2009	2045	2140
23	1597	1808	1847		1847
24	1600	2002	2061	2078	2181
25	1680	2016	2096	2141	2173
26	1722	2049	2085		2085
27	1811	2066	2200	2223	2254
28	1902	2207	2471	2485	2535
29	1917	2425	2621	2639	2686
30	2009	2467	2491		2491
31	2081	2475	2580	2591	2631
32	2287	2497	2733	2788	2838
33	2494	2609	2662	2704	2752
34	2523	2623	2724	2754	2786
35	2621	2666	2675	3305	3443
36	2697	2722	3258	3165	3305
37	2881	3269	3316	3444	3475
38	2914	3320	3378	3478	3510
39	3009	3365	3472	3512	3544
40	139	371	469	560	640
41	210	396	503	587	680
42	275	472	554	645	694
43	332	495	569	695	712
44	336	495	716	890	1007
45	414	507	562	685	753
46	452	564	639	758	803

47	504	565	612	715	755
48	525	571	700	763	888
49	552	614	760	1017	1087
50	595	642	728	830	863
51	815	986	1030		1030
52	726	752	980	1089	1132
53	798	822	1039	1134	1235
54	806	851	1099	1237	1391
55	818	995	1014		1177
56	892	1016	1103	1186	1246
57	997	1033	1149	1265	1307
58	1016	1044	1184	1309	1346
59	1032	1102	1187	1350	1392
60	1037	1109	1214	1393	1516
61	1208	1270	1325	1395	1436
62	1823	1851	1895		1895
63	1586	1604	1780	1832	1858
64	1961	2124	2163		2163
65	2491	2526	2601		2601
66	2295	2327	2668		2820
67	2576	2676	2767	2862	2975
68	2629	2690	2744	2820	2861
69	2681	2755	2885	3107	3115
70	3004	3114	3175		3175
71	2894	2973	3108	3124	3180
72	46	628	724	1149	1191
73	85	690	1022	1358	1395
74	133	722	784	1193	1242
75	248	788	880	1244	1356
76	333	979	1134		1134
77	345	886	974		974
78	441	1022	1131	1422	1516
79	465	1040	1082	1399	1416
80	486	1088	1160	1518	1611
81	532	1153	1176	1944	1962
82	604	1140	1201	1570	1615
83	619	1164	1233		1233
84	620	1207	1332	1626	1676
85	679	1208	1323	1615	1648
86	732	1213	1219		1219
87	803	1324	1529	1650	1724
88	915	1340	1415		1415
89	1054	1347	1742	1754	1835
90	1148	1530	2365		2365
91	1224	1681	1772	1839	1880
92	1720	1997	2149		2149
93	1592	1945	1995		1995
94	1303	1697	1826	1912	1940
95	1418	1774	1816	1887	1910
96	1422	1845	1914	1965	2016

97	1480	1929	2162	2183	2237
98	2405	2666	2723		2723
99	1780	2254	2304		2304
100	1722	2167	2247	2297	2366
101	1732	2006	2211		2211
102	1747	2152	2235	2251	2293
103	1759	2240	2380	2440	2497
104	1921	2349	2370		2370
105	1962	2372	2472	2592	2648
106	2025	2387	2450		2450
107	2087	2477	2524	2650	2685
108	2220	2480	2546		2892
109	2222	2530	2856	2894	3008
110	2248	2555	2996	3025	3150
111	2256	2559	2659	2687	2725
112	2408	2726	2790	2810	2872
113	2460	2750	3017	3307	3360
114	2558	2797	2864		2864
115	2751	2861	2892		2892
116	2770	2865	3035	3152	3202
117	2821	2894	3184	3205	3304
118	2976	3030	3128		3128
119	3195	3253	3561	3576	3599
120	3207	3255	3505		3505
121	3274	3526	3553		3553
122	490	524	595		595
123	480	498	630	642	722
124	572	600	805	726	895
125	701	720	820	897	999
126	830	862	990	1002	1229
127	875	890	1074	1141	1201
128	958	1076	1162		1162
129	940	1060	1190		1190
130	1062	1170	1276	1299	1335
131	1087	1237	1387	1407	1483
132	1185	1280	1314	1368	1397
133	1235	1317	1344		1344
134	1237	1348	1406	1485	1511
135	1377	1395	1483	1513	1563
136	1435	1468	2460		2460
137	1475	1533	1769	1804	1855
138	1899	1930	2007	2014	2055
139	1880	1919	1980	2057	2180
140	2023	2034	2112	2181	2225
141	2090	2165	2329	2370	2403
142	2077	2097	2225	2265	2327
143	2087	2114	2299	2503	2503
144	2500	2516	4396		4396
145	2159	2189	2268	2329	2365
146	2160	2272	2359	2405	2500

147	2348	2428	2485	2621	2650
148	2444	2475	2523		2523
149	2582	2603	2813	2830	2957
150	2693	2727	2910	3068	3092
151	2720	2737	2908	2961	3066
152	2817	2847	2925		2925
153	3007	3029	3170		3170
154	3115	3142	3194		3194
155	3172	3197	3250	3270	3313
156	3232	3252	3293	3299	3356
157	3290	3300	3345	3364	3403

CALCULATED TIMES:

A – B	A – C	C – D	C – E
671	693		0
692	750		0
533	596		0
534	583	26	84
328	401	44	117
338	436	65	99
311	416	56	83
307	361		0
238	331	60	109
253	396	171	335
251	411	143	205
289	345	51	182
257	290	314	343
225	612	23	142
196	968	27	72
215	271		0
235	310	49	84
278	510		0
170	192		0
79	245		0
245	304	14	115
245	448	36	131
211	250		0
402	461	17	120
336	416	45	77
327	363		0
255	389	23	54
305	569	14	64
508	704	18	65
458	482		0
394	499	11	51
210	446	55	105

115	168	42	90
100	201	30	62
45	54	630	768
25	561		47
388	435	128	159
406	464	100	132
356	463	40	72
232	330	91	171
186	293	84	177
197	279	91	140
163	237	126	143
159	380	174	291
93	148	123	191
112	187	119	164
61	108	103	143
46	175	63	188
62	208	257	327
47	133	102	135
171	215		0
26	254	109	152
24	241	95	196
45	293	138	292
177	196		163
124	211	83	143
36	152	116	158
28	168	125	162
70	155	163	205
72	177	179	302
62	117	70	111
28	72		0
18	194	52	78
163	202		0
35	110		0
32	373		152
100	191	95	208
61	115	76	117
74	204	222	230
110	171		0
79	214	16	72
582	678	425	467
605	937	336	373
589	651	409	458
540	632	364	476
646	801		0
541	629		0
581	690	291	385
575	617	317	334
602	674	358	451
621	644	768	786
536	597	369	414

545	614		0
587	712	294	344
529	644	292	325
481	487		0
521	726	121	195
425	500		0
293	688	12	93
382	1217		0
457	548	67	108
277	429		0
353	403		0
394	523	86	114
356	398	71	94
423	492	51	102
449	682	21	75
261	318		0
474	524		0
445	525	50	119
274	479		0
405	488	16	58
481	621	60	117
428	449		0
410	510	120	176
362	425		0
390	437	126	161
260	326		346
308	634	38	152
307	748	29	154
303	403	28	66
318	382	20	82
290	557	290	343
239	306		0
110	141		0
95	265	117	167
73	363	21	120
54	152		0
58	366	15	38
48	298		0
252	279		0
34	105		0
18	150	12	92
28	233		90
19	119	77	179
32	160	12	239
15	199	67	127
118	204		0
120	250		0
108	214	23	59
150	300	20	96
95	129	54	83

	82	109		0
	111	169	79	105
	18	106	30	80
	33	1025		0
	58	294	35	86
	31	108	7	48
	39	100	77	200
	11	89	69	113
	75	239	41	74
	20	148	40	102
	27	212	204	204
	16	1896		0
	30	109	61	97
	112	199	46	141
	80	137	136	165
	31	79		0
	21	231	17	144
	34	217	158	182
	17	188	53	158
	30	108		0
	22	163		0
	27	79		0
	25	78	20	63
	20	61	6	63
	10	55	19	58
Mean	228.51	370.50	111.56	124.32

Summary of Simulation Results:

Mean	135.11	260.74	95.55	135.30
St.Dev.	57.75	65.01	50.93	51.12
Mean − 2StD	19.61	130.72	−6.30	33.05
Mean + 2StD	250.62	390.76	197.41	237.54

In all cases, the mean of the observed results are within two standard deviations of the mean.

PART 3: CUMULATIVE PROBABILITIES FOR SDS FORM COMPLETION TIMES

Form Fill–out Time	Number of Obs.	Cumulative Number	Cumulative Probability
30	1	1	2.22%
36	1	2	4.44%
39	1	3	6.67%
53	1	4	8.89%
55	1	5	11.11%
59	1	6	13.33%
60	1	7	15.56%
63	1	8	17.78%
69	2	10	22.22%
72	1	11	24.44%
73	1	12	26.67%
77	3	15	33.33%
78	2	17	37.78%
82	2	19	42.22%
85	1	20	44.44%
87	1	21	46.67%
88	2	23	51.11%
94	2	25	55.56%
95	1	26	57.78%
96	1	27	60.00%
103	1	28	62.22%
112	1	29	64.44%
122	1	30	66.67%
127	1	31	68.89%
129	1	32	71.11%
133	1	33	73.33%
149	1	34	75.56%
153	1	35	77.78%
160	1	36	80.00%
162	1	37	82.22%
170	1	38	84.44%
181	1	39	86.67%
185	1	40	88.89%
220	1	41	91.11%
224	1	42	93.33%
265	1	43	95.56%
315	1	44	97.78%
358	1	45	100.00%

PART 4: PERCENTAGE OF TRAVELLERS USING SDS WHEN SDS IS OPEN AND A POINT OFFICER IS PRESENT

Hour #	# SDS	# Regular	Total	% SDS
1	1	8	9	11.11%
2	7	16	23	30.43%
3	7	27	34	20.59%
4	4	34	38	10.53%
5	13	28	41	31.71%
6	10	10	20	50.00%
7	9	17	26	34.62%
8	1	21	22	4.55%
9	6	12	18	33.33%
10	9	21	30	30.00%
11	6	30	36	16.67%
12	12	24	36	33.33%
13	3	23	26	11.54%
14	12	25	37	32.43%
15	2	13	15	13.33%
16	6	9	15	40.00%
17	8	38	46	17.39%
18	6	13	19	31.58%
19	18	18	36	50.00%
20	18	20	38	47.37%
21	6	25	31	19.35%
22	1	31	32	3.13%
23	4	22	26	15.38%
24	10	21	31	32.26%
25	15	31	46	32.61%
26	21	35	56	37.50%
27	26	37	63	41.27%
28	24	39	63	38.10%
29	25	28	53	47.17%
30	5	31	36	13.89%
31	8	11	19	42.11%
32	9	12	21	42.86%
33	11	17	28	39.29%
34	19	20	39	48.72%
35	14	18	32	43.75%
36	2	30	32	6.25%
37	8	17	25	32.00%
38	5	10	15	33.33%
39	18	20	38	47.37%
40	9	31	40	22.50%
41	1	42	43	2.33%
42	0	36	36	0.00%
43	13	19	32	40.63%
44	8	28	36	22.22%
Averages	9.55	23.14	32.68	28.51%

PART 5: CUMULATIVE PROBABILITIES FOR SDS SERVICE TIMES

Service Time	Number of Obs.	Cumulative Number	Cumulative Probability
26	1	1	1.06%
29	1	2	2.13%
30	1	3	3.19%
32	1	4	4.26%
34	1	5	5.32%
35	1	6	6.38%
37	3	9	9.57%
41	1	10	10.64%
42	3	13	13.83%
43	3	16	17.02%
46	1	17	18.09%
47	1	18	19.15%
49	2	20	21.28%
51	1	21	22.34%
54	1	22	23.40%
55	1	23	24.47%
56	1	24	25.53%
57	2	26	27.66%
58	1	27	28.72%
60	1	28	29.79%
61	1	29	30.85%
62	3	32	34.04%
63	1	33	35.11%
65	1	34	36.17%
68	2	36	38.30%
69	2	38	40.43%
71	3	41	43.62%
72	1	42	44.68%
76	1	43	45.74%
79	2	45	47.87%
81	1	46	48.94%
84	1	47	50.00%
87	1	48	51.06%
89	1	49	52.13%
97	1	50	53.19%
99	1	51	54.26%
102	1	52	55.32%
110	1	53	56.38%
113	2	55	58.51%
118	1	56	59.57%
121	1	57	60.64%
122	1	58	61.70%
128	1	59	62.77%
133	1	60	63.83%
135	1	61	64.89%

137	1	62	65.96%
142	1	63	67.02%
146	1	64	68.09%
155	1	65	69.15%
163	1	66	70.21%
182	1	67	71.28%
186	1	68	72.34%
199	1	69	73.40%
217	1	70	74.47%
221	1	71	75.53%
223	1	72	76.60%
229	1	73	77.66%
242	1	74	78.72%
268	1	75	79.79%
286	1	76	80.85%
290	1	77	81.91%
313	1	78	82.98%
315	1	79	84.04%
317	1	80	85.11%
344	1	81	86.17%
381	1	82	87.23%
392	1	83	88.30%
407	1	84	89.36%
417	1	85	90.43%
436	1	86	91.49%
442	1	87	92.55%
473	1	88	93.62%
547	1	89	94.68%
594	1	90	95.74%
664	1	91	96.81%
987	1	92	97.87%
1072	1	93	98.94%
1078	1	94	100.00%

Average service time = 176.56 seconds.

PART 6: SIGNIFICANCE TESTS FOR SDS EXPERIMENTS

A: ANALYZING DIFFERENCES IN REGULAR TERMINAL SERVICE TIMES

ANALYSIS OF VARIANCE ON REGULAR TERMINAL SERVICE TIMES

SOURCE	DF	SS	MS	F	p
C30	5	389785	77957	11.24	0.000
ERROR	174	1206969	6937		
TOTAL	179	1596753			

LEVEL	N	MEAN	STDEV	INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV
R4-S0	30	435.81	111.14	(----*----)
R4-S1	30	357.54	110.63	(----*----)
R4-S2	30	330.21	78.43	(----*----)
R5-S0	30	348.84	57.62	(----*----)
R5-S1	30	294.60	71.44	(----*----)
R6-S0	30	302.39	49.52	(----*----)

POOLED STDEV = 83.29

300 360 420 480

Fisher's pairwise comparisons

Intervals for (column level mean) - (row level mean)

	R4-S0	R4-S1	R4-S2	R5-S0	R5-S1
R4-S1	20.9 135.7				
R4-S2	48.2 163.0	-30.1 84.7			
R5-S0	29.6 144.4	-48.7 66.1	-76.0 38.8		
R5-S1	83.8 198.6	5.6 120.3	-21.8 93.0	-3.1 111.6	
R6-S0	76.0 190.8	-2.2 112.5	-29.6 85.2	-10.9 103.8	-65.2 49.6

From the Fisher comparisons, we can see that the regular terminal service times are significantly longer in the base case (R4-S0) than in any other case. In addition, the case with 4 regular terminals and 1 SDS terminal is significantly longer than the case with 5 regular terminals and 1 SDS terminal. No other significant differences are apparent, however. This suggests that adding an additional regular terminal is much more effective than adding an SDS terminal.

B: ANALYZING DIFFERENCES IN SDS SERVICE TIMES

ANALYSIS OF VARIANCE ON SDS SERVICE TIMES

SOURCE	DF	SS	MS	F	p
sdsgroup	3	2597224	865741	21.31	0.000
ERROR	116	4712013	40621		
TOTAL	119	7309238			

LEVEL	N	MEAN	STDEV	INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV
R4-S0*	30	435.8	111.1	(----*----)
R4-S1	30	658.0	277.0	(----*----)
R4-S2	30	294.0	83.6	(----*---)
R5-S1	30	622.8	257.7	(----*---)

POOLED STDEV = 201.5

300 450 600 750

* regular terminal service time from base case is used as a benchmark.

Fisher's pairwise comparisons

Family error rate = 0.0595
Individual error rate = 0.0125

Critical value = 2.537

Intervals for (column level mean) - (row level mean)

	R4-S0	R4-S1	R4-S2
R4-S1	-354 -90		
R4-S2	10 274	232 496	
R5-S1	-319 -55	-97 167	-461 -197

From these intervals, we can see that the average service time when one SDS terminal is used is significantly higher than the base case service time, while the service time when two SDS terminals are used is significantly lower than the base case time.

C: ANALYZING DIFFERENCES IN THE NUMBER OF TRAVELLERS SERVED

ANALYSIS OF VARIANCE ON NUMBER SERVED

SOURCE	DF	SS	MS	F	p
reggroup	5	510.7	102.1	5.46	0.000
ERROR	174	3254.1	18.7		
TOTAL	179	3764.8			

LEVEL	N	MEAN	STDEV	INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV
1	30	40.400	3.927	(------*-----)
2	30	36.500	5.036	(-----*-----)
3	30	39.900	3.960	(------*-----)
4	30	40.833	4.878	(-----*------)
5	30	37.100	3.968	(-----*------)
6	30	40.067	4.025	(-----*------)
POOLED STDEV =		4.325		35.0 37.5 40.0 42.5

Fisher's pairwise comparisons

Family error rate = 0.0869
Individual error rate = 0.00833

Critical value = 2.669

Intervals for (column level mean) - (row level mean)

	R4-S0	R4-S1	R4-S2	R5-S0	R5-S1
R4-S1	0.920 6.880				
R4-S2	-2.480 3.480	-6.380 -0.420			
R5-S0	-3.414 2.547	-7.314 -1.353	-3.914 2.047		
R5-S1	0.320 6.280	-3.580 2.380	-0.180 5.780	0.753 6.714	
R6-S0	-2.647 3.314	-6.547 -0.586	-3.147 2.814	-2.214 3.747	-5.947 0.014

APPENDIX D: CHOICE OF MODELLING TECHNIQUES

The queuing process in the customs office is comprised of a number of separate events, including the arrival of border crossers, the initiation/completion of service at the terminals, and the initiation/completion of service at the cashier. Each of these events occurs at discrete but random points in time. As a result, discrete-event simulation can be a useful tool for examining the current border-crossing situation, and for analyzing proposed changes (Schriber, [14]). Discrete-event simulators were originally developed as quantitative aids to examine complex queuing situations that were not "amenable to analytical solution" (Bales et al., [2]). Although the border-crossing system is not overly complex, simulation is still a very attractive alternative for a number of reasons. One major reason is simulation's popularity and familiarity. The 1979 survey conducted by Thomas and DaCosta [16] reported that 84% of the large firms questioned used simulation techniques, second in popularity only to what was termed "statistical analysis". Similar results were obtained in 1989 by Harpell et al. [8], with simulation again ranking second in terms of utilization. Simulation's continuing popularity is explained by Solomon [15], who believes that simulation was once seen as "a method of last resort for solving problems" but will most likely become the method of preference. Her belief results from the trend toward modelling methods that are more cost-

effective, more reliable, more comprehensive, and easier to use and understand.

Some of the general advantages of simulation as presented by Schriber [14] are the ability to realistically capture the characteristics of the system being modelled; the ability to model non-existent systems; the possibility of time compression; the ease of experimental control; the reproducibility of random conditions; and the ability to "win-over" the client. Graybeal and Pooch [7] indicate two additional benefits: the lack of disturbance of the real system and the effectiveness of simulation as a training tool. Simulation is, of course, not without flaw. Some disadvantages listed by Schriber [14] and by Graybeal and Pooch [7] include the inability to produce exact results; the inability to generalize results to other situations; the failure to optimize; the long lead times; and the large expense in terms of manpower, money, and computer time.

In addition to the advantages noted above, there are particular benefits that are obtained by combining simulation and animation when presenting results to management and clients (Brunner et al., [4]). One major advantage is animation's ability to help explain the simulation model, thereby increasing its credibility (Law and Kelton, [11]). In addition, the visual nature of animation allows for increased ease of model debugging and verification (Sadowski, [13]). In the situation at hand, the decision to use simulation

and animation was greatly influenced by the fact that these modelling tools are intuitively appealing and relatively easy to understand.

According to Law and Kelton [11], the choice of a programming language is one of the most important decisions to be made when performing a simulation study. Graybeal and Pooch [7] specify a number of considerations that determine the language choice. These include the suitability of the language to the model, the presence or absence of facilities in the language to support routine activities, and the analyst's familiarity with the language.

Available programming languages can be separated into two major categories: general-purpose languages such as FORTRAN, C, Pascal and BASIC, and special-purpose simulation languages such as GPSS/H, SIMAN, SIMSCRIPT II.5 and SLAM II. Although general-purpose languages may be more well-known and easily accessible, Law and Kelton [11] have noted several important advantages of special-purpose languages. For example, the use of a simulation language may reduce programming time, since most of the features needed in simulation model programming are automatically provided. Also, the basic components of a simulation language can help to provide a framework for the model, which is not often the case in general-purpose languages. In addition, the use of a simulation language may lead to easier error detection since many types of potential

errors are checked automatically, and may lead to more efficient model debugging since fewer lines of code have to be written.

As a result of these factors, it was decided to use a special-purpose language for programming. The language chosen was GPSS/H, mainly due to GPSS/H's flexibility and the modeller's familiarity with the language. GPSS/H was developed in 1977 by James Henriksen and has been described as "an outstanding choice of language for modelling systems composed of units of traffic that compete with each other for the use of scarce resources" (Schriber, [14]), as is the case at the border-crossing facilities. The main complaint in the past concerning GPSS was that its ability to generate random numbers was poor (Bratley et al., [3]), but improvements have since been made (Law and Kelton, [11]). Thus, GPSS/H remains a suitable language choice.

The animation software package which was chosen was PROOF, a high-quality, PC-based animation and presentation software which was released in 1990 (Brunner et al., [4]). Again, user familiarity was a key deciding factor, although the choice was also based on PROOF's speed and smooth animations.