Application of an Interactive Surrogate Simulation to Canadian Air Transport Policy

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Abstract

A man-man/man-machine interactive surrogate simulation for use by policy makers, policy advisors and administrators is outlined and related to air transport policy-making in Canada. Air transport is visualized and described as a 'regulatory sphere' of activity where the sphere concept is used to provide a working analogy for consideration of the relationships existing within a community consisting of such actors as government, airlines, consumers, unions and others. A vehicle descriptor system forms the foundation upon which a complex and sensitive closed-loop (demand and supply) model is constructed. Realistic assumptions and accurate specification render the model useful for testing a wide range of policy alternatives for their impact on inter-organizational relations, quantity and quality of air service provided, organizational well being and for unexpected side effects within the air transport environment.

INTRODUCTION

This model is a player-interactive simulation game which is designed to recreate an air transport policy environment in microcosm. It consists of a brief set of written rules and conventions as well as a computer software package to support the participants. This simulation began as a fully multi-model fleet strategy game in which players built large transportation consortia by acquiring railway cars and locomotives, trucks, steamships and aircraft. Play was governed by the use of a simple board. As the game developed more and more features were added: data networks, hydroelectric utilities, oil companies, mines, etc. All equipment was given a score or rating in one or more categories of points (passenger/surface, passenger/air, freight, electrical energy, oil energy, communications). These were proportional to a vehicle or unit's net revenue input to the type of an operation for which it was designed. The total point score in each category, charted against independent economic conditions, determined profitability. While excellent as a financial and corporate planning tool, this version did not give the player a specific enough 'feel' for any particular mode as wide diversification of each firm was a prerequisite to survival.

An air-mode only version was created which involved a government, 10 airlines, a union and a consumer participant as well as a game master who acted as a generator of various economic conditions.

It very quickly became evident that as the functions of the government (regulatory control of airlines and airports etc.) grew ever closer to those of the real federal government that the calculative burden imposed on the players was slowing the progress of play (fuel subsidies, rebates, currency exchange equalization, income taxes, etc.). Surely the government player could be more easily accommodated and the functions of the airline players could be expanded if the game were more thoroughly specified and played on a computer system. A major theoretical and practical overhaul of the game resulted in the definition of a regulatory 'sphere' or 'community' of all those involved in air transport - detailing their functions and relation to each other in quantitative terms.

The next step was to use this definition to design a model where each of the participants would affect all the others in a manner close to that found in real life. Each player would control all of the impor-

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tant variables: for example, the government would control taxes, landing fees, electrical charges and route subsidies while interacting with the machine but could use moral suasion or threats of action or refusal to grant fare or route requests directly in dealing with the airline players. While interactions occurring inside the machine can and must be closely defined, those occurring among the players directly are more difficult to handle; difficult but not impossible. To cope with this problem the process of 'policy calibration' was developed. If the simulation can be set in motion at year 1 and run through to the present with the government behaving exactly as it did behave (with respect to policy, law on the books and regulatory disposition) in each period and with basic economic indicators following their historic trends and if the results for the most recent year simulated approximate reality, then the simulation can be said to be calibrated with respect to policy. The industry in the most recent year must be in aggregate very close to the size, structure and financial health of the real world industry. The trends and characteristics must be clear regardless of what actions were taken by any individual carrier in any one year during the run. This assumes high government influence and that the state of the economy is exogenous to our policy sphere.

The public manager finds himself in the middle of a particular complex sphere of influence which he must regulate in a manner which is both consistent with its own health and in accordance with his overall national economic (and other) objectives. He exerts great influence on the cost of money, the ease of selling equity, airline size and route structures, bilateral air agreements, the price of aircraft, fuel, labour and other factors of production, the power of unions and consumers to directly (or through him) affect airline behaviour.

A player-interactive simulation game can be successfully applied to a policy area where it is possible to delineate basic economic and other laws or principles which govern that area and where it is possible to define that area's parameters. Canadian air transport policy is a sufficiently specific area of governmental influence to allow an appreciation of the direct results and indirect implications of policy choices taken.

THE REGULATORY SPHERE

In any area of regulatory interest or concern there is a group of clearly defined actors or participants. The theory of a 'round table' is enlarged upon and the set of participants is said to comprise a 'sphere'. We borrow from geometry to describe our sphere thus:

1. There is a smooth outer surface such that any two points on that surface can only be joined by a surface or exterior line or path that is not the shortest (and hence is a sub-optimal) route between them

2. The shortest line (or 'relationship axis' for our purposes) between any two points (or parties) whether they exist on the surface of the sphere or within it, lies within the sphere

3. All components of the sphere compliment each other's existence and fit snugly together

4. A component can exist solely along the surface, along the surface and within, or solely within the sphere

5. All axes on which the sphere can turn or move pass through the same central point; it therefore has a true centre or universal pivot

The representation in Figure 1 is by no means ideal but it does give a general idea of what is meant. Three dimensional representations have been found to be too confusing.

Each part of a sphere has a clear and definable relationship to each other part of that sphere and the sphere exists more unto itself than as a part of society at large; the participants are inward facing and center around a concept. Centered around this concept or idea we find primary, secondary and tertiary actors. Primary actors are those who use the regulatory tools and those upon whom they are used. Usually the function of the principal 'regulatee' has the most to do with the concept around which the sphere is formed. The removal of any one primary actor will hurt all those remaining in the sphere and the complete removal of any category of primary (ex-all airlines) would cripple the sphere. The secondary actors are those participants who are important to the operation of one or more of the primary actors but who the primary actors could singly or in some combination, replace if they withdrew or perished. Whereas the primary actors (with the government being the obvious exception) exist mostly or wholly within the sphere the secondary actors tend to exist as a part of many different spheres; this gives them a more global (and discerning) view of activities in any one sphere. This also tends to prevent them from forming loyalties to any one sphere. (An oil company might be indifferent as to whether it sells jet fuel or gasoline). It should be clear, however, that secondary actors are probably the biggest contributors of exogenous inputs into a sphere due to their omni-spherical nature. Third level or tertiary actors are those who by their functions or strategic position (often through historic accident) are included as a part of the sphere but without whom the sphere could survive without need for major adjustment.

VEHICLE DESCRIPTORS

The basis on which the original board game was operationalized, and one carried through into (although less important in) the software supported version is the point system of vehicle descriptors. Originally a simple point score was assigned to an aircraft to reflect its relative value as a passenger carrying vehicle and another score reflected its cargo carrying capability net of passengers and baggage. The following assumptions were made at an early stage to allow meaningful description of a diverse selection of aircraft.

1. There will be a utilization floor below which the rational operator will not operate the equipment. For aircraft considered this was set at 100% of 'break-even'. Although economies of scale will lower the break-even point somewhat experience has shown that small carriers such as Wardair and large ones such as American seem to have <u>approximately</u> the same break even point with, for instance, a Boeing 707-320.

2. The market will be available to at least reach the break-even level in all except the worst economic conditions. In most cases economic strength will be such as to provide a level of ridership (load factor) in excess of the break-even point. <u>Economic conditions will reflect equally in all markets</u>. While these assumptions are the weakest in the set and are, to some extent, the Achilles' heel of the basic game, they <u>have</u> proven workable.

3. Incremental revenue from the operation of a vehicle will cover all of that unit's variable costs except fuel, electricity and insurance <u>and</u> will cover fixed maintenance and maintenance burden plus other allocated overhead. Fuel, electricity, insurance and capital costs will be borne directly out of point-score-generated income which is the only portion of incremental revenue actually seen by the player in the board game. (See Figure 2.)

4. Point scores will reflect absolute and <u>not</u> marginal productivity.

5. Point scores will be transitive.

6. Point scores of the same type will be additive.

7. Unlike categories of point scores cannot be added or compared (passenger and cargo).

8. All operators will get equal productivity from the same equipment given the same utilization (this is the converse of the earlier assumption about equal break-even points).

In many cases the point score system will appear confusing. For instance the Boeing 707-320 has a passenger score of 1000 and freight score of 210 while the Lockheed L-1049G Super Constellation rates 750 and 200 respectively. Are not jets far more productive than piston aircraft one may ask? While there can be no argument to this it must be pointed out that jet aircraft are more profitable only <u>at the margin</u>. Where the Super Constellation had a maximum potential utilization of 2000 to 2500 hours the 707 could fly 3500 or even 4000 hrs. At a 60% load factor the Super Constellation would make money while the 707 might just be breaking even if the piston airliner was being flown at its maximum of 2500 hrs, while the 707 was at the low end of its utilization range at the assumed 3000 hr. year.

Even in the basic game it was necessary to allow airlines to exploit the marginal benefits from jet operation. The net productivity increases with utilization but is governed by physical limits such as mean time between overhaul and the number of hours per day in which profitable operation is possible. Propeller aircraft needed a lot more ground time for maintenance and offered less extra capacity at the margin. In this game, however (and in real life) the jet is only slightly more profitable when operating at 100% of breakeven (3000 hr.) which is usually higher than the maximum possible hours for the older aircraft. While the following system lends itself more easily to computer versions of the game it can be used in the basic version as well. See Table 1.

DOCUMENTATION

The intermediate air version uses approximately the same concepts as the basic air version but the similarity, especially from the player point-of-view ends there. It is an interactive, computer supported surrogate simulation in which the players talk, alternately to each other and then to the computer, and receive a printout indicating their progress. Before play can begin each of the players must read four documents. The Introduction provides general information on the game and how it is played and delineates the roles of each of the players. The software supported version accommodates a Game Master, Government, Union, Consumer and five to ten airlines. A Primer provides a policy history up to the initial year of play as well as a narrative and previous annual report from each of the participating carriers so that the airline players have a good data base from which to start. Fleet and route data are also provided. The Equipment Catalogue gives the airline players the information shown in Figure 3 for each aircraft which is available.

The Players' Manual is a very brief document which details how the player actually interacts with the computer. Since it involves the use of the terminal as well as the responses to computer prompts this will differ depending upon what computer system the support package is being run on.

RUNNING THE SIMULATION

After a meeting at which the government presides and which considers all initiatives of the carriers (applications for routes, fare changes, aircraft import permit requests, etc.) and other participants and in which the government may take legislative action each participant will access the computer. The following order of interaction is required: game master (who controls the economy and primes the demand model), government (who regulates), consumer (who sets the buying pattern), union (who always demands more...) and airline (who manages his company).

PARTICIPANT	ITEMS MANIPULATED
Game Master	-economic growth - fuel price-electrical cost - inflation-aircraft data - operating costs - carrier route - fleet and balance sheet data
Government	-fuel price and tax - electrical price - minimum wage - tariffs - taxes - landing fees - subsidies to carriers
Union	-salary, working conditions demanded for upcoming contract renewals
Consumer	-market closing prices - propensity to buy charter travel-carrier ranking
Airlines	-purchase, sell, lease aircraft - borrow cash - issue bonds or stocks - hold outside securities - perform traffic analysis - evaluate aircraft - renegotiate labour contracts - set fares - open or close routes-assign aircraft to network

The demand model is a fairly simple scoring algorithm but it is sensitive to the size of the cities at either end of a route segment, segment length, carrier expenditure on advertising and passenger service, daily frequency offered, type of equipment offered, the consumer's opinions of the carrier, the satisfaction of the carrier's passenger service employees, and

Table 1
BOEING 707-320B UTILIZATION

	Weak	Standard	Strong	High Growth
Passenger Points	800	1,000	1,200	1,400
Freight Points	168	210	252	214
Multiplier	4/5	1	6/5	7/5
% of Breakeven	80%	100%	120%	140%
Utilization	2,400 hours	3,000 hours	3,500 hours	4,200 hours
Fuel Cost	400,000	500,000	600,000	700,000

Notes

1. The multiplier is the factor by which the standard point score is multiplied to get the contribution for the increased or decreased utilization.

2. This is the more economical, 707-320B being a fanjet and not a turbojet like the 707-320 which costs $700,000 of fuel for 3000 hr. utilization.

3. All fuel costs are rounded to the nearest $50,000 and reflect 10¢ per gallon prices.

the number of carriers on the route and percentage of capacity offered by the carrier. This demand model is just a small part of the total calculating process executed by the computer program. Before discussing these actual calculations it is necessary to detail the assumptions on which they are based:

1. It is possible to calculate supply (and demand) on a route segment basis as long as the segment is considered as part of a route and part of a passenger's path which may or may not follow such route.

2. It is possible to plug in a schedule optimizing model of the type presently used by the airlines to weed out logic errors in the assignment of a particular aircraft's hours to routes (such as assignment to non-connecting route segments) and to maximize the connection among routes.

3. For runs of one year (at most) it is possible to run the system as a pure supply model without even calculating demand but the dynamic use of the model will require some sort of demand feed-back whether using the DMAX or a more advanced demand model. A loop must be established.

4. Demand on a segment will be a function of population of the end-points, distance between them, price, frequency, quality of on-board service, product differentiation (advertising) and carrier reputation.

5. It will be possible later to use a more advanced demand model which will take account of the jointness of costs and revenues and also of the effect of network-induced demand on a particular segment.

After the airline player has entered all the decisions which he makes during his interaction the model moves to consider his first operating region. The first action will be to compute the number of aircraft hours by type flown in this region during the year. This total will be seen to be represented by equations:

(1) where the totals by aircraft are limited to those hours entered for routes declared to be in region R. The carrier operating hours total will be simply the sum of the total for all operating regions.

$$(1) \quad HRS_R = \sum_{AC=1}^{TP} ACHR_{AC}$$

where HRS_R = total aircraft hours in region R.

AC = aircraft type

TP = total number of aircraft types flown in region R.

ACHR = total hours of that type of aircraft assigned to routes in region R.

The next operation is to find the number of employees who will be needed given the schedule movements that have been planned. For pilots (for example) equation (2) determines the average number of pilots required per aircraft.

$$(2) \quad NPTAC = \frac{\sum_{AC=1}^{TP} N_{PAC} \cdot N_{PAC}}{\sum_{AC=1}^{TP} NAC}$$

where N_{PAC} = number of pilots on type AC

N_{AC} = number of aircraft of type AC in the fleet

The number of pilots necessary to support the operations is then calculated in equation (3). A similar process is used for other employee/aircraft ratios (checked for consistency to IATA figures.)

$$(3) \quad NP_R = \frac{HRS_R}{WKYR_P \cdot WKDY_P \cdot NPTAC}$$

where NP_R = number of pilots required in region R

$WKYR_P$ = days per year worked by pilots

$WKDY_P$ = hours per day worked by pilots

Once all employee category requirements have been determined the total wage bill for each category is calculated as are all fixed costs.

Equations (4) and (5) demonstrate this

(4) $WBP = PCONT \cdot NP_{R}$

where WBP = wage bill for pilots

PCONT = average pilot wage set by

(5) $GUTC = \sum_{GV=1}^{TGV} GVCOST_{GV} \cdot NOV$

where GUTC = ground vehicle total cost

TGV = number of types of ground vehicles

$GVCOST_{GV}$ = cost for fuel and insurance for one year standard operation of vehicle of type GV

NOV = number of vehicles of type GV

A further typical fixed cost calculation is that for a region's electrical expense in equation (6). Note, however, that advertising and passenger service costs are set directly by the player.

(6) $KWCOST_R = 10{,}000\ (NSTAT_R \times 35.00 + (FLTS_R \times (25))$

where $KWHCST_R$ = electrical cost for region R

$NSTAT_R$ = number of stations in region R

$FLTS_P$ = total number of flights made in region R

Direct operating cost is then calculated by aircraft type. The program then proceeds to the first route segment to be considered. The fact that players are prohibited from exceeding a standardized maximum utilization limit for all aircraft types obviates the need to check for adequate turnaround time at this step. After running a check for previously superimposed scheduling restrictions (imposed when a higher priority segment was being calculated), the number of flights on this segment is calculated in equation (7). The landing fees charges incurred are calculated in equation (8).

(7) $FLTS_{ij} \sum_{AC=1}^{TP} ACHR_{AC} \cdot \frac{VBLK_{AC}}{DIST_{ij}}$

where $FLTS_{ij}$ = non directional flights on segment ij

$ACHR_{AC}$ = hours of aircraft type AC assigned to ij

$VBLK_{AC}$ = block speed of type AC

$DIST_{ij}$ = statute mile distance from i to j

(8) $LDGFCR_{ij} = \frac{(FLTS_{ij}\ \ LDGFEE_i)}{2} + \frac{(FLTS_{ij}\ \ LDGFEE_j)}{2}$

where $LDGFCR_{ij}$ = landing fees for segment ij

$LDGFEE_i$ = landing fee at location i

$LDGFEE_j$ = landing fee at location j

Now that all constraints have been considered we are free to establish the schedule for ij so as to maximize connections with other routes. If there are unscheduled hours of an aircraft previously assigned to a route occurring on adjacent and next-to-adjacent routes (see 9) we can arrange them so as to suit the scheduling priorities of this route which will be:

1. run an early AM frequency
2. run a dinner hour frequency
3. run a noon frequency
4. run up to two additional frequencies in the AM
5. run up to two additional frequencies in the PM
6. fill any space of one hour or more
7. fill any space of one hour or more
8. fill any space of 30 mih or more

(9) Z a i j b x

Scheduling Algorithm

1. Check all ia, if aircraft is present check all aZ,
2. Check all jb, if aircraft is present check all bx,
3. If aircraft being scheduled is found on ia, jb, aZ or bx align ij to existing schedule on aj or jb and schedule remaining legs afterwards,
4. If aircraft is found unscheduled on ia or jb with or without aZ or bx respectively schedule ij first and arrange other legs to correspond,

5. If the same aircraft is found on aZ or bx and not on ia or jb respectively, indicate logic error, dump all previous allocations and ask player to re-schedule.

We can now calculate ASM for this segment as in equation (10).

(10)
$$ASM_{ij} = \sum_{AC=1}^{TP} \frac{ACHR_{AC} \cdot CAP_{AC}}{UBLK_{AC}}$$

<u>where</u> ASM_{ij} = available seat miles on route segment ij

CAP_{AC} = passenger capacity of aircraft AC

The system ASM total is merely the total of all ASM_{ij}'s for total unduplicated route mileage. The sum of ASM for all carriers can be compared to the maximum output that would have been possible had all carriers utilized each aircraft to the fullest as in equation (11).

(11)
$$ASM_{CMAX} = \sum_{C=1}^{NCARR} \sum_{AC=1}^{TP} \frac{NP_{AC} HRMAZ_{AC} CAP_{AC} \text{ x}}{VBLK_{AC}}$$

<u>where</u> ASM_{CMAX} = maximum possible industry available seat miles

NCARR = number of carriers

C = carrier number

$HRMAX_{AC}$ = maximum possible annual utilization for aircraft type AC

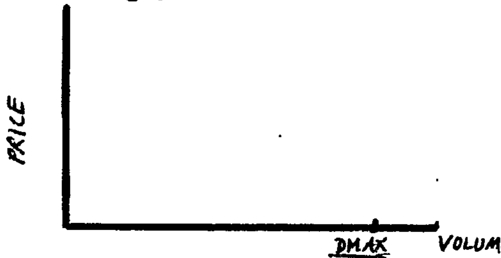
We now turn to the actual Demand Matrix (DMAX) demand model.

<u>Matrix DMAX</u>

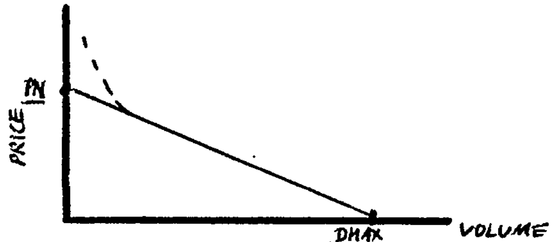
City Size Level	1	2	3
1	500,000	1,000,000	1,300,000
2	1,000,000	2,100,000	

Let us suppose that this is a portion of the demand matrix entered for a given year and that we are considering a route segment between cities of sizes 1 and 2 respectively. The route segment is determined to be in the short range category so the price/mile set by the airline for medium range flights entered by the carrier will be recalled from memory.

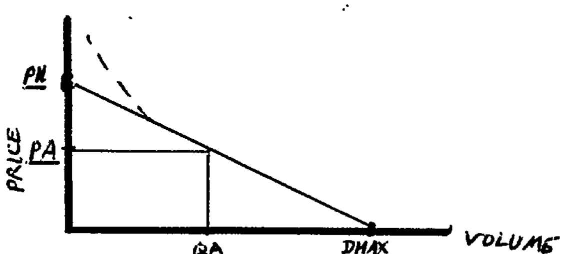
1. On a graph with the axes price and volume we can plot DMAX (1,2) which is the number of people who would travel if there were a token (or even no) charge,



2. We now recall PN the price of travel at which the consumer feels no one would take a medium range air trip (this can be modified from "no one" to a small number of demand inelastic travellers if desired. - see dotted line). We have a demand curve for this carrier for a route of this length connecting cities of this size given the present propensities of consumers,



3. We now enter PA the carrier's price for medium range travel to determine QA, the number of people who will travel, given this price,



While other carriers may have selected a different price and may well be in competition with this carrier they would face the same demand curve on the same route. Since this model does take account of the number of carriers in the market and the percentage of capacity offered by each, the chances of the sum of the passengers for all carriers exceeding DMAX are very slim but do exist.

The lack of real time simultaneity in our present computers precludes a running "percentage of passengers already served" meter because this would be areal; the air carriers will be serving the market simultaneously throughout the year. It is therefore necessary that the DMAX figures be several times existing passenger levels in routes like the one being simulated.

Another weakness of this model is that scheduling advantages of large carriers and daily peaking are ignored. They are not explicitly treated. While daily peaking is not presently built into the model the scheduling advantages accruing to carriers with adjoining route segments should show up.

A simple scoring algorithm is used to determine demand.

1. Using the matrix find the appropriate DMAX value and calculate QA using PV and PA

   EXAMPLE QA = 2,000,000

2. If there is not a separate matrix for each distance category, weight the QA value for stage length

* Short	-	multiply by 2
Medium	-	multiply by 1
Long	-	multiply by 7

   (Either separate matrices or this weighting system can be used)

   EXAMPLE QA = 4,000,000

3. Compare carrier's expenditure on advertising in the region to the threshold level set by consumer behaviour

   IF ADCOST (C.R.) ADDMIN
   add 10 to SCORE

   EXAMPLE SCORE = 0

   where ADCOST (C.R.) is advertising expenditure of carrier C in region R and ADDMIN is the threshold.

4. Similarly, compare passenger service expenditure to threshold PTR

   IF PSHR (C.R.) PTR add 5 to SCORE
   where PSHR (C.R.) = passenger service cost per passenger hour of carrier C in region R

   EXAMPLE SCORE = 5

5. Rate daily service

   If daily flights are between 4 and 9... add 5
   If daily flights are more than 9 ... add 10

   EXAMPLE SCORE = 15

6. Check the carrier's consumer ranking. Add 20 if it is first, 15 if second, 10 if third, 5 if fourth, 0 if fifth or sixth. Subtract 5 if seventh, 10 if eighth, 15 if ninth, 20 if tenth.

   EXAMPLE SCORE = 35

7. If passenger service personnel satisfaction is greater than .8 add 10
   less than .7 subtract 10

   EXAMPLE SCORE = 45

8. If passenger score points on aircraft operating on this segment exceed

10,000	add	5
15,000	add	10
20,000	add	15

   Note that this does not consider hours spent in the market by each aircraft

   EXAMPLE SCORE = 50

9. Add 25 to score
   IF the number of carriers in the market is one set market maximum (MKTMAX) variable to 10.

   EXAMPLE SCORE = 75

10. IF the number of carriers = 1 calculate the maximum market percentage this carrier can hope to achieve.

$$MKTMAX = \frac{1}{NCARR} (2) \frac{PXCAP}{(100)} (QA) =$$

$$\frac{1}{5} (2)(\frac{40}{100}) (4,000,000)$$

   where NCARR = number of carriers in market
   PXCAP = percentage of capacity offered

   EXAMPLE MKTMAX = 640,000

11. Calculate passengers emplaned (PAX) by multiplying the carrier score by MKTMAX and dividing by 100

$$\frac{75}{100} \times (640,000)$$

   EXAMPLE PAX = 480,000

(for discussion let us assume this is a 400 mi. stage to which the following were assigned)

4 B-727 - 400 flts each	(150 seat)
3 B-747 - 820 flts each	(350 seat)
3 B-707 - 1080 flts each	(180 seat)

These would produce:

	Flights	Seats	Miles	ASM
B-707	1,080	(180)	400	77,760,000
B-727	400	150	400	24,000,000
B-747	820	350	400	114,800,000
				216,560,000

EXAMPLE ASM = 216,560,000
RPM = 192,000,000

12. Find RPM RPM = (400) (480,000)

13. Check that RPM is not greater than ASM
If it is, set RPM = ASM

14. Calculate load factor LF=(RPM/ASM)(100)

EXAMPLE LF = 88.6%

15. Calculate Passenger Service Cost

TPSCST = PSHR(C.R.) x PAX
where TPSCST = total passenger service cost

The simulation has been coded and entered into Xerox and Cyber computer systems and the high core requirements of the program presented considerable challenges. Since the Cyber system necessitated considerable changes from Xerox-unique Fortran, it was decided to re-write the entire program in portable Fortran.

Verification has been long and tedious due to the necessity of modularizing the code (similar but not identical executive programmes control similar but not identical sets of subroutines) and has caused a lot of back-tracking. At the time of writing validation and calibration are not complete, however dry runs have produced good data on 'flying the airplanes' so it is believed that these hurdles will be smaller than those of verification.

The present author chaired a multidisciplinary evaluation team composed of operations researchers, market researchers, economists, planners and line managers at M.D.C. in Long Beach. While the model was not running smoothly enough (after four months of feverish work) to permit a full evaluation, a very valuable partial evaluation was conducted by this team. It was found that the Mark 1 version lends itself only to use by senior managers, or by airline players who act in multi-disciplinary teams. It was suggested that the model in the present version, is best suited to short intensive participation instead of periodic play by people with other duties. This was an important consideration for M.D.C. who were hoping to define a version of the game with the aircraft manufacturers as the principal input-giving player (instead of the government or airlines although these would continue to retain most of their decision-making powers).

OUTPUT

The outputs include the situation existing among the participants at the end of the run (each participant must describe quantitatively and qualitatively his perceived relationship to each other player at the end of the simulation) and the following printout results for each 'year' of the run:

by region:
- number of stations
- ground vehicle cost
- total wage bill
- advertising cost
- electrical cost
- telephone expense
- supplies expense
- equipment cost
- rentals
- contracted services
- general
- storage/hangers
- protective
- insurance
- buildings/grounds
- taxes
- aircraft direct operating costs-
  - crew salaries
  - fuel, oil
  - insurance
  - passenger service
  - direct maintenance
  - maintenance burden
  - electrical
- landing fees paid
- total revenue, expense
- charter operations summary

by route: by aircraft type - flights made
- ASM
- ATM
- hours flown

by total system:
- total and hourly direct operating costs by aircraft type
- passengers emplaned
- cargo emplaned
- RPM (revenue passenger miles)
- ASM (available seat miles)
- GTM (goods ton miles)
- ATM (available ton miles)
- system passenger and cargo load factor
- profit summary by region
- profit after bond cost and income earned
- government subsidy received
- profit after subsidy
- taxes paid after use of tax shield
- final net income
- balance sheet

CONCLUSIONS

From previous research and from the development of this model it has been concluded that, in the general sense, a surrogate simulation is useful for public administration in two broad ways. It can be used to test the choice of a particular policy and to speculate what the results of such a choice might be. It can be used to select from among various methods of implementation of a specific policy once the policy choice has been made. (For example, once we have decided to deregulate fares and route entry, how should we go about it?)

It is also concluded that Canadian air transport is a sufficiently distinct sphere of influence, both in present structure and with regard to historical events, to serve as workable simuland. There is a good possibility of easily varying the number of surrogates depending on the level of detail (and aggregation) required.

It should also be pointed out that surrogate simulation has been found to be a middle-of-the-road simulation technique lying on a continuum including econometric modelling, optimization, non linear models, surrogate simulations, gaming and think-tanking. Surrogate simulation combines many of the good points of both think-tanking and econometric modelling without dragging in too many of their defects. Some of the outputs of the model can be quantified (such as carrier performance) and some cannot (such as the prevailing regulatory mood). Such a simulation can be used as a supply model and/or can be driven by a demand model and is capable of being mathematically specified on both the demand and supply sides.

Finally, such a simulation is only possible where it is possible to aggregate interests (such as those of various unions in aviation) into single surrogates who cannot be attacked as 'having to have battles going on inside them' because two of the elements they represent might be held, at some point in the simulation, to be in conflict. The fit of simulated to real interests and structures must be 'tight'.

Figure 1 AIR TRANSPORT POLICY SPHERE

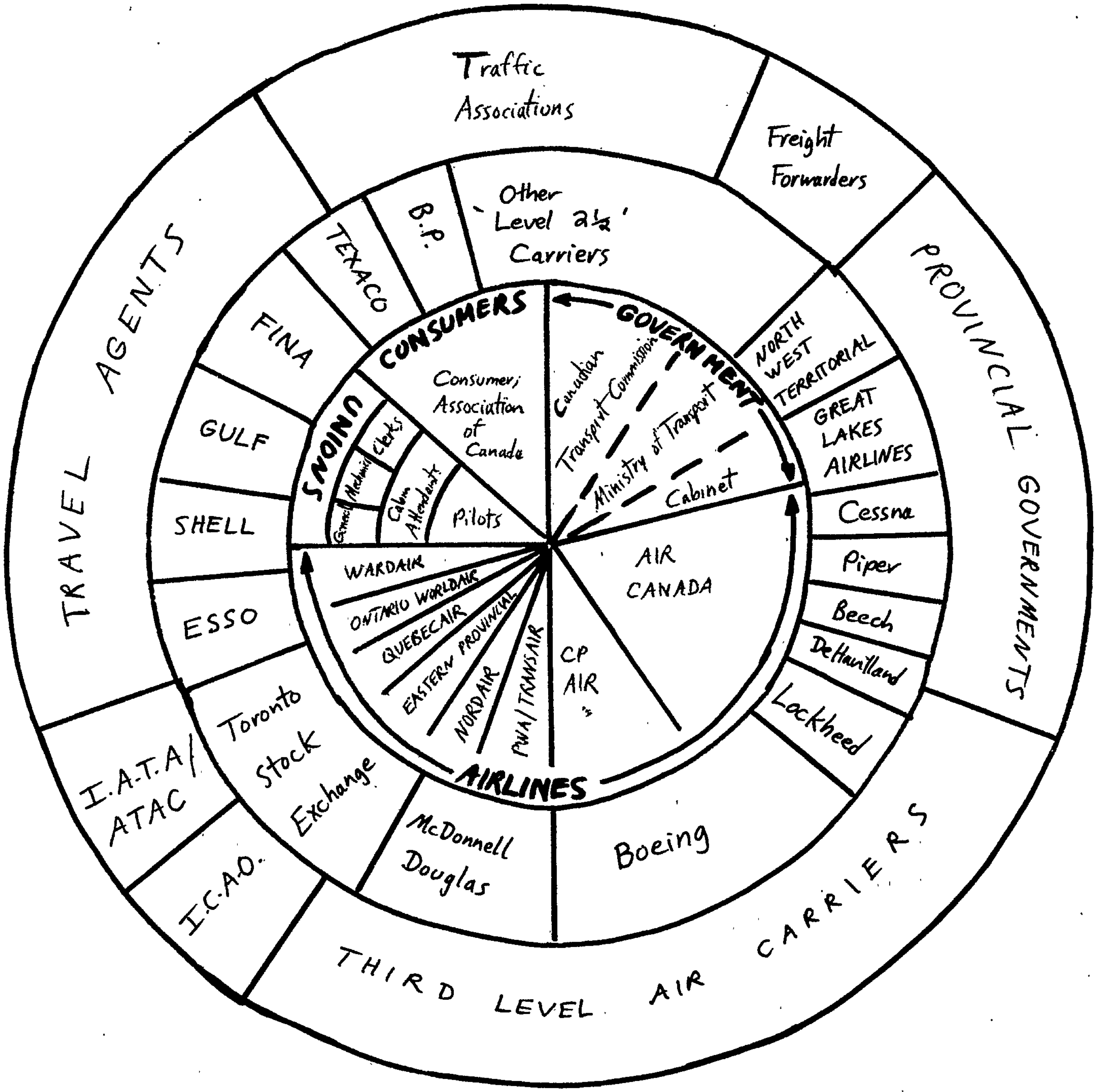


Figure 2 PROFILE/NON PROFILE COSTS

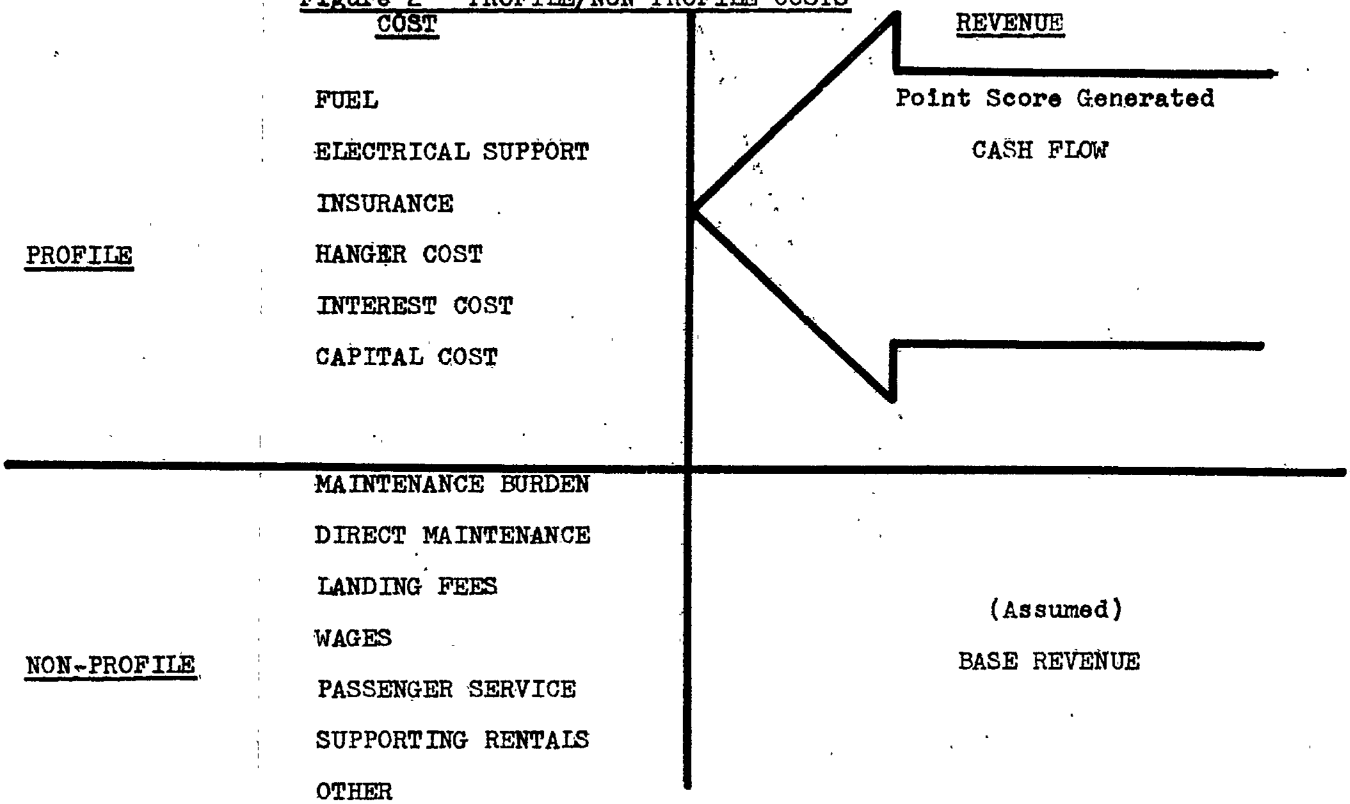


Figure 3 OMNIUM VEHICLE DESCRIPTORS

Passenger Point Score	1,000
Freight Point Score	210
Fuel cost for standardized year (10¢/gal.)	500,000
Operating hours on standardized year	3,000
Cost of vehicle new	8,000,000
Hours of use on vehicle since new	0
First class seats	14
Economy seats	133
Signal to call manufacturer name	1,401
Signal to call vehicle name	8,081
Cargo ton capacity net of passengers	7
Range with full passenger load (st. mi.)	5,000
Operating crew	4
Infrastructure fee category	4
Block speed (weighted average)	510

Figure 4   COMPUTER FLOW DIAGRAM

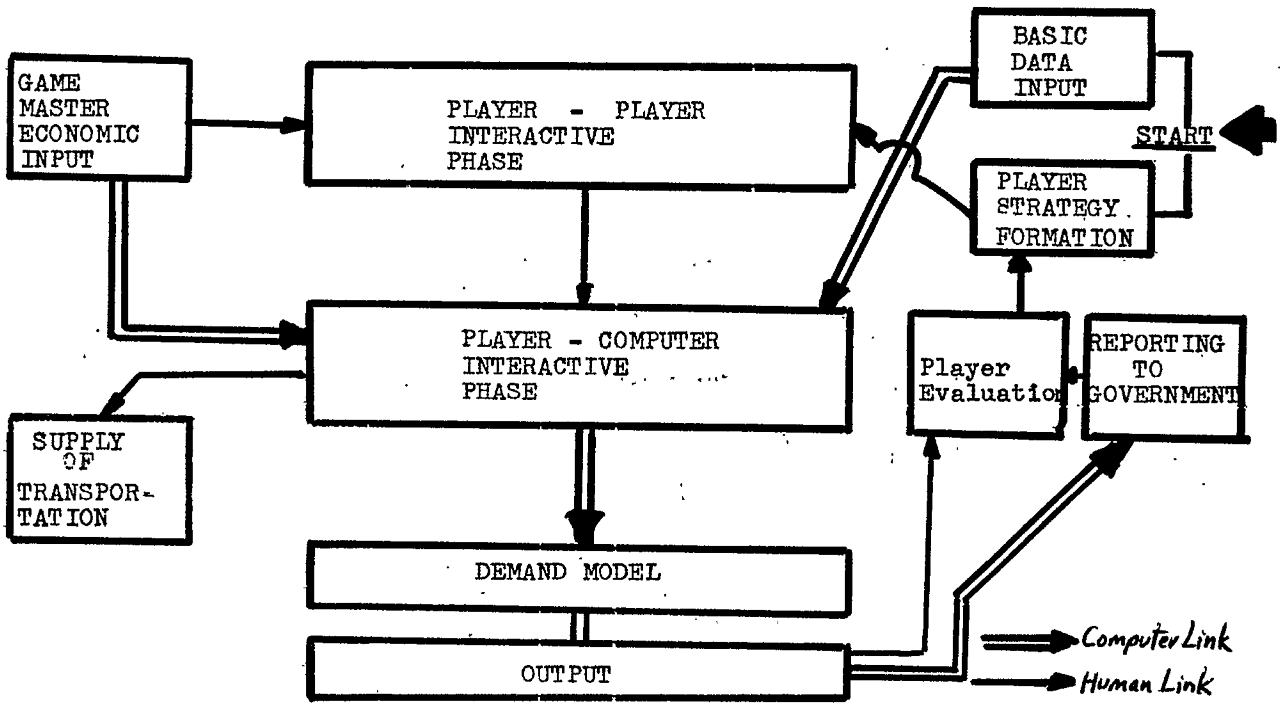


Figure 5   INTER-RELATIONSHIPS IN THE MODEL

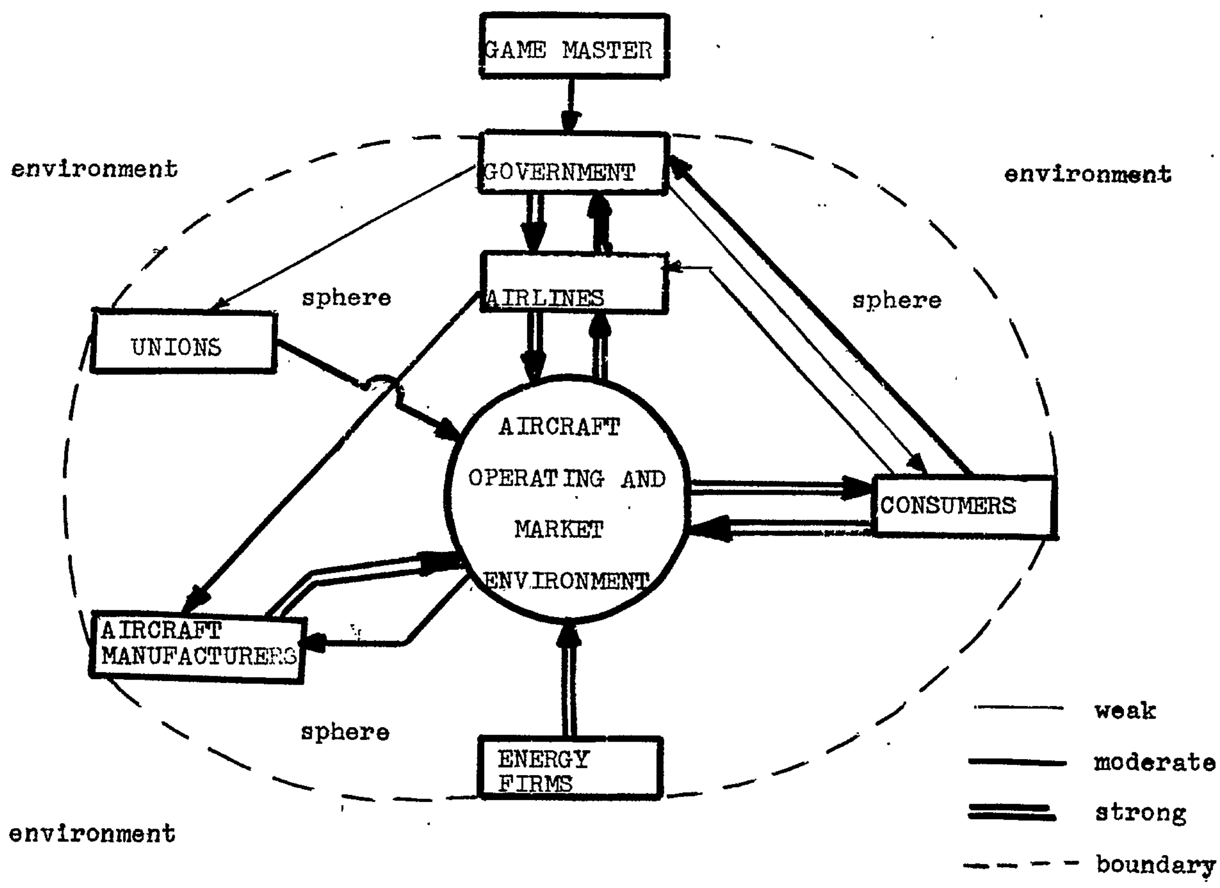


Figure 6 CALCULATION SCHEMATIC