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A COMPUTER SIMULATION GAME OF THE LOCATIONAL DECISION PROCESS

by

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CONTENTS

ABSTRACT

MACKETT, R. and CHEW LAN ONG (1980) A computer simulation game of the locational decision process. Leeds: University of Leeds, Inst. Transp. Stud., WP.141 (unpublished)

A method of representing the locational-decision processes of home and workplace for a household as a game has been developed on a microcomputer. A ten-year period is represented, and each year rail fares, house values and incomes rise by a different amount. The player is able to request information on the houses and jobs available, and can then make decisions to meet a pre-defined objective and to avoid bankruptcy and, if desired, to accumulate capital or savings. On some occasions the player is forced to find a new job because of redundancy or a new home because of demolition. Furthermore, each year a proportion of savings is spent on furnishings and house repairs. These events of redundancy and house demolition, as well as the fares, income and house values are all generated by the computer using stochastic functions.

The game is being used to increase understanding of the processes at work as the cost of travel increases and to demonstrate the complexities of the decisions. Extension of the methodology into simulation of the transport and location interaction process is discussed.

1. Introduction

The work described in this paper is part of the research programme being carried out on an SSRC-sponsored investigation into the impact of rail fare increases on the choice of home and job location and consequent transport decisions (Kirby et al, 1979). There are two major components to the project - survey and analysis. The surveys are being used to investigate the locational and modal choice decisions over the past ten years, and the household characteristics at the time of the decision (Mackett, 1980a). In parallel with this work we are developing models of individual behaviour to represent the dynamic behaviour described in the surveys. As part of the design process we believe that there is a need to analyse the actual processes we wish to represent, so that we can obtain a 'feel' for the decision processes, in particular, the inter-relationships between the decisions and the constraints imposed on the available choices by antecedent decisions. The approach that has been adopted is the development of a game on a microcomputer, in which the person at the keyboard (the player) is offered a set of choices of home, job and mode, together with the monetary implications of the choices, so that he or she can go through a ten year cycle making decisions in order to achieve a pre-determined objective. Even in its present simple form the game requires some skill to be played successfully.

2. The systems of interest

As transport costs increase individuals have a number of possible responses. Firstly, they can continue as they are, merely paying the extra cost. This will have an impact on their savings or expenditure pattern. Secondly, the individual can change his or her job, in order to reduce the cost of travel, or to increase his or her income. Thirdly, there can be a change of residential location. Unless it is a one person household this will affect others, who may also have jobs, and consequent journeys to work. A fourth response might be to buy a car, if one is not owned already, and it is rail fares that are increasing. Another possible response might be to sell a car, in order to raise some cash to pay for the rail fare. Other possible responses include increasing the household income by taking a part-time job, secondary workers ceasing to work or leaving the household to live nearer to their jobs. Clearly, there are a large number of alternative responses; three comments can be made: firstly, some decisions affect the household as well as the individual; secondly, whilst some aspects of these processes include money, there are many others (for example quality of the residential environment) that cannot be easily given a monetary value, and thirdly, many other processes will be going on in the household, some quite independently of changes in transport costs for example, dying, giving birth and marrying and some which could be related to the cost of travel but may occur for other reasons, for example moving home, changing job, and so on. Clearly, we are dealing with some fairly complex processes. Their implications for modelling are discussed more fully in Mackett (1979,1980b).

3. The principle of the game

As explained above the game represents a set of inter-related decisions. The decision made will be a function of the current characteristics of the individual and his or her household, the choices available, information about the expected increases in prices and incomes next year, and the player's objective over the ten-year period.

The game is based on a set of locations, which, for convenience, are regarded as being on a line from the centre of a large city. The cost of living, other than on travel, is assumed to fall with increasing distance from the city centre, while the cost of travel increases linearly with distance.

The player starts off with the following characteristics:

a) marital status - single

b) residential location - in a house with a value

c) job location - with an income

The player can then make decisions on the following topics:

a) marriage

b) residential location

c) job location

d) car purchase

e) car sale

f) mode of travel to work.

The items in the choice sets have the following characteristics:

item	characteristics
houses	location, monetary value
jobs	location, salary
mode of travel	price per unit distance
cars	value

At present the list is fairly brief, but there are the following complications:

a) The cost of living, represented by the proportion of income that is spent on goods other than travel, increases with nearness to the city centre.

b) Money left over spending on other goods and travel can be saved, and so carried forward in time and spent on travel then.

c) Each year a proportion of savings, determined by the computer, has to be spent on house repairs and furnishings.

d) Once the decision to marry has been made both employment locations, and consequent travel costs must be taken into account, but the cost of the two journeys is considered jointly, so that one person in the household can, in effect, subsidize the journey to work costs of another.

e) The journey to work can only be made by car if a car is owned. A car can be purchased out of savings, or if this is insufficient, money can be borrowed at a fixed rate of interest, and paid back in equal annual instalments. The amount borrowed and the period of the loan are determined by the player, but the loan must be paid off within the ten year period. Cars depreciate in value so that the money raised by selling it may not be sufficient to pay off the outstanding loan. Under these circumstances money is paid out of savings at a later date.

f) Only one car can be purchased, and only one person can use it to travel to work.

g) In order to prevent the same locations being retained continuously some unexpected events occur at random. A worker can be made redundant, and so have to find a new job, or the home can be demolished so that a new one must be bought (with compensation at the market value).

h) If a house is sold and a new one purchased a charge which is a function of the values of the two houses must be paid.

Some simplifying assumptions are made to facilitate the easy operation of the game. Some have already been implied, but the following list contains some of the more important:

a) House value and house price are equal, although there is a cost of moving home; that is, there is no bargaining on the sale or purchase of a house.

b) Car value and car price are equal; once again, there is no bargaining.

c) Income and salary paid are equal, that is, the effect of income tax is ignored.

d) A fixed proportion of income is spent on goods and services other than travel to work.

4. Playing the game

In this section the sequence a player goes through in playing the game will be described. A mathematical description is given in the Appendix.

a) Objectives

A player can merely run through the game and react pragmatically, but, clearly, it becomes more purposeful to have a well-defined objective. This can be determined by the player or he or she can use one of a set stored in the computer. These have to be defined in terms of the concepts of the game, so tend to be financial, for example, to maximize savings, or maximize capital, Other objectives are rather contrived, such as, maximizing the distance between home and work, to represent the aspiration of living in a pleasant environment.

b) Randomness of events

Some of the events, the choices available and their values, and the increases over time are determined at random by the computer, within certain ranges. Each time the game is played a different set of events, choices and values will be presented, so that the player can respond to the new conditions. However, the game can also be used in a competitive mode to see which of a set of players can best achieve the given objective. To make the competition fair each player must have the same conditions, so the game has been designed so that, if desired, the same conditions can be repeated, by ensuring that the same random values are selected. There are over 10,000,000 unique fixed sequences of random events.

c) Initial state

The following information is given:

i) the year

ii) marital status

iii) residential location

iv) job location of the player and his or her spouse (if applicable)

v) income of each individual, and the joint income

vi) amount of money available for travel to work

vii) expenditure on the journey to work

viii) the amount of money left over after spending on the journey to work ('savings')

ix) the value of the house

x) the value of the car

xi) total assets (the sum of the value of the house and the car, plus savings)

xii) capital, which is given by total assets, less any outstanding debts on money borrowed to purchase a car.

d) The information about changes over time

To assist in the decision-making process the player is given the information about changes in the cost of the following items:

i) the increase in travel per unit distance by each mode

ii) The mean rise in house prices

iii) The mean rise in incomes

iv) The cost of purchasing a car

The rises in individual house prices and incomes are distributed around the mean at random, so that, for example, the selection of an expensive house does not guarantee that its value will rise more than that of other properties. Thus there is an element of unpredictable risk in the game, which is fairly realistic given the nature of the housing and job markets.

The player is also given information on the proportion of savings that will be spent on house repairs and fittings over the next year, so that the player can decide whether it is wise to hold onto savings, or to purchase other assets.

e) The decisions to be made

The player is invited to make a set of decisions given his or her characteristics, and information about the changes in the system over the next year as defined about and the items in the choice set that are available.

The following deicisons can be made:

i) Marriage: if single the player can decide to marry

ii) Residential location: the player is asked whether he or she is considering moving home. If the response is yes, the set of available houses is displayed, and the player can then decide whether to move home, and if so, choose a new home.

iii) Job location: the player is asked whether he or she and/or his or her spouse is considering changing job. If the response is positive the sets of jobs available to one or both of them are displayed, and the player can decide whether to change jobs, and if so, choose a new job.

iv) Car purchase: if the player does not own a car he or she is asked whether they wish to purchase a car. If the answer is 'yes', the player is then asked if he or she wishes to borrow money to do so. If the answer is 'yes' the player must decide the amount, and period of the loan.

v) Mode of travel: the player is asked to decide which mode of travel will be used by the player and his or her spouse for the journey to work.

f) The decisions processes

The player can find out the immediate consequences of his or her decisions because the computer will calculate the financial implications, as well as indicating any that are impossible, such as attempting to purchase a house that costs more than the player has available. One fairly complex decisions is the borrowing of money to purchase a car. The rate of interest is fixed, but the player can determine the amount and the period of the loan, which must not exceed the outstanding period of time.

An overall constraint on the decision is that the player can afford them, that is the amount of savings implied by the decisions is greater than or equal to zero. If no combination of decisions can be found to meet this constraint the player is declared bankrupt, and so out of the game.

Once the player is satisfied with the potential decisions he or she indicates that these are the changes to be made over the next year, and so, goes forward in time, and starts the sequence again, with a new initial state. This process is repeated for as long as desired. A ten-year cycle is the norm, but other periods can be specified.

5. Computational aspects

The computer program has been written in Applesoft II, which is the version of floating point Basic of the Apple Computer Inc, and implemented on an Apple II 64K microcomputer with one disk drive using standard 5" diskettes.

6. Conclusions and future work

The game described in this paper has evolved from some very simple ideas. It can be extended quite easily. Possible further developments include giving houses and jobs more characteristics so that they are only available to individuals with certain characteristics, introducing children and dwelling size, so that the player may have to move to a bigger dwelling (this does imply either placing a financial benefit on having children or making them random events because otherwise nobody will have any!). On the financial side loans to purchase a dwelling could be introduced.

The game performs several useful functions. Its original conceptualization to help identify the processes that we are interested in seems to work. Furthermore, it is fairly easy to move from a game where a play inputs decisions to an individual choice model of all these processes where the outcome of decisions can be determined at random, until we can obtain a better understanding of the complex processes. The surveys that form part of the project will supply some data on the rates at which the processes go on, and the relationships between the decisions made and the characteristics of the decision-making units.

The information that is being collected contains data on the residential and employment location, mode of travel to work and household characteristics over the period of the last ten years. Hence there is a close relationship between the game and the data we are collecting. We shall be able to test the model against the actual behaviour of a group of individual histories.

A further, very interesting possibility, would be to take the microcomputer into people's homes and ask them to respond to the decisions, so that we could collect information on the responses to choices of a wide range of people.

There are many other issues we are considering at present such as definition of the choices available, the constraints on the choices and the search sequence in the processes. These all impinge on the ideas represented in the game, which is one, but not the only, way in which we shall examine these issues.

ACKNOWLEDGEMENT

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APPENDIX. The mathematical specification of the game

1. Notation

a) Residential

X = the set of houses

X^A = the set of houses that is available for purchase

N = the total number of houses in the system

r = a residential location

v = value of a house

n = number of a house (between 1 and N)

x_{nr} = nth house which is in area r

v_{nr} = price or value of nth house which is in area r

q_1 = proportion of value of old house spent in selling a house

q_2 = proportion of value of new house spent in buying a house

b) Employment

L = set of all jobs

L_p^A = set of jobs available to person p

K = total number of jobs

j_p = job location of person p

k = number of a job (between I and K)

k_p = number of the job held by person p

$l_{k,j}$ = kth job in area j

i_p^s = single person income

i^H = household income

c) Travel

M_p = set of modes available to person p

m_p = mode of travel to work by person p

c_p = amount spent on travelling by person p

d_{rj} = distance from r to j

b_m = cost of travel per unit distance by mode m per annum

h_r = proportion of household income available for travel for a household living in area r.

d) Financial

a = assets

u = capital

o = money broughtforward in time after spending on repairs, furnishings etc.

s = cumulative amount of money saved after implementation of location and travel decisions.

e) Car-owning

e = price of car

z = amount of money borrowed

y = annual repayment

f = depreciation rate for value of car

g = rate of interest for borrowing money

w = number of years money is borrowed for

$\bar{w}$ = number of years outstanding on the loan

f) Time

t = year

g) Greek notation

α = lower bound for change in variable from which a value is selected at random

β = upper bound for change in variable from which a value is selected at random

γ = upper and lower bounds of individual disperson around the value in the range α to β

τ = probability that job is available, subject to a minimum of one

θ = probability of a disaster

$\emptyset\{\alpha\ \beta\}$ = random function taking values between α and β

$\rho\{1,N\}$ = an integer random function taking values between I and N

h) Annotation

$\hat{}$ = the direct outcome of a choice process

$\tilde{}$ = dependent on the direct outcome of a choice process

' = being considered

* = an unexpected event.

2. The initial conditions

A household consists of either one person (p=1) or two people, a husband (p=1) and a wife (p=2).

At a point in time (t) the household will have the following characteristics:

residential location	$\hat{r}(t)$
job location of person p	$\hat{j}_p(t)$
mode of travel to work by person p	$\hat{m}_p(t)$
income of person p	$\tilde{t}^s_{\tilde{p}}(t)$
value of the house occupied	$\tilde{v}(t)$
value of the car owned	$\tilde{e}(t)$

A ^ over a variable implies it is the direct result of a decision, a ~ implies that the variable follows from a decision, but was not, itself, a choice.

The cost of travel to work by person p ($\tilde{c}_p$) is given by

$$\tilde{c}_p(t) = d_{\hat{r}\hat{j}_p} \; b_{\hat{m}_p}(t) \tag{1}$$

where $d_{\hat{r}\hat{j}_p}$ is the distance between the chosen home and job location, and $b_{\hat{m}_p}$ is the cost of travel per unit distance by the mode chosen by person p.

Household income ($\tilde{i}^H$) is given by

$$\tilde{i}^H(t) = \sum_p \tilde{i}_p^s \; (t) \tag{2}$$

where $\hat{i}_p^s$ is the income of individual p.

The amount of money saved ($\tilde{s}$) is given by

$$\tilde{s}(t) = \tilde{o}(t) + h_{\hat{r}}(t) \; \tilde{i}^H(t) - \sum_p \tilde{c}_p(t) \tag{3}$$

where $h_{\hat{r}}$ is the proportion of household income available for travel to residents of area $\hat{r}$, and $\tilde{o}$ is the amount of money brought forward after spending on house repairs and furnishings during the preceding year.

Total assets (a) are given by the sum of the value of the house, the value of the car and the savings:

$$\tilde{a}(t) = \tilde{v}(t) + \delta_1 \; \tilde{e}(t) + \tilde{s}(t) \tag{4}$$

where δ_1 = 1 if a car is owned
= 0 otherwise.

The value of the car, $\tilde{e}$, is given by

$$\tilde{e}(t) = (1 - f) \; \tilde{e} \; (t - 1) \tag{5}$$

where f is the annual rate of depreciation of cars.

Capital ($\tilde{u}$) is defined as total assets, less any outstanding debts for money borrowed for car purchase:

$$\tilde{u}(t) = \tilde{a}(t) - \delta_2 y(t) \; \overline{w} \tag{6}$$

where δ_2 = 1 if there are outstanding loans for money borrowed
= 0 otherwise

y is the annual repayment on the loan, and $\overline{w}$ is the number of years outstanding for the loan.

3. The information provided about change over time

Before being asked to make any decisions the player is given information about changes in the cost of the following items in the next year:

a) The cost of travel per unit distance by each mode.

b) The mean rise in house prices.

c) The mean rise in incomes.

d) The cost of purchasing a car.

The player can then make his or her decision in the light of this information.

The cost of travel per unit distance by mode m, b_m, is given by:

$$b_m(t + 1) = b_m(t) \; (1 + \emptyset_m^b \{\alpha_m^b, \; \beta_m^b\}) \tag{7}$$

where $\emptyset_m^b$ is a function which takes values selected at random between the values of α_m^b and β_m^b.

The price of house n which is in area r, at time t + 1, v_{nr} is given by

$$v_{nr}(t+1) = v_{nr}(t) \; (1+\emptyset^v \{\alpha^v, \beta^v\} + \emptyset_r^v \{-\gamma_1^v, +\gamma_1^v\} + \emptyset_{nr}^v \{-\gamma_2^v, +\gamma_2^v\}) \tag{8}$$

where $\emptyset^v$ is a function which represents the overall mean increase in house prices, selected at random from a range α^v to β^v, $\emptyset_r^v$ is a function which represents the deviation of the mean value of houses in area r from the overall mean, which is selected at random within a range $-\gamma_1^v$ to $+\gamma_1^v$ and $\emptyset_{nr}^v$ which is the deviation of the value of house n from the mean for area r, selected at random from a range $-\gamma_2^v$ to $+\gamma_2^v$. This mechanism ensures that house prices change individually, but maintain a close relationship within the residential areas, and that these relationships are maintained over time.

The change in incomes associated with jobs is represented in a similar manner. The income from job k which is in area j (i_{kj}) is given by:

$$i_{kj}(t+1) = i_{kj}(t) \; (1+\emptyset^i\{\alpha^i,\beta^i\} + \emptyset_j^i \{-\gamma_1^i, +\gamma_1^i\} + \emptyset_{kj}^i\{-\gamma_2^i,+\gamma_2^i\}) \tag{9}$$

where $\emptyset^i$ gives the overall mean increase, selected at random from the range α^i to β^i, $\emptyset_j^i$ represents the mean deviation of incomes in area j from the overall increase, and $\emptyset_{kj}^i$ represents the deviation for job k, which is in area j.

The price of a car is given by

$$e(t+1) = e(t) \; (1 + \emptyset^e\{\alpha^e, \beta^e\}) \tag{10}$$

where $\emptyset^e$ is a function which takes values in the range α^e to β^e, selected at random.

The amount of money brought forward in time after spending on house repairs and furnishings during the preceding year (o) is given by:

$$o(t+1) = s(t)\ (1 - \emptyset^{o}\ \{\alpha^{o},\ \beta^{o}\}\ ) \tag{11}$$

where $\emptyset^{o}$ is a function which takes values at random between α^{o} and β^{o}, where β^{o} is less than or equal to 1.0. The value of the function represents the proportion of savings spent on repairs and furnishings during the year.

Whilst the information is provided about the levels of the cost of travel, salaries and the price of houses and cars, in the next period, the results of the decisions being considered are based on the current values of houses and cars. In other words, the player is able to make decisions now, in the light of information about the future, which is rather more interesting than merely reacting to the current situation. The values given for house values and incomes are means. The individual values will be spread around them.

4. The choice sets and constraints on them

a) Marriage

If the player is single and decides to marry, he or she must then take into account the job location of his or her spouse, which is given by the computer.

b) Residential location

The set of houses at time t is defined as $X(t)$. The set of homes that is available for purchase at time t is defined as $X^{A}(t)$. House number n, which is in area r, x_{nr}, is not available for purchase if:

$$x_{nr}(t) \notin X^{A}(t) \text{ if } n = \hat{n}(t) \text{ or } \emptyset^{x}_{n}\ \{0,\ 1.0\} \geq \tau^{x} \text{ unless } n = \rho^{x}\{1,\ N(t)\} \tag{12}$$

where τ^{x} is a random function which takes an integer value between 1 and $N(t)$ where $N(t)$ is the number of houses in the set $X(t)$; this ensures that at least one house is available. $\emptyset^{x}_{n}$ is a non-integer function which takes values between 0 and 1.0 at random; if the value is greater than or equal to τ^{x} for a particular house x_{nr}, then it is defined as not available. The house currently lived in cannot be regarded as available. All other dwellings are available for purchase.

Besides moving voluntarily, residents are forced to move home when their home is demolished. This occurs when:

$$\emptyset^{x*}\ (0,\ 1.0) < \theta^{x}$$

where $\emptyset^{x*}$ is a random function which takes a value between 0 and 1.0. The house is demolished whenever it takes a value of less than θ^{x}.

c) Job location

The job availability function is similar to that for homes. $L(t)$ is the set of all jobs at time t, $L_p^A(t)$ is the set of jobs available to person p. Job number k, which is in area j, l_{kj}, is not available if

$$l_{kj}(t) \notin L_p^A(t) \text{ if } k = \hat{k}_p(t) \text{ or } \phi_k^L\{0,\ 1.0\} \geq \tau^L$$
$$\text{unless } k = \rho^L\ (1,\ K(t)) \tag{14}$$

where ρ^L is an integer function that takes a value between 1 and $K(t)$, which is the total number of jobs, to ensure at least one job is available, and ϕ_k^L is a function that takes values between 0 and 1.0; if its value is greater than, or equal to τ^L, job k is regarded as unavailable. The job currently occupied is also regarded as unavailable. All other jobs are available.

The job equivalent to demolition of housing is redundancy, which occurs when

$$\phi^{L*}\ (0,\ 1.0) < \theta^L \tag{15}$$

where ϕ^{L*} is a random function which takes a value between 0 and 1.0. Redundancy occurs when its value is less than θ^L.

d) Car purchase

A car may be purchased at any time, provided that the player does not already have one. Since the only characteristic of a car is its monetary value, which depreciates at a fixed rate, there is no point in buying a more expensive one.

If the price of the car (e) is greater than the savings (s) then money can be borrowed. The amount borrowed (z) must meet the following inequality:

$$z(t) \geq e(t) - s(t) \tag{16}$$

must be met. If the amount borrowed is equal to the difference between the price and the available cash, the player will be left with no money in hand. Money that has been borrowed must be paid back. The annual repayment (y) is given by:

$$y = z(1 + g)^w\ /\ w \tag{17}$$

where g is the rate of interest and w is the term of the loan, in years. The rate of interest is fixed, but the player is free to define his or her own values of z and w, but the value of z must meet inequality (16) if a car is to be purchased.

e) Car sale

A player can sell his or her car in order to receive the current value defined by equation (5), but must, of course, own one in order to do so.

f) Mode of travel

Two modes of travel are available, but only one member of the household can travel to work by car, and this can only occur when a car is owned, that is:

$$m \in (M_1 \cup M_2) \quad \text{for } m = 1$$

$$m \notin (M_1 \cap M_2) \quad \text{for } m = 2$$

where m is the mode of transport (m = 1 is rail, m = 2 is car), and M_p is the set of modes available to person p.

5. The decision processes

The player who has indicated a wish to consider one or more of the decision processes is able to discover the financial implications of the decisions, so that he or she can ensure that bankruptcy is avoided. The choices being considered and their consequences are indicated by '. If a particular decision is not being considered at the current time point the existing values are used.

The cost of travel by person p between the home and job locations being considered (c'_p) is given by:

$$c'_p\ (t+1) = d_{r'j'_p}\ b_{m'_p}\ (t+1) \tag{18}$$

The household income ($i^{H'}$) resulting from the new job locations is given by:

$$i^{H'}\ (t+1) = \Sigma_p\ i^{s'}_p\ (t+1) \tag{19}$$

$$\begin{aligned} s'(t+1) = o'(t+1) &+ h_{r'}(t+1)\ i^{H'}(t+1) - \Sigma_p c^{p'}(t+1) + \delta_3[\tilde{v}(t)-v'(t) \\ &-q_1\tilde{v}(t) - q_2 v'(t)] - \delta_4[(1-\delta_5)e'(t) + \delta_5 y'(t)] \\ &- \delta_6\tilde{y}(t) + \delta_7[\tilde{e}(t) - \delta_2\tilde{y}(t)\bar{T}] \end{aligned} \tag{20}$$

where δ_3 = 1 if a new home is being considered
= 0 otherwise

δ_4 = 1 if the purchase of a car is being considered
= 0 otherwise

δ_5 = 1 if money is to be borrowed to buy the car
= 0 otherwise

δ_6 = 1 if a car is owned and money has been borrowed and the loan is still outstanding
= 0 otherwise

δ_7 = 1 if the sale of a car is being considered
= 0 otherwise

q_1 = proportion of value of a houe spent in selling it

q_2 = proportion of value of a house spent in buying it

The value of y' the money being considered for borrowing is given by

$$y'(t) \quad = \quad Z'(t)(1+g)^{w^t}/w' \qquad (21)$$

where

$$z'(t) \geqslant e'(t) - s'(t) \qquad (22)$$

The set of choices made must be such that the player remains solvant, that is

$$s'(t+1) \geqslant o \qquad (23)$$

If inequality (23) does not hold the player has lost the game.

The player is free to consider as many choices as he or she wishes, but once a decision has been made, it cannot be reversed at the current point in time.

Once a particular set of choices have been decided the new values are adopted and carried forward to the next time point, and so used in equations (1) to (7). If no change has been made the same values are retained.

6. Values used in the ITS application of the game

	area 1	area 2	area 3	area 4	area 5	area 6	area 7
Average house price (£)	25000	20000	19000	18000	17000	16000	15000
Average income (£)	10000	9000	8500	8000	8000	8000	8000
Distance from city centre (km)	0	10	20	30	40	50	60
Proportion of income available for travel	0.04	0.06	0.08	0.10	0.12	0.14	0.18

Initial values

Residential location = 4
Value of the house = £18000
Job location = 1
Single person income = £10000
Mode of travel to work = 1 (1 represents train)
Cost of travel by train = £30 per km per year return
Cost of travel by car = £20 per km per year return
Distance from home to work place = 30 km
Amount spent on travelling = £900
Amount of money brought forward in time after spending on repairs, furnishings, etc. = £0.

Percentage increase in rail fare	=	0-15%
Percentage increase in cost of petrol	=	0-15%
Percentage increase in price of house	=	0-10%
Percentage increase in income	=	0-15%
Percentage increase in price of car	=	0-10%
Percentage of cumulative amount of money saved that will be spent on repairs, funishing etc.	=	0-50%

Probability that house will be demolished	=	0.1
Probability that player will lose his/her job	=	0.1