DYNAMIC MODELS FOR PLANNING TOURIST COMPLEXES

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ABSTRACT

Planning tourist facilities is a highly complex task. It is necessary to evaluate carefully, with an interdisciplinary approach, all the variables of a technical, architectural, commercial, economical and financial nature that may be involved in a given project, without however ignoring the natural resources of the environment where the facilities are to be set up.

For a correct evaluation, these resources must be considered limited and seen as a wealth that can be exploited but not wasted, used but not destroyed.

The approach outlined above is all the more important in countries like Italy, for instance, where there is a risk of overexploiting the natural resources of the environment.

In all but exceptional cases, an evaluation that does not take the above principles into account will result in a tourist enterprise that is ultimately a failure, as it degrades, often irreparably, the natural environment until it ceases to be an adequate source of revenue.

This paper describes an integrated approach which provides, by means of simulation techniques, tools for a proper implementation of tourist facilities taking into due account all the variables and constraints involved, and likewise for the assessment by the Public Administration authorities of the wisdom and soundness

of projects submitted to them for approval.

1. INTRODUCTION

The simulation model of a firm or company, that can be used for the design of the company itself or its development, must have a sufficient degree of descriptive detail to allow all the necessary evaluations.

Generally speaking it is not enough to consider a company as merely an economic phenomenon. A company is always a far more complex phenomenon and it does not usually suffice to know whether it is able to support itself economically and make a profit; it is also necessary to know how it uses the resources at its disposal in order to yield profits and how it interacts with the market.

A company therefore has to be viewed from at least three different standpoints, and at least three different models have to be prepared:

a) A 'physical model' describing the process according to which certain raw materials, with the aid of particular resources, are transformed by the company into the product
b) A 'market model' describing the relationship of the company with its market, taking into account the initiatives of competitors
c) A 'financial and economic model' translating each company phenomenon into monetary terms and giving the economic balance of the operation to check its capacity to yield a profit.

Clearly the 'financial and economic model' will have a structure that remains unchanged, whatever the type of company. Since this structure is based on accounting principles and the juridical grounds of company management, the nature of the product or of the services offered by the company are irrelevant.

At the most, there may be different models in that they have a different degree of detail, according to what one wishes to highlight for evaluation.

The 'market model', and even more so the 'physical model' are specific to the type of company to which they refer and are therefore studied on a case by case basis.

In our case the company that is to be studied offers its clients tourist services; by using the natural resources of a site and adding accommodation structures and the related infrastructures, it offers its clients the possibility of staying in a pleasant place in exchange for the payment of an appropriate price.

Thus the 'physical model' must describe the evolution of the site conditions as a function of time according to the use to which the site is put (number of people present, effectiveness of the infrastructures, type of clientele and its aggressiveness towards nature and the accommodation structures, etc.). Conversely, the 'market model' must describe the quantitative and qualitative evolution of the clientele as a function of time taking into account all the important variables (degree of crowding, deterioration of the natural environment in the course of time, price policy, model of behaviour of different types of clients, etc.).

In this paper we shall briefly describe the approach followed for the model of a tourist concern; we shall describe with a certain degree of detail the 'physical model', briefly refer to the concepts of the 'market model', and in the present case, leave aside the 'financial and economical model'.

This model has been developed according to methods derived from Industrial Dynamics and it will shortly be tried out for

for some practical cases in Sardinia. The results of the experimentation will be available in the future.

2. PHYSICAL MODEL

2.1 Description of the 'trend' of the natural species present

Let us assume that we start with conditions in which a small local population lives in equilibrium with the environment using the existing housing and infrastructures that are adequate for its requirements. A tourist complex (for example a village) able to accommodate clients on an assumed seasonal basis is built is this location (for instance a seaside village near a pre-existing fishermen's village). It is assumed that the system is delimited by an ideal line circumscribing the surrounding area up to the distance that can be reached on foot by the clients.

In such a situation the natural environment can be described by a vector of variables $y_1, y_2 \ldots y_n$, each of which represents quantatively the presence of a living species, whether animal or vegetable, which is characteristic of the environment and which indicates, with its increase or progressive disappearance, the present conditions of the environmental system one wishes to study.

The equation that governs the trend overtime of one of these species is of the type:

$$\frac{dy_i}{dt} = S_i + (K_1^i - K_2^i)\, y_i - \sigma_i\, n\, y_i - \lambda_i\, y_i^2 \qquad (1)$$

where:

S_i : stands for what is imported (for example, in the case of a vegetable species, S is the contribution made to species

y_i from outside by a team of gardeners);

$(K_1^i - K_2^i) y_i$: represents the contribution of nature to species y_i in terms of birth (K_1^i) and death (K_2^i); $K_1^i - K_2^i$ is usually expressed as δK_i;

$\sigma_i \, n \, y_i$: represents the destruction brought by man to species y_i (n = the number of people present) which is found to be proportional by means of a coefficient σ_i (the specific aggressiveness of man towards species y_i) at product $n \, y_i$, which represents the probability of an encounter between a man and an individual of species y_i;

$\lambda_i \, y_i^2$: stands for the self-limitation of the species that occurs when individuals of the same species y_i, contend for living space.

This first version of equation (1) contains an oversimplified term, in respect of reality. Indeed, in the term $\sigma_i \, n \, y_i$ we have considered that all the people present have an equal aggressiveness towards species y_i. In practice one should consider a vector of classes of people:

$$n_o, n_i, \ldots, n_m$$

where at index 'o' we insert the value referring to the local inhabitants. In this case equation (1) becomes:

$$\frac{dy_i}{dt} = S_i + \delta K_i y_i - \sum_{o}^{m}{}_j \; \sigma_{ij} \, n_j \, y_i - \lambda_i \, y_i^2 \qquad (2)$$

where σ_{ij} represent the specific agressiveness of the class of men n_j towards species y_i.

It should also be noted that we have considered the effect of the relative interaction between two different y_i species to

be nill. If we wished to take this effect into account, equation (2) would become:

$$\frac{dy_i}{dt} = S_i + \delta K_i y_i - \sum_{o}^{m}{}_j \; \sigma_{ij} \, n_j \, y_i - \sum_{o}^{n}{}_k \lambda_{ik} \, y_i \, y_k \qquad (3)$$

where coefficients λ_{ik} represent the specific agressiveness of species y_k towards species y_i.

A series of general equations like (3) can become very numerous if we wish to consider in detail the species present on the site. Since one is likely to find a few hundred living species in any natural place, it is clear that a complete application of (3) would raise great difficulties, also in determining all the coefficients. If then we think of the other secondary effects that have been overlooked, such as, for example, the indirect effect of man on species y_i by means of his refuse, it will be readily understood that before long the systems of equations can become unpracticable.

However it should be borne in mind that the objective of this model is not to evaluate in depth the evolution of the natural environment; it can very well be limited to detecting symptoms of deterioration that would already indicate reliably an excessive exploitation of the natural resources available. It is therefore possible to have many simplifications that are not far removed from our objective. In the present case, owing to the limits imposed by this paper, we shall only deal with a very simple case.

First of all it comprises only two species. One of these will be indicative of the average situation of the natural environment: on the one hand it will be the most characteristic and evident one, and on the other it will have the characteristic of an average resistance to deterioration (in the case of a village on the coasts of Sardinia this species could be the "MEDITERRANEAN MAQUIS").

The second species that we shall examine is a species that is characteristic of very good conditions from an environmental point of view. That is to say, it is a very delicate and 'noble' species that does not stand up well to even slight changes in the environmental conditions (there are numerous examples of this type in many areas: the red algae that give colour to the waters of lake TOVEL in the Alps in spring, some types of butterflies or flowers, etc.).

When applied to the two selected species, equation (3) becomes:

$$\frac{dy_1}{dt} = S_1 + \delta K_1 y_1 - \sum_{o}^{m} {}_j \sigma_{1j} n_j y_1 - \lambda_1 y_1^2 \qquad (4)$$

$$\frac{dy_2}{dt} = S_2 + \delta K_2 y_2 - \sum_{o}^{m} {}_j \sigma_{2j} n_j y_2 - \lambda_2 y_2^2 - \lambda_{12} y_1 y_2 \qquad (5)$$

It will be seen that the multiplicity of classes of clients is maintained in both equations and that (5), which represents the trend of the noble and more delicate species, maintains also the term that expresses the agressiveness of species y_1 in respect of y_2.

Before proceeding with other variables, it should be noted that in our case it is difficult to operate with the variables chosen: an absolute definition of the quantity of species present is a difficult task. It will therefore be preferable to operate with adimensional variables.

In order to do this we shall take as a reference condition one in which only local inhabitants are present ($n_1=n_2=\dots,n_m=0$)

and equilibrium is assumed. Under these conditions (4) becomes:

$$0 = \delta K_1 y_1^* - \sigma_{10} n_0 y_1^* - \lambda_1 y_1^{*2} \qquad (6)$$

where y_1^* is the value of y_1 that is reached when only local inhabitants are present on the site. From (6) we get:

$y_1^* = 0$ (when the local population totally destroys species y_1, which is a case we can rule out)

or

$$y_1^* = \frac{\delta K_1 - \sigma_{10} n_0}{\lambda_1}$$

Moreover, in order to make all the other variables adimensional, we assume:

$S^* = \sigma_{10} n_0 y_1^*$ (which means that S^* is the value given to what is imported in order to compensate for the destruction caused by the local inhabitants alone)

$Y_1 = \dfrac{y_1}{y_1^*}$ (quantity of species y_1 in relation to the quantity present in the above conditions of equilibrium)

$N_j = \dfrac{n_j}{n_0}$ (quantity of class j tourists in relation to the local inhabitants)

$\bar{\sigma}_{1j} = \dfrac{\sigma_{1j}}{\sigma_{10}}$ (agressiveness of class j tourists in relation to the aggressiveness of the local inhabitants)

If we divide both the members of (4) by y_1^*, we get, after some simple algebraic transformations:

$$\frac{dY_1}{dt} = \delta K_1 \left\{ \left[1 - \frac{\sigma_{10}\, n_o}{\delta K_1} \sum_{o}^{m}{}_{j} (\bar{\sigma}_{1j} N_j) \right] Y_1 - \left(1 - \frac{\sigma_{10} n_o}{\delta K_1}\right) Y_1^2 + \frac{\sigma_{10} n_o}{\delta K_1} \frac{S}{S^*} \right\} \qquad (7)$$

In this form the equation relating to species y_1 is now much easier to tackle. Let us now have a look at the coefficients:

δK_1 : can be expressed as $\frac{1}{T_1}$ where T_1 is the regeneration time, that is to say the time required for species y_1 to reappear throughout the territory after serious damage (eg. a fire).

$\frac{\sigma_{10} n_o}{\delta K_1} = \gamma_1$: is the relation between the capacity for destruction of species y_1 by the local inhabitants and the capacity of the same species for self-generation. We can assume $\gamma_1 < 1$ otherwise this would mean that the inhabitants had already completely destroyed species y_1 in the past.

$\bar{\sigma}_{1j}$: constitute a vector of values to be estimated which, with 1 as the aggressiveness of the local inhabitants towards species y_1, assign a relative value to the aggressiveness of the various classes of tourists to the same species.

Equation (7) thus becomes:

$$\frac{dY_1}{dt} = \frac{1}{T_1} \left\{ \left[1 - \gamma_1 \sum_{o}^{m}{}_{j} (\bar{\sigma}_{1j} N_j) \right] Y_1 - (1 - \gamma_1)\, Y_1^2 + \gamma_1 \frac{S_1}{S_1^*} \right\} \qquad (8)$$

Following a similar process, equation (5) can be transformed into adimensional variables, and becomes:

$$\frac{dY_2}{dt} = \frac{1}{T_2} \left\{ \left[1 - \gamma_2 \sum_{o}^{m}{}_{j} (\bar{\sigma}_{2j} N_j) \right] Y_2 - \beta_2 Y_1 Y_2 - (1 - \gamma_2 - \beta_2) Y_2^2 + \gamma_2 \frac{S_2}{S_2^*} \right\} \qquad (9)$$

In (9) the symbols have a meaning analogous to those in (8), with the further introduction of:

$$\beta_2 = \frac{\lambda_{12}\, y_1^*}{\delta K_2}$$

which represents the relation between the aggressiveness of species y_1 in respect of species y_2 and the capacity of species y_2 for self-generation.

In the case of the 'noble' species y_2, which is assumed to be very delicate, we can introduce another simplification by supposing that the aggressiveness of the various classes of tourists is equal. This amounts to considering that this species is so delicate that the mere presence of man is harmful to it, regardless of the specific behaviour of the various classes of tourists.

With this simplification (9) becomes:

$$\frac{dY_2}{dt} = \frac{1}{T_2} \left\{ \left[1 - \gamma_2 \bar{\sigma}_2 N \right] Y_2 - \beta_2 Y_1 Y_2 - (1 - \gamma_2 - \beta_2) Y_2^2 + \gamma_2 \frac{S_2}{S_2^*} \right\} \qquad (10)$$

2.2 Other variables that are indicative of the environment

Two other variables are needed in order to complete the description of the environment surrounding the tourist complex that one wishes to evaluate; one of these defines the 'trend' of the refuse produced, and the other the appearance of possible parasite species marking the beginning of a situation of environmental deterioration.

Naturally, in the case of these variables too, it would be necessary to identify a vector of magnitudes. In point of fact, different types of refuse behave in a very different manner, and thus the appearance of every species of parasite may not only announce the beginning of a different degree of environmental degradation, but may also have a very different effect on the various types of tourists present. It is therefore only for the sake of simplicity that we shall refer to only one variable to identify refuse and also to a single parasite species.

The basic equation for refuse is:

$$\frac{dw}{dt} = \sum_{1}^{m} {}_j K_j n_j - \alpha w - f(w) \qquad (11)$$

where the first term represents the production of refuse by the various classes of people present, the second term the self-disposal of refuse by natural processes and the third the disposal of refuse by means of a cleaning service; to f(w) is attributed a 'trend' of the type shown in Figure 1:

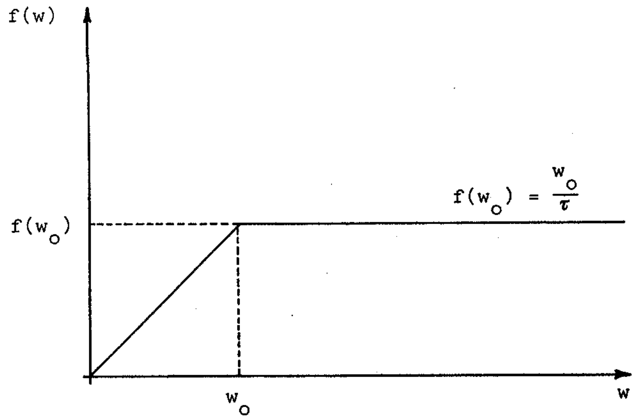


Figure 1

The inclination of the sloping part of f(w) depends on the time the cleaners can operate. Thus

$$\text{if } w < w_o \qquad f(w) = \frac{w}{\tau}$$

$$\text{if } w > w_o \qquad f(w) = \frac{w_o}{\tau}$$

in the second case the cleaners cannot eliminate all the refuse, that will continue to accumulate.

Expressed in adimensional variables and assuming that the refuse is the same for the various classes of people present, (11) becomes:

$$\frac{dw}{dt} = \alpha (N - W) - \frac{f(w)}{(w)^*} \qquad (12)$$

where if $w < w_o \quad \frac{f(w)}{w^*} = \frac{w}{w^*} \cdot \frac{1}{\tau}$

$$\text{if } w > w_o \qquad \frac{f(w)}{w^*} = \frac{w_o}{w^*} \cdot \frac{1}{\tau}$$

w^* is the quantity of refuse present under equilibrium conditions with only the local inhabitants

w is the present quantity of refuse referred to w^*

The basic equation for the parasite species (y_3) is as follows:

$$\frac{dy_3}{dt} = \varphi(w)\, y_3 - \sigma_3\, y_3 \sum_1^m {}_j\, n_j - \lambda_3\, y_3^2 - \frac{y_3}{\tau_3} f_3(t) + S_3 \qquad (13)$$

It will be noted that this equation is similar to the ones used for the other natural species present. The following type of process has been assumed. Originally the parasite species was not present; it is continuously imported from the surrounding environment (S_3); it is subject to the negative effects of the actions of the people present ($- \sigma_3\, y_3 \sum_1^m {}_j\, n_j$), of the self-limitation of the species ($- \lambda_3\, y_3^2$), and of disinfestation ($- \frac{y_3}{\tau_3} f_3(t)$); the only term that is positive and hence favourable to the parasite species is $\varphi(w) \cdot y_3$ because we should normally introduce (by means of $\varphi(w)$) a threshold below which the positive effect becomes nil. However since we have only one parasite species, it is worth taking the species that is most likely to appear, and thus the term $\varphi(w) \cdot y_3$ can be replaced by $K_3\, y_3$ where K is a constant. With regard to $\frac{y_3}{\tau_3} f_3(t)$, this is made up of a factor $\frac{y_3}{\tau_3}$ that represents the decline in the action of disinfestation, and by a function ($f_3(t)$) with a square wave configuration that represents the action of disinfestation itself.

Expressed in adimensional variable, (13) becomes:

$$\frac{dY_3}{dt} = \frac{1}{T_3} \Big\{ W\, Y_3 - \eta\, Y_3 \sum_o^m {}_j\, N_j - \frac{y_3^*}{\bar{y}_3^2} \cdot \frac{T_3}{T_{S3}}\, Y_3^2 + $$

$$- \frac{T_3}{\tau_3} f_3(t)\, Y_3 + (\eta - 1) \Big\} \qquad (14)$$

In the above equation Y_3 refers to the quantity of parasite species present with only the local inhabitants, without refuse removal and without taking self-limitation into account (which is negligible in such conditions): the reference value is y_3^*.

$T_3 = \frac{1}{K_3 w^*}$: the regeneration time of the parasite species in the presence of quantity of refuse w^* (generated by the local inhabitants only)

$\eta = \frac{T_3}{T_{03}}$: the relation of T_3 with the time T_{03} needed for the local inhabitants alone to destroy the parasites without taking their regeneration capacity into account

$\bar{y}_3$: the presence of the parasite species under equilibrium conditions in the site considered completely uninhabited

T_{S3} : the time needed for the area to return to equilibrium conditions, after a total destruction of the parasite species, only with S_3 imported from the surrounding environment.

2.3 Other variables not relating to the natural environment

Three other variables that complete the physical model framework have been introduced.

The first refers to the state of the buildings and related equipment by means of an equation of the type:

$$\frac{dz}{dt} = S_z - \varrho z n - \lambda_z z \qquad (15)$$

where z represents the quantity of a certain type of efficient equipment, S_z is maintenance carried out by man, ϱz is the deterioration due to use, and $\lambda_z z$ is the deterioration due to aging.

The second is the level of crowding that greatly affects the degree of satisfaction of some classes of tourists, and is expressed by an equation of the type:

$$x_j = e^{(-n/n_j^*)^2} \qquad (16)$$

where (n being the total value of people present), n_j^* is the characteristic value of each class of tourists and represents the environments greater or smaller capacity to withstand the level of crowding.

The third is a variable that identifies the cost on the site of indispensable goods and commodities and identifies the rise through a series of thresholds (with greater crowding) from a normal cost to a higher cost level, due to the fact that supplementary structures have to be introduced.

The trend of the variable (c) is shown in figure 2.

Also these equations have been translated in adimensional variables for a homogeneous use in the model.

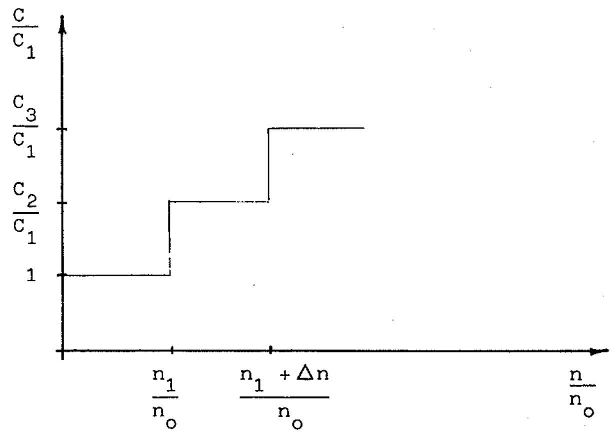


Figure 2

3. MODEL OF RELATIONS WITH CLIENTS

The 'market model' that has been prepared is at present extremely simple and has the sole aim of allowing a first experimentation of the model with a view to focusing and adjusting the physical part and the related parameters.

Consequently the model that describes relations with Clients is simply a function of the 'image' offered by a tourist enterprise.

The present model has been developed on the basis of the following principles:

a) It is assumed that the demand for tourist services is plentiful (this is true of Italy).
b) It is assumed that there will be no promotional activity except when the initiative is launched and that thereafter the

advertising message will be transmitted by the Clients who have already made use of the service.

c) Three classes of clients have been defined, with a different sensitivity to the different variables of the physical model and differentiated according to the trend over time of client attendance.

The curves of client attendance shown in Figure 3 have been preliminarly assumed.

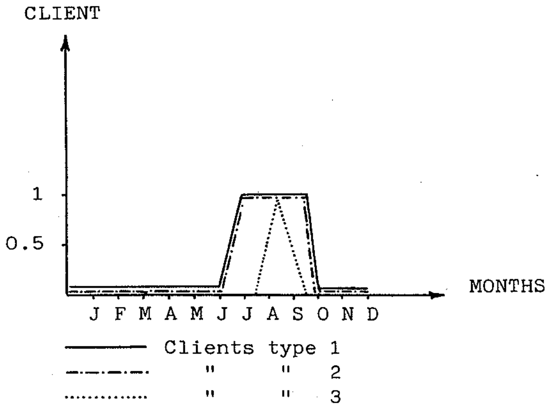


Figure 3

The 'image' is determined as a function of the variables of the physical model - i.e. natural species, crowding, equipment, and cost of living - in the period under consideration.

This image is measured in terms of the number of people, subdivided by type, who request the tourist service. It will be recalled that adimensional variables are adopted also for the market model. Thus, the number of tourists is expressed in relation to the local population.

At the end of each season, an evaluation is made of the level of satisfaction of the various classes of clients as a function of the image offerted. At this point the user can influence the image variable, as it has been proposed by the model for each type of tourist for the following year; it can be confirmed or modified on the basis of the constraints imposed by the structure, the state of the environment and also commercial decisions.

4. SIMULATION MODEL

The mathematical model described up to now has been translated into a computer simulation model by means of the MDS methodology that has been developed by TEMA on the basis of Industrial Dynamics concepts.

It is not possible here to go into the details of this methodology and the models management package that was developed in BASIC on HP 9845 and in FORTRAN on IBM in TSO and CMS environment. However, the attached bibliography can be consulted for further details.

We shall merely give a graph of the main subsystems that constitute the model at its present stage of development, indicating also the state variables (levels) and their variations (rates).(see figures 4, 5 and 6).

The coefficients of the equations are the parameters of the model that can be checked and/or programmed for all the duration of the simulation.

The results are given hereinafter of two simulations made in different conditions of refuse collection, considering all the other conditions unchanged, namely:

- curve of tourist attendance (Figure 3);
- sensitivity of classes of tourists to the quality of the environment (greater for class 1 and decreasing for the others);
- behaviour of natural species.

The simulation is made for a ten-year period at monthly intervals.

At the end of each year the 'image' proposes a certain number of requests. The tourists present the following year are limited to 3 times the local inhabitants. The surplus of requests is refused subdividing it between the three classes of tourists at the rate of 20% in the first, 30% in the second and 50% in the third.

The graphs represent the trend of the species and refuse (Figures 7 and 9) and the trend of the image, that is to say the number of requests for the tourist service (figures 8 and 10).

5. CONCLUSIONS

The model described in this paper is, as we have already pointed out, a first approach to the problem of evaluating a tourist enterprise.

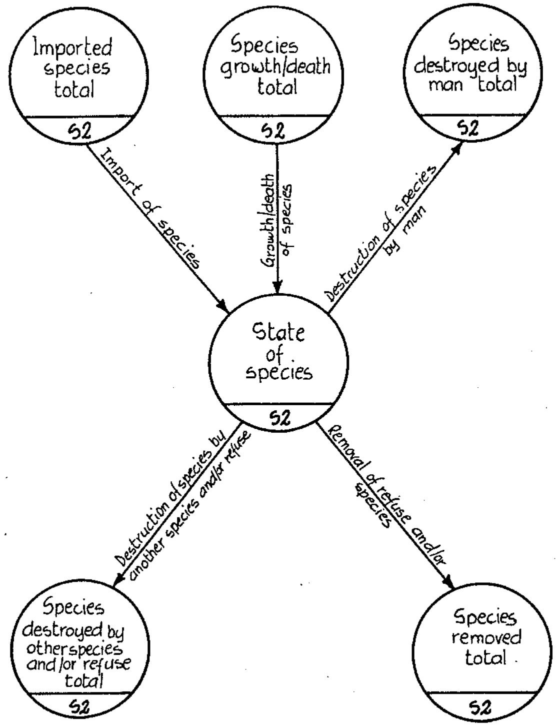
This approach can have two different lines of development. It can be used as a planning tool by the public administration to evaluate the impact of tourist enterprises on its own territory, as well as the corrective action that it must take or require of entrepreneurs. It can also be developed along company lines by constructing a model with which to evaluate the economic return of a tourist enterprise, thus keeping under control the costs of the investments represented by both the infrastructure and maintenance of attractive environmental conditions.

The following phase will be experimentation of the model. This experimentation will be carried out with the aid of interdisciplinary expertise to make in the first place an accurate check of the environmental model, with the identification of the appropriate species relating to a specific case and measurement of the related magnitudes.

Next the analysis of the market model will be developed in greater detail so as to determine, also through the direct experience of operators in this sector, any further variables that may affect the choice of the tourist service offered.

Lastly the model is completed by the financial and economic subsystem that determines the return of the tourist enterprise in economic terms.

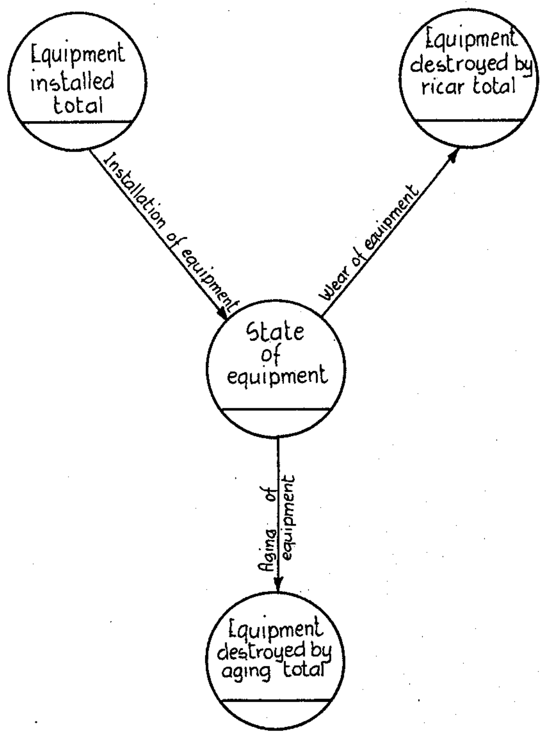
SPECIES SUBSYSTEM



S2 : — : average species (Y_1) ⟶ Equation (8)
— : noble species $(Y_2)^1$ ⟶ Equation (10)
— : parasite species (Y_3) ⟶ Equation (14)
— : refuse species (w) ⟶ Equation (12)

Figure 4

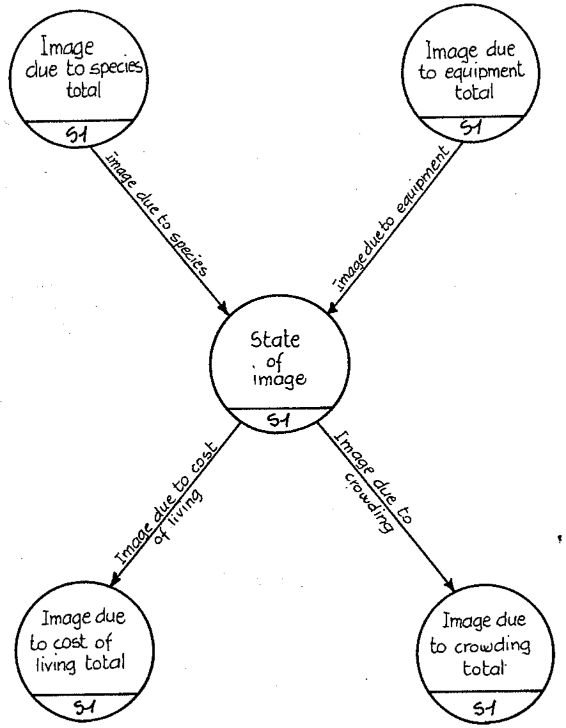
EQUIPMENT SUBSYSTEM



Equipment : (z) ⟶ Equation (15)

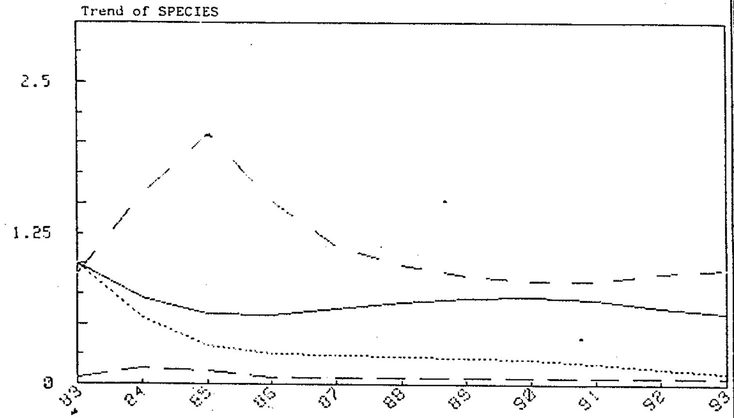
Figure 5

IMAGE SUBSYSTEM



S1 : - Clients type 1
- " " 2
- " " 3

Figure 6



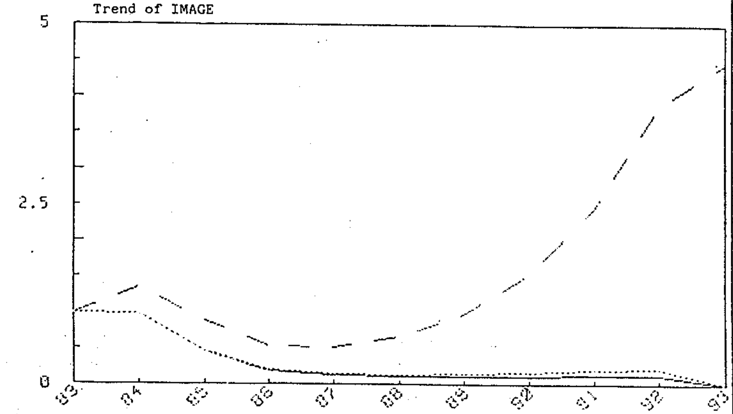
AVERAGE SPECIES

NOBLE SPECIES

PARASITE SPECIES

REFUSE SPECIES

Figure 7



CLIENTS TYPE 1

CLIENTS TYPE 2

CLIENTS TYPE 3

Figure 8

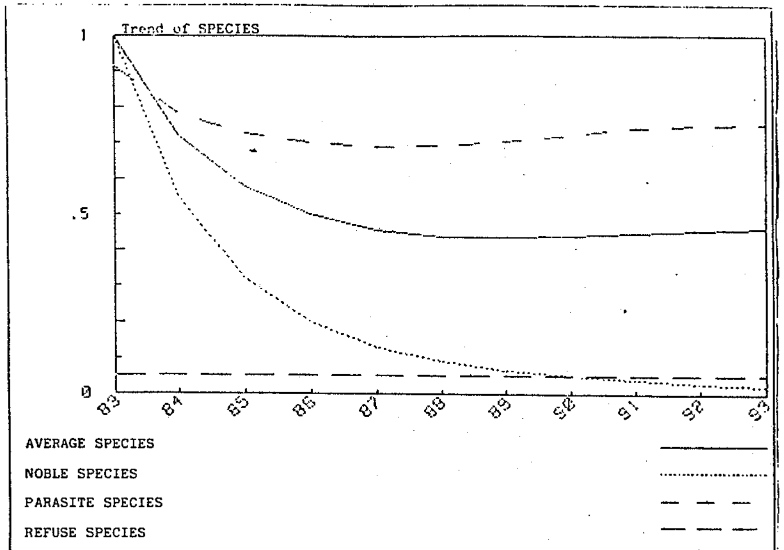


Figure 9

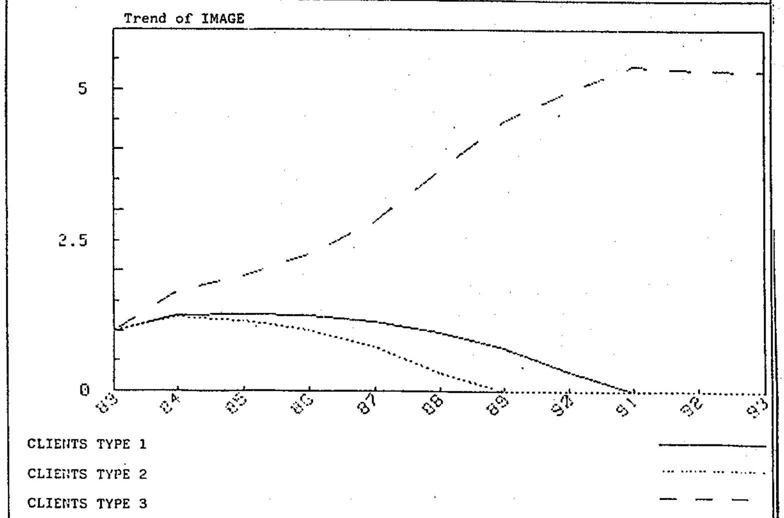


Figure 10

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