System Dynamics Model of The Canary Islands for Strategic Public Decisions Support

Miroljub Kljajić[1], Carlos A. Legna Verna[2], Andrej Škraba[1]

[1] University of Maribor, Faculty of Organizational Sciences Cybernetics & DSS Laboratory
Kidričeva cesta 55a, SI-4000 Kranj, Slovenia; miroljub.kljajic@fov.uni-mb.si, andrej.skraba@fov.uni-mb.si
[2] University of La Laguna, Department of Institutional Economics, Economics Statistics and Econometrics
38071 La Laguna, Spain; clegna@ull.es

Model sistemske dinamike Kanarskih otokov za strateške odločitve v javnem sektorju

Prispevek obravnava probleme na področju podpore odločanja ter samih odločitvenih procesov na nivoju odločanja v javnem sektorju. Opisan je razvoj metodološkega pristopa k podpori odločanju v primerih, ko so odločevalci soočeni z nepričakovanimi dogodki. Metodologija obravnava dejstvo, da je strateško odločanje povezano z velkim naborom spremenljivk, kvantitativnih in kvalitativnih ter, da le-te implicirajo interakcije med različnimi subjekti. Metodologija je zasnovana na izgradnji kvantitativnih modelov ter aplikaciji sistemske dinamike pri razvoju simulacijskega modela. Identificirane so bile spremenljivke, ki vplivajo na trajnostni razvoj ter izboljšavo kvalitete življenja na Kanarskih otokih. Relacije med spremenljivkami so podane s kvadratno matriko vplivov M z dimenzijo n=53. Možne vrednosti elementov M so med 0 in 3. Če je a_{ij} =0, sprememba vrednosti spremenljivke V_i ne vpliva na V_j. Če je vrednost a_{ij} med 1 in 3, sprememba spremenljivke »i« povzroči spremembo spremenljivke »j« proporcionalno s predpisano ojačitvijo. Prestavljena metoda je bila uporabljena pri reševanju problema analize vzročno posledičnih sil in razvoju modela sistemske dinamike.

Ključne besede: kvalitativno modeliranje, sistemska dinamika, strateško odločanje v javnem sektorju

1 Introduction

Public decisions, particularly ones related to strategic issues, involve qualitative and quantitative aspects of social systems. Quantitative variables are often crucial for strategic decisions. In addition, qualitative information is provided by a social actor and decision-maker (DM) with an implicit character of uncertainty. The DM has to take decisions in respect to problems that are softly defined in an uncertain and volatile world. In this paper, our efforts are oriented to build a methodological approach that may be useful to improve the public strategic decision-making processes related to sustainable development. This approach needs to allow the integration of quantitative and qualitative information; to treat indetermination of social systems and the uncertainty about the behavior of the variables; and to take into account the implicit knowledge of social actors and decision-makers. The main pillars of our approach are the following: the building of qualitative models that integrate qualitative and quantitative information; the application of Systems Dynamics that is particularly useful in determining the interrelations between the subsystems, to build scenarios and to do strategic simulations; the analysis of the leading forces that help to identify the role of the variables, their leverage potential and, consequently, to highlight key areas of the social system to implement policies. At present, we are working on the identification and interaction of main variables as well as a causal loop diagram (CLD) necessary for building the simulation model for strategic decisions in the Canary Islands. We are also working on structural model validation.

2 The qualitative model of the Canary Islands and the role of variables

The qualitative models and the methodology presented in this paper are useful to help Public Decision-Makers (PDM) in the comprehension of strategic problems and in the preparation and implementation of their decisions. The complexity of the system involved and the uncertainty about key forces and events are at the core of these problems. They involve aspects of different nature;

some of them may be treated in quantified terms and others not. Therefore, to improve the Strategic Decision-Making Process (SDMP), a holistic approach is necessary, which is capable of managing a non-deterministic context at the same time. This is the essential nature of the public decision-makers' problems in respect to the strategy. Being conscious of this nature, the main target of the paper is to develop a model and a methodology to tackle it, in order to improve the SDMP.

As has been stated, an important aspect of the nature of the public decision-makers' problems is that the strategic decisions need a holistic vision, either for the comprehension of the problems, the definition of the strategy or their implementation. However, the public sector tends to think and act in separated compartments, constituted by its different branches. As has been pointed out by Allison (1988), the public sector may be understood as a conglomerate of independent organizations, that have programs established in the functions of their past experiences. When a problem comes about, the organization reacts according to these programs. This deciding process may be useful to face repetitive circumstances that appear in the limits of the decision area of each public organization. However, it is incapable of producing good results at the level of the strategic decisions when the problems are new, involve different areas of the public sector or when it is necessary to cope with long term trends in their general socio-political, economic, ecological and technological environment. In these cases, the qualitative models, combined with the building of scenarios, as the approach developed in this paper proposes, help the decision-makers in their selection of the strategy and the main policies. In fact, not only is the qualitative model treated in this paper, but also the: a) methodological approach to help the DM in respect to their strategic decisions. This is important because it is a system thinking approach, that allows a holistic vision and the transcendence into restrictive areas of each public organization; b) permits the selection of the trends and variables that are relevant and to discard those which are not; c) allows treatment of the uncertain in respect to future trends and other events; d) and, finally, because it makes it possible to concentrate thoughts and decisions on aspects and solutions that are critical in respect to the main problems.

In the Canary Island case, the global vision result of the model was discussed with Government officials as well as with Trade Union Leaders; and the team is presently working on the elaboration of strategies and policies. Thus, the work on the Canary Employment Plan, which is being carried out at present, is particularly important. More details of these processes will be explained in the following paragraphs.

2.1 How the values in the matrices were derived

The Canarian qualitative model is a result of research made for the Islands' government and for the European Trade Union Confederation (ETUC), as part of projects to identify strategies and policies for the Ultra-Peripheral European Regions (Legna & Rivero, 2001; Legna 2002). The bibliography in respect to these models and their utilization to elaborate strategic decisions is extensive. See, for instance, Schlange & Jüttner, (1997). The Canarian Model identifies the principal variables from the perspective of the Sustainable Improvement of the Quality of Life of its population (SIQL) and the implementation of the European Strategy for Employment (ESE): this is the Desired Scenario, the target, of the strategy. It has 53 variables, from which 12 are exogenous. Consequently, it has 41 functions. To build the model, it was necessary to express the Desired Scenario in operational terms. Consequently, a list of indicators of the advances in the direction of the SIQL and the ESE was determined. These indicators constitute the independent variables of Function 1 (column 1 of the matrix that will be explained later on). This function expresses value judgments and is conceptually different from the others in the model. Consequently, in the specific case of this function, the improvement in respect to Vector (column) 1 components means advances in respect to the SIQL and the implementation of the ESE in the Canarian Social System (CSS). For instance, an increase of the real wages and a decrease of the social marginality imply an improvement in respect to the SIQL and the ESE. The model identifies the dealing forces in respect to Vector 1 variables. It gives answers to questions such as: Which are the leading forces of the CSS that shape its future path? Which roles do they play? Which are relevant and which are not for the SDMP?

The qualitative model establishes the relationships between different variables that directly or indirectly affect the Function 1 independent variables. These relationships are represented as: $\mathbf{v_7 = f(v_1; 3v_2; 3v_3; -2v_4; 2v_5; 3v_6)}$. This function means that changes in the variables v_i (i=1...6), will produce changes in the variable "v_7". In some cases these impacts may be quantified and in others it is not possible. In these last ones, it was necessary to work with indicators. In this paper, the functions are expressed in a Matrix "M", where each column represents a function. It reveals the **Direct** cross impacts or **Effects** between the variables. A function as $\mathbf{v_7 = f(v_1; 3v_2; 3v_3; -2v_4; 2v_5; 3v_6)}$ and a vector (column) of M have an identical meaning. If we were to build a matrix M with this function, Column 7 would have the following values in its cases: v_{17}=1; v_{27}=3; v_{37}=3; v_{47}=-2; v_{57}=2; v_{67}=3; and all the other cases equal to "0". A minus sign in a case or in a function means that there is an inverse relationship between the independent and dependent variable: an increase (decrease) of the former implies a decrease (increase) of the last one.

The impacts of the independent variables where estimated with a rank between 0 and 3. A "0" in a case "vij", means that there is no impact from "i" to "j". On the contrary, there is a "3" when the change in an independent variable "i" is capable of producing, **by itself**, a relevant impact on the dependent variable "j". This is the case of x3 in the former function. It is possible that in a function (column of the matrix) there can be more than one independent variable weighted with a 3, as is the case of column V21 (Agricultural Production) of the model. This is because the agricultural production may be substantially affected by the Public Policies (V41) or the endowment of Natural Resources (V36). If there is a "2" in a case, it means that the impact of a change in the independent variable may be important if it is reinforced with changes in other variable(s). For example, the decrease of mortality and birth rates and the increase of immigration, which reinforce each other, affect the Canary Islands' population growth rate (see column V2 of the matrix). For this reason, no column of the matrix has only one 2. The difference between the variables that have a "3" and a "2" in a column (function) is that a change in the former is capable of producing important changes in the depending variable without needing feedback from others: acting independently, it can produce important impacts. On the contrary, the variables that have a "2" need to work together (at least two) to produce significant effects. A variable vi is included in a column with a value equal to "1" when there is a situation similar to the preceding case (weight equal to "2"), but the impact is weaker. It helps to understand these criteria and to evaluate the impacts if we put them in terms of questions, as follow:

- A case vij will have a "3" if the answer to the following questions is "yes": a) the power of "i" over "j" is so essential that these changes are capable of producing a significant impact over "j"; b) Can it produce the effect by itself?
- A "2" will be assigned to a **set of cases** v_{ij} (i=1,2....n) when the answer is affirmative to the following first question and negative to the second one: a change of one variable of the set, interacting with others (any one of the three categories) is capable of producing important changes in the depending variable "j"? Is it capable to produce significant changes in "j" if just it changes?
- Finally, the same questions and answers are applicable to the third category of variables, but taking into account that the impacts are weaker.

2.2 Foundations of the forms of causal relationships

The foundations of the relationships (matrix M) may be explained by means of a description of how the model was built. Throughout their experiences in building these qualitative models, the authors of this paper followed a methodology whose main steps were the following: The first step consisted of an open discussion with the leaders interested in the work in order to establish an initial definition of the problem: for instance, the implementation of the European Strategy for Employment. Keeping in mind the results of the first step (which "did not permit the leaders to sleep"), a brainstorming session was carried out next. Its target was to identify a first list of variables that could be important in respect to the key problem recognized and agreed on during the first step. The members of the team, as well as those in charge of constructing the model, and other specialists and leaders all participated in the brainstorming sessions. At this stage, it was important not to "kill the imagination" by discarding variables that could be crucial. The third step centered on the construction of the functions of the model, that is to say, the matrix M. It was based on the results of research made previously or ad hoc for the model. We will explain these processes with an example. For instance, a conclusion made based on the research conducted by Dirk GODENAU and Sebastián J. ARTEAGA HERRERA, was the following: *"...the aging of the (Canarian) population is due more to the reduction of the fecundity than to the diminution of mortality"* (Godneau & Artaga, 1997). This conclusion may be expressed as a relationship: env = f (tnat), where env = aging rate and tnat = birth rate. This would be the function if we were to build a model to reflect past tendencies. Nevertheless, we were interested in the estimation of future impacts. Our vision was dynamic. Therefore, in order to build a function we always had to answer the next question: How will the independent variables impact the depending one? After additional studies, the function adopted was env = f (2tnat; 2tmort), where tmort = mortality rate (see column 11 of the matrix). Finally, we have to emphasize that the process is iterative; it is necessary to repeat the step, going back over and over.

Another aspect has to be explained in order to understand the meaning of functions that imply behaviors, for instance, the Canarian entrepreneurs' low propensity to innovate. They have to be understood in probabilistic terms. As has been pointed out by Yager:

"The environment in which people make decisions in many cases consists of a milieu in which the decision-maker has information as to the "usual" value of certain variable and/or the "usual" course of action in a given situation. In addition, these usual rules of thumb involve granular types of knowledge. Examples of these types of decision rules are "John usually takes his car if the weather is nasty" and "We usually invest in companies with good growth potential". These types of rules are characterized by various forms of uncertainty and imprecision." (Yager, 1986).

Table 1 and Table 2 present the variables that were identified, whose relationships are in the matrix M. They were grouped in blocks, as follows:

Table 1: Grouping blocks of identified variables I-V

Blocks	Variables
I	Variable 1. Its column is a vector that expresses the "Desired Scenario", in order to improve the quality of life and to advance in the direction of the EES in a sustainable way.
II	Demographic variables, labor market, employment and rate of employment (V2-V17): V2, Total population residing in the Canary Islands; V3, Birth Rate = (quantity of births by year/total population residing in the Canary Islands)x1000; V4, Mortality Rate=(quantity of people that die by year/total population residing in the Canary Islands)x1000; V5, Immigration Rate=quantity of immigrants that arrive to the Canary Islands in one year/Canarian Population; V6, Female activity rate=(Employed female population + Non-employed female population looking for employment/feminine population between 16 and 65 years old)x100; V7, Male activity rate=(Employed male population + Non-employed male population looking for employment/male population between 16 and 65 years old)x100;V8, the Canary Islands' population rate of activity = [(employed population + population looking for employment)/population who is between 16 and 65 years old)]x100; V9, Active population = Employed population + non-employed population that is looking for work; V10, Population employed; V11, Population aging index = (population residing in the Canary Islands aged 65 years or more/total population residing in the Canary Islands)x100; V12, Labor productivity = Value of the production of the sector/employment in the sector; V13, real wage;V14, Unemployment rate; V15, Internal markets of work; V16, Labor market Primary Segment; V17, Probability to be unemployed.
III	Sectors' production, GDP (Gross Domestic Product) and the effects of the distance of the Canary to central areas (V18-V29): V18, Services Sector Production Value; V19, Construction Sector Production Value; V20, Industry Sector Production Value; V21, Primary Sector Production Value; V22, the Canary Islands' Gross Domestic Product (GDP) -It is also an indicator of the Size of the Market; V23, the Canary Islands' medium propensity to import = Total Imports/GDP; V24, Value of the Annual exports of goods and services value; V25, Annual imports of goods and services value; V26, Medium dimension of the Canary Islands' firms; V27, Costs of water; V28, Costs derived of the insularity, the double insularity and the distance; V29 Subsidies to some Canary Islands imports .
IV	R&D, Human Capital and the effects of Values and Culture (V30-V34): V30, Density of the innovation = quantity of innovative companies /quantity of region or sector companies; V31, Canarian Entrepreneurs Propensity to innovate (general values that prevails in Canarian Entrepreneurs in respect to the role of innovation); V32, Human Capital (the set of abilities, dexterities, qualifications, aptitudes and the population's attitudes that favor the economic and social development); V33, R&D Services produced by Canarian Universities and R&D institutions; V34, General values that prevails in Canarian population.
V	Environment (physical and social) and related variables (V35-V39). V35, Urban, rural and marine environment, including that of the beaches. Indicators of its state are the following, among others: the quantity of urban and non-urban residuals that remain without processing in the cities and in the rural areas; the levels of sonic contamination; the contamination either of the air, the sea and the beaches; traffic congestion (measured, for example, by displacement times), and the visual effects of the urbanization pattern and of the extraction of solids that are carried out by the construction sector; V36, Endowment of natural resources; V37, Demographic density=(quantity of population residing in the Canary Islands + V29)/square km. of the Canary Islands territory; V38, Techniques applied in agriculture that produces negative impacts on the environment;V39, Urban violence, drugs, social unrest.

Table 2: Grouping blocks of identified variables VI-VIII

VI	Only one variable, tourism, V40=Total of daily tourists that the Canary Islands receive in a year = tourists that arrive in one year multiplied by the average days that they stay in the Islands. It was treated separately due to the fact that it is a crucial variable.
VII	Political System, only one variable, V41=Public Policies= norms and policy instruments + decision criteria -that produce effects on the population, the companies and the social actors of the Canary Islands. This block needed a special research.
VIII	All the exogenous variables, (V42-V53) -Some of them are external to the Canary System, as the GDP of other countries (V42 and V53); others, as Social Marginality (V51), are internal, but they were treated as exogenous to not extend the model: V42, GDP of countries where immigrants come from; V 43, Percentage of female population aged between 20 and 49 years in respect to the total female population between 16 and 65 years (the women in this stratum have a higher activity rate); V44, Percentage of male population aged between 25 and 54 years in respect to the total male population between 16 and 65 years (the men in this stratum have the higher activity rate); V45, Female; V46, Young active population; V47, European policies (the norms and policy instruments, such as the Structural Fund, the Community Initiatives, etc., that produce effects on the Canary Islands); V48, Supply of Financial Services for the Canary Islands Entrepreneurs' R&D activities; V49, Relative prices of the Canarian tourist services, in respect to the price of the same services in the regions that compete with it; V50, Social Marginality; V51, Revenue distribution between the social groups; V52, Relative rate of inflation of the Canary Islands in respect to the countries that compete with their tourist sector = rate of inflation in the Canary Islands/rate of inflation in the countries that compete with the Canary Islands tourist sector (in the model it is an exogenous variable); V53, GDP of the countries that are market for Canarian exports and of those where tourists come from.

In order to build scenarios and to elaborate strategies it is important to know the role that these variables play in the system. We used two methods to do this: the Analysis of the Driving and Dependent forces that we explain in the next sections and Systems Dynamics.

2.3 The results of the Analysis of the Driving and Dependent forces

Matrix M gives important information about the Canarian Island social and economic system. For instance, if the sum of the values of column "j" is high, it means that the problem "j" has a high level of dependency in the systems: the changes in the other variables affect it strongly. On the contrary, if the sum is low, its dependency is also low. If the sum of a line "i" is high, its changes produce strong impacts in the system. If its sum is low, its effects are not important. But, it only detects the direct effects between the problems. Nevertheless, in social systems the indirect relationships are important: if "A" changes, its change impacts over "B" and "B" affects "C". In addition, variables play different roles in the social game. We will apply the analysis of *"Motricité et Dépendance"* to identify both the indirect effects and the roles. The literature about this analysis is extensive, especially in France. For instance, see Roubelat, (1993).

Multiplication of the matrix permits the detection of indirect effects. For instance, if M is elevated at two, each case aij of the new matrix includes the effects that pass through one variable: $X_i \rightarrow X_u \rightarrow X_i$, X_u being in this case the intermediate variable. If the matrix is elevated at four, it will reveal the effects that pass through 3 intermediate variables, and so on. In the case of our work, we elevated M at two, three and four and afterwards, we built a new matrix MS, which is the sum of M, M^2, M^3 and M^4. Consequently, each case a_{ij} of MS is the sum of the a_{ij} cases of M, M^2, M^3 and M^4 and includes the direct effect of "i" over "j" and the ones that pass through the 1, 2 and 3 intermediaries. With the information provided by M^4 or MS it is possible to detect the role of the variables: a) Active Variables" or "Driving Forces" (AV) that strongly affect other variables but at the same time are not affected (or weakly affected) by them; b) "Passive" or "Reactivates Variables" (RV), that are more affected by the system than they themselves affect the other variables; and c) "Critical Variables" (CV), that have strong feedback effects with the others. Their changes powerfully impact the system and at the same time they are strongly affected by the changes in the other variables. They are strongly interactive and determine the direction the system will take in the future. If a change is produced in a leading variable, it produces feedback loops between the critical variables that may be positives or negatives. If they are negatives the system will return to the previous state. It is the "Equilibrium Poverty" case that development theories have studied. However, if the positive feedback predominates, the system will be pushed out of its present state moving to new ones. Due to these facts, a strategy has to be designed in order to produce changes in the AV and the CV forces that may lead the system to a desirable scenario. If some of these variables are external and there is no capacity to act over them, it is crucial to prevent their possible evolution. We will appreciate these conclusions in the Canary Islands case.

Using the MS matrix of the Canary Islands we built the Graphic of leading and depending forces, which is shown in Figure 1. For each variable, the vertical axle expresses the value of the sum of its line in MS, that is its leverage potential; and the horizontal axle expresses the sum of the column, its dependency. The dependency reveals the level of “steering potential” of a variable. The graphic classifies the variables in four categories: AV, in quadrant I; CV, in quadrant II; RV, in quadrant III; and finally, the variables that are not important due to their low level of leverage and steering potential in quadrant IV. We will concentrate the analysis to the first three quadrants.

The key variables to advance toward the Desired Scenario are in the quadrants I and II. Those in the third quadrant are mainly the results of the structure of the system. The Tourism drives the Services Sector and this one impacts the Construction. These two sectors have multiplying effects over the employment and the GDP; and, consequently, an increased of the final demand is produced that newly stimulates these two sectors: a positive feedback loop is induced by the tourism. In fact, there is a cascade of effects that elevate the demand addressed to all the sectors. The Production of Services is the Economic Base of the Canary Islands. The fluctuations of this base depend on a variable (Tourism) with a very strong leverage potential; and so, all the economic activity and the employment are very sensitive to this variable. It is a society with a high risk. The Economic Base depends on the Environment State, which, in turn, is a result of the Canarian Development Model (quadrant III). This is another crucial feedback loop: the development model impacts over the environment and, if this is destroyed, it will ruin the Economic Base. At present, this base and its effects are producing negative consequences over the environment, via three main processes: a) the pressure over the territory derived from tourism, urbanization and construction persistently reduces scarce agricultural lands and, at the same time, spoils the urban environment; b) an important part of the techniques adopted in the agricultural sector pollute the lands and the water sources; and c) the high rate of growth of construction has ruined some rural environments, by means of the extraction of minerals. Consequently, the Canary Islands are destroying the source of its own economic base and its quality of life: They need to change their development model.

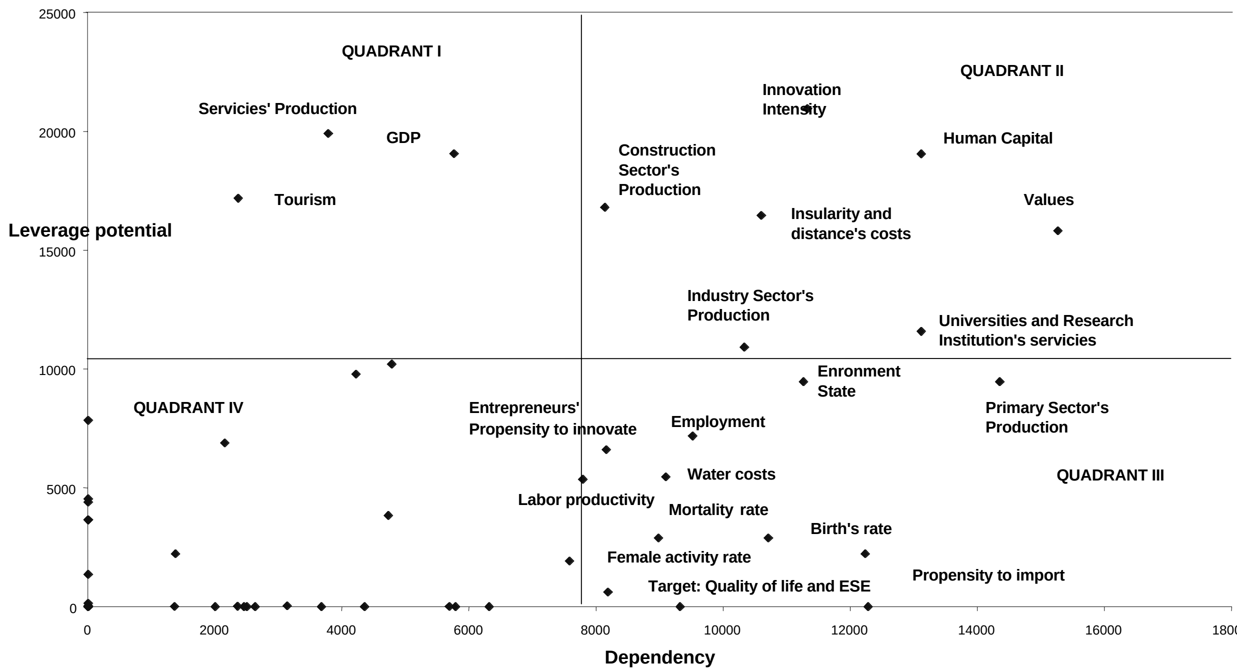

Figure 1: Graphic of leading and depending forces

Other sets of variables also play important roles. The GDP (which is at the same time an indicator of the size of the market) is another center of feedback impacts. Its increase is either a condition to elevate employment and the real salary or to permit the development of activities that need scale economies; and, in turn, is the result of the sector activities, mainly of those of the Base. Its increase reduces the general costs of the system by taking advantage of scale economies. The empirical evidence shows that the increase of the market size reduces the weight of the cost of insularity and the distance over the system.

The state of the variables related to the R&D sub-system (Innovation Intensity, Human Capital, Values and Research Institutions’ Services, in quadrant III) is the consequence of the behavior of the system but, at the same time, it determines the path that the Canary Islands will take in the future. The culture and the human capital are a result of the Canary Islands' history and of the policies implemented by the Canarian governments. They have improved steadily during the last decades. However, in spite of this fact, in some sectors of society values predominate that do not impulse the propensity to innovate, especially in small enterprises.

The agricultural (quadrant III) and industrial (low part of quadrant III) sectors have low leverage effects. The first depends strongly on the natural resources (scarce, save the ones related to tourism); and the second is conditioned by the size of the market. They produce positive impacts over employment and revenue, but not as important as those of the services and construction sectors. The entrepreneurs' propensity to innovate (quadrant III) clearly reveals a characteristic of this system: it is highly dependent on the cultural level and the values that predominate in the enterprises; and, at the same time, it has low effects over the competitiveness of the Canarian firms. Due to the fact of this low tendency to innovate, the economic growth has been based on an increase of employment with low productivity and wages. These facts pose a strategic dilemma to the Canary Islands: the development model that has been implanted during the past decades is producing a degradation in the environment; and this degradation is more and more becoming a barrier that will stop the economic growth and the improvement in the quality of life.

With this knowledge of the Canarian Islands system we can build scenarios. To do so, we classify the studied variables in function of the predictability of their behavior during the next five years. We distinguish two sets. The first one consists of the variables in which behavior may be reasonably forecast. The second set includes those that may carry on different paths in the future. In Table 5 we specify the behavior that may be foreseen as variables of set one, and the most important factors that may condition the evolution of set II variables during the next five years.

Table 3: Behavior of the variables in the future

SET I		SET II	
Variables	**Behaviour**	**Variables**	**Its behaviour depends on**
V47, European Policies	≈	V40, Total of tourists	EF +V49+V52+V53+V35
V28, Costs the insularity	≈	V18, Services Production	V40+V27+V22+V11
V32, Human Capital	≈ ↑	V19, Construction Prod.	V41+V47+V27+V22+V18
V34, Values	≈ ↑	V22, Market Size	V18+V19+V20+V21
V4, Rate of mortality	≈ ↑	V10, Employment	V18+V19+V20+V21+V12
V33, Production of R&D	≈ ↑	V12, Labour productivity	V18+V19+V20+V21
V20, Industrial Production	≈ ↑	V6, Female rate of activ.	V5+V32+V41+V43
V21, Primary Production	≈ ↑	V36, Available natural res.	V19+V37+V38
	≈ ↓	V35, Environment	V32+V34+V40+V41
		V38, Agric. technologies	V34+V41
		V27, Water costs	V41+V36
		V30, Innovation density	V22+V28+V31+V32+33+ V48

Meanings of the signs and abbreviations: ≈ = more or less the same; ≈ ↑ = more or less the same or slightly increasing; ≈ ↓ = more or less the same or slightly decreasing; EF = External or non controllable Factors, as natural catastrophes or terrorists attacks that increase the fear to travel; PubPol = Canarian Public Policies; V = variable of the qualitative model.

Set I contains characteristics that probably will have or accentuate the Canarian Society during the next five years. Therefore, in the Canarian society the weight of the elderly will probably become more important and at the same time the proportion of youth will be reduced. Combined with characteristics, the cultural general level and the human capital will probably be more important. These features will be present in the different scenarios that depend on the path of the set II variables. Some key scenarios are the following:

- Scenario I, "Auto-destructive Growth with recession". This scenario is Auto-destructive because it supposes the same model of growth of the Economic Base that will lead to the destruction of the environment, so, it will destroy its own basis. The recession is due to the fact that tourism may suffer an important contraction, due especially to external factors (such as the fear of traveling) and internal factors (such as the increase of violence and the contamination of the beaches).
- Scenario II, "Auto-destructive Growth with recession". This is Scenario I but with an increase of tourism. It will accelerate its auto-destruction.
- Scenario III, "Desired Scenario". The main features of this scenario are the following: a) continuation of economic growth and reduction of unemployment; b) but this economic growth is combined with more qua-

lified services provided to tourists, increase in salaries and labor productivity and with a preservation of the environment, in order to ensure the sustainability of the model.

3 The relationship between influence matrix and CLD suitable for SD Modeling

In the previous section the main variables and their interconnection with the Canary Islands, suitable for qualitative analysis of future development, are defined. To move to a quantitative model capable for cause-consequence analysis of decision-maker impact on the long-term behavior influence matrix, they have to be transformed to SD methodology. In this way it is possible for a direct connection between scenario planning (as a consequence of DM) and variable behavior. 53 variables are a rather demanding problem especially in the frame of model validation. In this case it is necessary to specify the initial value of variables, parameters and other functions necessary for model implementation. Therefore, we will develop a procedure of influence matrix transformation to Causal Loop Diagram CLD. The influence diagram is obtained from the influence matrix. The variables in influence matrix *M* represent vertex i.e. the node of the graph and the value represents a gain of a certain branch. Here we suppose that the vertex value represents a directed branch. A different weight in the coefficient matrix represents gain of the certain element in the system. By definition, it is assumed that the vertex or variables belong to a certain entity in the system. Variable relevance in the systems will be estimated with matrix. From this point, the transformation to SD methodology is only the next step. Variables, which represent entities, have cumulative or flow property suitable for system dynamics modeling. To perform the transformation, the influence matrix *M* could be decomposed. In our case we split the influence matrix into several sub-matrixes. In order to facilitate matrix decomposition it is desirable to aggregate variables in natural order. Several similar variables were mapped in one, for example: population, ecology, industry etc. Subjective mapping defined by an aggregation function

$f(v): V \rightarrow X$ give us the following subsets:

$$X_1 = \{V_{48}, V_{30}, V_{33}\}$$
$$X_2 = \{V_{36}, V_{27}, V_{38}, V_{35}\}$$
$$X_3 = \{V_8, V_{11}, V_{10}, V_{12}, V_9, V_4, V_3, V_5, V_{37}, V_{32}, V_2, V_6\}$$
$$X_4 = \{V_{22}, V_{28}, V_{29}, V_{49}, V_{24}, V_{25}, V_{52}\}$$
$$X_5 = \{V_{26}, V_{18}, V_{19}, V_{20}, V_{21}, V_{40}, V_{42}, V_{53}\}$$

As a result of mapping we obtained aggregated connection matrix *C*:

$$C = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{array} \begin{array}{c} \begin{array}{ccccc} X_1 & X_2 & X_3 & X_4 & X_5 \end{array} \\ \left[\begin{array}{ccccc} 0 & 0 & C_{13} & C_{14} & C_{15} \\ 0 & 0 & 0 & C_{24} & C_{25} \\ C_{31} & C_{32} & 0 & C_{34} & C_{35} \\ C_{41} & C_{42} & C_{43} & 0 & C_{45} \\ C_{51} & C_{52} & C_{53} & C_{54} & 0 \end{array}\right] \end{array}$$

In matrix *C* the variables describe the following subsystems: X_1 = R&D, X_2= Ecology, X_3 = Population, X_4 = GDP, X_5 = Economy. C_{ij} represent the sub-matrix of the connection between sub-systems X_i and X_j. The elements of the matrix under the main diagonal represent the feedback connections. If sub-systems X_i ; i = ,2,…5 are represented as the nodes of the graph (vertex) and C_{ij} ; i = ,2,…5 ; j = ,2,…5 ; $i \neq j$ represent the branch of the directed graph, we can represent the matrix *C* as the influence diagram or influence graph, see Figure 2.

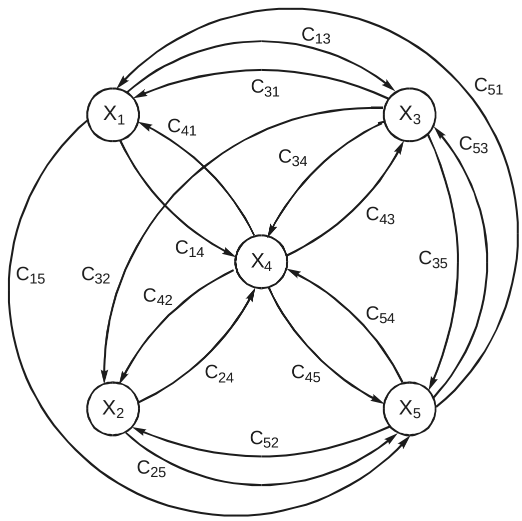

Figure 2: Graph of the aggregated system

Interconnections C_{34} and C_{24} could be neglected because of the small impact on the subsystem which is derived from the original matrix *M*. Although the interconnections exist in the matrix they are not significant on the top level of the influence diagram. This graph is identical to matrix *M* but yet convenient for modeling in SD. The diagram represents a high level of abstraction convenient for further decentralized modeling. At this moment we will analyze the interconnection between main variables relevant for the causal loop diagram CLD as shown in Figure 3. Feedback loops and interactions of particular subsystem are shown in the causal loop diagram. The locations, which are defined with variables, represent the system state element while arrows show the direction of influence between a particular pair of elements. The symbol at the arrowhead in the input and output of a particular element shows the trend of change. For example, if

Gross Domestic Product increases, the Investments in Education and R&D production increases above what it would have been and vice versa, therefore the arrowhead is marked with the "+" symbol. If the Investments in Education and R&D production increases, the Economic volume increases above what it would have been, which is also marked with the "+" symbol. If the Population increases, the Quality of Environment decreases and the cause effect is marked with the "-" symbol. All other causal connections are marked in the same manner. In the simulation process, an expert group in the form of a suggested policy determines key parameters heuristically. The causal loop diagram in Figure 3 represents interactions in the context of regional development and its influence on the regional prosperity and quality of life. The structural analysis of the system is of great significance since mental models of various kinds can be captured using the proposed methodology.

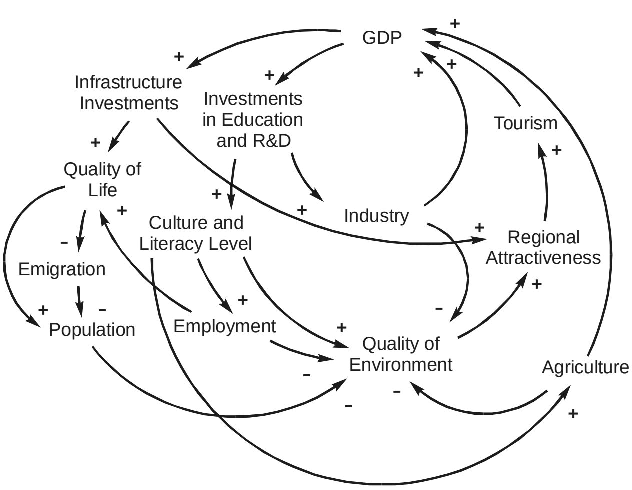

Figure 3: Causal Loop Diagram of The Canary Islands case

After the aggregation of variables i.e. the joining of similarities, the next step is the determination of levels and rates according to system dynamics methodology. Figure 4 represents the population sub-model i.e. X_3 from matrix *C*. Variables are represented by circles and denoted by V_i as defined in matrix *M*, which are interconnected in the form of a directed graph. According to data in matrix *M*, each arrow has its influence marked by a sign +/-. The variables are determined according to System Dynamics methodology as the Levels and the Rates or Auxiliaries marked with *L*, *R* or *A* respectively.

The output from the Population sub-model X_3 is connected to the input of the Ecology subsystem X_2, Finance sub-model X_4 and Economy X_5. In the input, the subsystems of X_1: R&D, X_2: Ecology, X_4: GDP and X_5: Economy influence the Population sub-model.

Figure 5 represents the Finance sub-model, which incorporates the main financial factors for the studied case. The Finance sub-model has an influence on all the other sub-models, which indicates the importance of this sector.

With the proposed methodology the system can be entirely determined by the System Dynamics models,

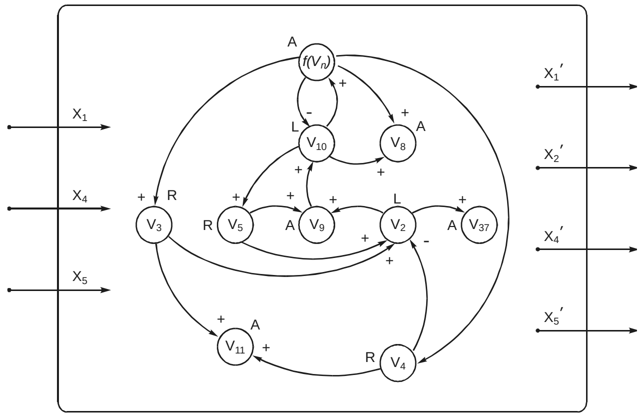

Figure 4: Population sub-model X3 influence diagram

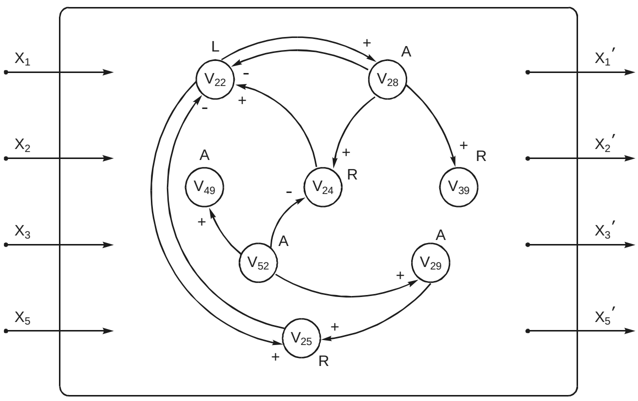

Figure 5: Finance sub-model influence diagram

which form the general simulation model for the regional development of the considered case. Such decomposition allows for a multilevel approach in modeling, which facilitates the process of model validation. System Dynamics simulation models provide a basis for designing more effective industrial and economic systems in terms of material, energy and other aspects such as ecology (Forrester, 1973). The combination of System Dynamics, expert systems and interactive experimentation based on business scenarios aids in the process of creating a regional policy.

A preliminary sub-model was developed for population dynamics, which incorporated 150 parameters. The model enables changes for different population variables, which are relevant for decision makers. Users have the opportunity to actively participate in the decision process by defining relevant criteria and their importance, in spite of the large number of different simulation scenarios. The decision process is clear and creative. The user-friendly interface of the developed simulator in the early stages of the development cycle allows the user to perform the tests easily. Later developments in the field consider group model building (Vennix, 1996) and the application of System Dynamics models (Kljajic et al., 2000b; 2000a). The preliminary model is built using the simulation tool Powersim (www.powersim.com), which provides results for the real application of the organizational strategy. The completed simulation model should enable the testing of different simulation scenarios and alternatives i.e. policies considering certain effects of actions on the environment and population. Simulation also enables the inner view of system behavior for the selected scenario. The System makes it possible to analyze different situations, which is the basis for achieving the consistent formulation of a policy. The building of the model is still in progress.

4 Conclusion and discussion

This contribution describes the concept of using dynamic model building for decision assessment of sustainable development in the Canary Islands. Model development is based on the influence matrix and SD methodology. Nowadays, a strategic and public decision-making model for political planning in the global market is ultimate. Rapid development of information technology and the Internet significantly contribute to the globalization of markets and idea sharing. A typical branch of economy that is influenced by such changes is tourism. Tourism subsystems are strongly inter-connected enabling them on one hand to smoothly obtain the world market while on the other hand to create turbulence in the world market with the demand for flexibility and quick reactions from the entire service industry. Tourism organizations, which are of significant importance in our case, belong to inter-organizational systems with global and local properties. Problems are softly defined and phenomena uncertain. Policy makers, who have the task of providing sustainable development, are requested to make fast and integral decisions and are responsible for the satisfaction of citizens. Thus, there is an urgent need for a methodology approach for the presented problem (Kljajić 2000b; Kljajić & Lazanski, 2001). There are many different methodologies and methods, which try to master soft-structured problems. Here we meet the methods and tools of System Dynamics and system thinking, which became common tools of management in the 90s. These tools were first brought into force in the learning and training area in the form of different computer games and later as tools for decision-making and systems re-engineering. Decisions, which include wide financial, technical, logistic and environmental resources, demand the decisions' simulation before they go into action in a form of policy realization (Kljajić, et al., 2000a). With all organizational systems, human skills and creativity play an important role in efficient problem solving. Therefore, teamwork has to be included in the decision process for achieving the satisfactory solution. Implementation of a group decision support system enables participants the testing of different simulation scenarios and the sharing of common views regarding a problem. Following this, the indirect effect of testing policies is understood in an environment, which is less risky prior to the actual implementation of regional policy (Legna, 2000). On the outline one can find the polarity of the loop and estimate the qualitative trend of system behavior. The business system simulator will be the base for the assessment of strategy development. The simulator will be connected to a Group Support System (GSS) as well as the database so that an expert group can analyze each scenario. In this way the dynamics of a business system can be better understood. Simulation results are evaluated with the help of group decision support systems and with expert systems. The model and its sub-models are in the phase of structural validation and relevant parameter values determination.

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Miroljub Kljajić completed his Doctorate at the Faculty of Electronics in Ljubljana in 1974. He is a professor at the Faculty of Organizational Sciences in Kranj in the area of System Theory, Cybernetics and Computer Simulation. His main fields of research include control principles of the extremities of paretic patients with the method of electrical stimulation, and methods of modeling and simulation of organizational systems. He has been the principal investigator of many national and international modeling and simulation projects. As author and co-author he has published more than 20 scientific articles recognized in SCI.

Carlos A. Legna Verna is PHD in economics (Pierre Mendès France University, Grenoble, France) and was expert of the United Nation technical cooperation for the development (Department of Economic and Social Affairs), working in Latin America and Africa. He has specialized in development theory and planning and public decision making, particularly in respect to underdeveloped countries and regions. At present, he is professor of Strategic Regional Planning, Economic Regional Policies, and Evaluation of Social Project at La Laguna University, Canary Islands, Spain. He has published recently Gestión Pública Estratégica y Prospectiva, con aplicaciones al ámbito regional, between other books and articles.

Andrej Škraba obtained his Ph.D. in the field of Organizational Sciences from the University of Maribor. He works as a researcher at the Faculty of Organizational Sciences in Cybernetics and DSS Laboratory. His research interest covers system dynamics, decision processes and multiple criteria decision-making. His recent interests are focused on experiments with decision groups applying system dynamics simulators in experimental and real environments.