DOI: 10.2478/v10051-010-0011-4

A Methodology for Improving Strategic Decisions in Social Systems with a Lack of Information

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

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

The design of strategies for social systems requires the use of qualitative information owing to the fact that quantitative information can be insufficient to solve the problems involved. The information that the specialists and the decision makers obtain is often incomplete and unreliable. Nevertheless, leaders have to make strategic decisions despite these deficiencies which should be based on the formal models (Kljajić et al. 2000; Škraba et al, 2003; Škraba et al 2007).
This paper describes a methodology elaborated to design the strategy of the city of Santa Cruz (on the Canary Islands). It has two main sections: the elaboration of a qualitative model and the use of System Dynamics. We combine them in a way that allows mixing qualitative and quantitative information to achieve a better understanding of the structure of the region, to know the tendencies of the present scenario and to estimate of the effects of alternative strategic decisions. We have obtained these results working with scarce quantitative information. This methodology may be applied to any social systems with similar characteristics.

Key words: Qualitative models, System Dynamics, Social Strategies

1 Introduction

This article is a continuation of a line of research (Kljajić et al. 2002, 2003a, 2003b; Legna Verna, 2000; Legna Verna and González 2004, 2006; Legna Verna et al., 2005a, b) aiming to help policy makers to improve the strategic decision-making process, in a context where there is a lack of information, particularly of a quantitative sort. When decision makers must make strategic decisions, usually the problem is complex and the available information is insufficient. Nevertheless, they must decide. Moreover, their strategic decisions deeply influence the future of their society and the well-being of its citizens. Taking into account this challenge, we have been working, alongside decision makers, to try to answer the following issues: a) how to integrate the available quantitative and qualitative information in a logical context; b) how to obtain a better understanding of the structural characteristics of the social system that influence its future; and c) how to estimate the impact of alternative strategic decisions.

As a response to these questions, we have developed a methodology that has been implemented in diverse regions and cities in order to design strategies. In this article, we present the methodology that we have designed to improve the strategic decision-making process of the city of Santa Cruz, Canary Islands, whose government requested the advice of our team of professors at La Laguna University (Guirao et al., 2007).

2 Methodology and results

2.1 First step: construction of the quality model

General characteristics of these models

Social systems are highly complex; to understand them in order to prepare decisions, particularly strategic ones, it is necessary to work with variables that are not quantitative with special attention to feedback system concepts (Sterman, 1994). Additionally, even in the case of quantifiable variables, researchers do not have sufficient information to build econometric relationships between them. These two restrictions may be overcome by the construction of qualitative models, such as the one that is presented in this chapter. It does not give precise

relationships between the variables, as is the case of econometric models, but allows one to understand the structure of the system and to detect the main relationships and roles of the variables.[1] In addition, it provides the basis for estimating the possible future path of the system and to build scenarios.

The general structure of the functions is the following: Y = f (X; V; Z; PolDec). This means that:

a) if an independent variable X (or V) increases at the rate X (or V), it will have a positive impact over the variable Y (where Y is the estimate rate of increase of the variable); and
b) if the independent variable (Z) is preceded by the minus sign, the impact will be negative.

X, V and Z are all independent variables, with different influence.

The weights of the impacts produced by the independent variables oscillate between 1 and 3; 3 is the stronger effect, 1 the weak and 2 medium. Research and interviews were made to assign these weights. When a variable is underlined, it means "increase rate", except for the variable "PolDec"; in this case, it ought to be understood as a decision (or a set of decisions) of the decision maker that will produce an impact over the dependent variable. In other words, "PolDec" means that a policy has been adopted and implemented (PolDec means Political Decision).

With qualitative models, the importance of precise data applied by the econometric and quantitative models is diminished and, evidently, we enter a more imprecise field. In this world, the relationships or equations, such as the ones that are presented in the next section, have to be understood as estimations of the direction (positive or negative) of the change of a dependent variable that is a consequence of a change of an independent one.

The relationships of the Santa Cruz's qualitative model.

The model has been built to answer the following questions: what are the main forces – and the feedback between them – that lead the transformation of Santa Cruz's economic system? What are the main policies that may be applied to these variables and feedbacks, with the aim of improving the quality of life of the population?

The model is organized in five blocks.

Block I: Employment

1) E = f (3 E-Com, 1.61 E-Const, 1.94 E-ServEnterp, 1.89 E-PA, 1.19 E-Educ, 1.23 E-TransCom, 1.08 E-SanitServ)

Where E= total employment in Santa Cruz; E-Com = employment in the commercial sector; E-Const = employment in the construction sector; E-ServEnterp = employment in the qualified services to enterprises and real estate services sector; E-PA employment in the public administration sector; E-Educ = employment in the education sector; E-TransCom = employment in the transportation and communication sectors; E-SanitServ = employment in sanitation services. The weights of independent variables were estimated as a function of the contribution of each sector to total employment. The sector with the largest contribution to employment has been given a weight of 3. Weights of other sectors have been established in proportion to this maximum.[2]

The functions of independent variables are the following (the sign * means "exogenous variable"; and AV means "added value", so AV-Com is the added value of the commercial sector):

2) E-Com = f (AV-Com);
3) E-Const = f (AV-Const);
4) E-ServEnterp = f (AV-ServEnterp);
5) E-PA*;
6) E-Educ = f (AV-Educ);
7) E-TransCom = f (AV-TransCom);
8) E-SanitServ = f (AV-SanitServ).

According to information available, the added value of the sector is the principal factor determining employment.

Block II. AV and AVpc (Total Added Value and Added Value per capita **in Santa Cruz)**

9) AV = f (2.77 AV-Com, 1.88 AV-Const, 3 AV-ServEnterp, 1.81 AV-PA, 1.50 AV-Educ, 2.60 AV-TransCom, 1.41 AV-SanitServ, 1.12 AV-Host, 1.87 AV-FinancInst);

This function is similar to the first equation, but in respect to the total added value. The sectors have been designated in a similar way to the ones of the employment block, replacing "E" with "AV". AV-Host is the added value of the hotel industry and AV-FinancInst is the added value of the finance sector. The weights have been calculated with the same formula used for the first equation, applied in this case to the added values.

The general criterion for the construction of the independent variables functions is that the AV of the sector depending on their demands and the quality of their offers (denoted "QualOf"). In others words, it means that the increase in economic activity in the city of Santa Cruz or in its environment (the rest of Tenerife) will produce an increase in the demand directed at their sectors. In general, the total added value of Santa Cruz (AV) and the total added value of the rest of Tenerife[3] have been used as indicators of their demands. In some cases (for instance the tenth equation), other indicators of demand have been used, but respecting the general criterion.

The "quality of offer" (QualOf) of a sector is defined as the result of the combination of: a) the variety of the products offered (for instance, the diversity of the services offered by the commercial sector); and b) the quotient between the quality of its products offered and its price. Consequently, the variable "QualOf" improves when either the diversity or the quotient increases. Therefore, to increase the value of this vari-

1 The literature on these models is large. See, for instance, Godet 1991a and 1991b and de Jouvenel, 1993. In Legna Verna, 2005: chapter I.1, the use of these models as a tool to prepare strategic decisions is studied.

2 The formula of the weight of the "i"-th sector is: (% of the employment – in respect to the total employment – in the sector that generates the maximum employment/% of the employment – in respect to the total employment – in the "i" sector)x3

3 Tenerife is the island where the city of Santa Cruz is located. More precisely, "rest of Tenerife" should be understood as Tenerife Island minus Santa Cruz.

able, it is necessary to introduce innovations in the sector and to elevate its labour productivity.

The increase of the Added Value of Santa Cruz (AV in the ninth equation) depends on the behaviour of other variables (the independent variables in the ninth equation), which have their own equations. They are the following:

10) AV-Com = f (PurchR; PurchNR), where PurchR = purchases made by the inhabitants of Santa Cruz and PurchNR = purchases made by inhabitant of the rest of Tenerife and tourists**;**
11) AV-Const = f (AV);
12) AV-ServEnterp = f (AV; AVt; QualOfServEnterp);
13) AV-PA*;
14) AV-Educ = f (Prsc; Prnsc) or Prsc = inhabitant of Santa Cruz and Prnsc = population that has its residence near Santa Cruz and that use education services located in this city;
15) AV-TranspCom = f (AV; AVt; QualOfSerTranspCom);
16) AV-SanitServ = f (AV; AVt; QualOfSSS), where QualOfSSS = quality of the offer of sanitation and social services;
17) AV-Host = f (NightT), where NightT = Number of nights that tourists have been lodged in hotels of Santa Cruz, per year;
18) AV-FinancInst = f (AV; AVt; QualOfFinancInst);
19) QualOfSSS* ;
20) QualOfTransCom* ;
21) QualOfFinancInst* ;
22) PurchR = f (AV; QualOfCom)
23) PurchNR = f (AV-t; TR; QualOfCom; LifeQ), where TR = the total revenue left by tourists that visit Tenerife per year (medium revenue multiplied by the number of tourists) and LifeQ = the quality of life of inhabitants of Santa Cruz (that will be definite in Block III;
24) QualOfCom*;
25) AVt*;
26) TR*;
27) QualOfServEnterp* ;
28) NightT = f (AV; LifeQ; QualOfHost) ;
29) QualOfHost*; and
30) QualOfSSS*.
31) AVpc = f (-0.8 AV-Com, -0.2 AV-Const, 0.5 AV-ServEnterp, -0.5 AV-PA, 1.6 AV-TransCom, 0.2 AV-Host, 2.5 AV-FinancInst, 0.7 AV-ProdDistW, -0.2 AV-OtherSServ, 3 AV-ExtProdEner)

According to this function, the added value per worker employed in Santa Cruz either increases or decreases if the weights of the independent variables are positives or negatives. The signs of theses weights depend on the relationships between two quotients: AVpci = (added value by the sector / number of worker in the sector); and AVpc= (total added value in Santa Cruz/total number of workers); i.e. the average labour productivity of the city. If AVpci>AVpc, an increase of the added value of the sector "i", will increase AVpc.[4] This is the reason the sign of its weight is positive. The same reasoning explains the negative values. The absolute values of the weights have been calculated in the function of the contribution of each sector to the total employment and the difference between AVpc and AVpci. An equation such the 30th one is very important in regards to the elaboration of strategies, because it allows the detection of sectors whose increases have stronger effects on the elevation of productivity of the labour force, and therefore, their wages. We have been obliged to adopt the explained form of this equation due to the scarcity of statistics.

The equations of the independent variables that were not definite previously, are the following:

51) AV-EnergProd* = Added Value of Energy Production Sector;[5]
53) AV-OtherSServ = Added Value of Other Social Services Sector= f (AV; QualOfOtherSS);
54) AV-ProdDistW = Added Value of the Production and Distribution of Water Sector = f (AV; Prsc).

Block III: Quality of Life

27) LifeQ = f (-Delinq, -Drug, AdmDesc, -AcPoll, -TrafficProb, Anaga, LeisureLitt, EquipColect, PublicServEfic, HistPatrim, CityClean, AVpc, E)

The independent variables of this equation are the urban and social problems that concern the inhabitants of Santa Cruz and additional two: the total employment and the added value by worker. These two last are included in the equation because of their impact on the revenue of the population. The first group of variables has been selected based on a poll conducted in the city (Ayuntamiento de Santa Cruz de Tenerife, 2006).

The definitions of the new variables are the following:

31) Delinq = Delinquency and insecurity = f (PolDec, ME, PublicServEfic), where ME = Municipality Expenses and PublicServEfic = Efficiency of the delivery of the public services. This equation means that delinquency and insecurity are reduced if the local government implements new policies to solve these problems, increases municipal expenses or augments the efficiency of the services to resolve them. The same formula has been adopted for the following equations, excepting equation number 39.
32) Drug = Drugs = f (PolDec, ME, PublicServEfic);
33) AdmDesc = Administrative Decentralization = f (PolDec, ME, PublicServEfic);
34) AcPoll = Pollution of the environment due to the noise = f (PolDec, ME, PublicServEfic)**;**
35) TrafficProb = Traffic problems = f (PolDec, ME, PublicServEfic);
36) Anaga = Quality of the environment in Anaga (this is an area visited by the population for leisure activities) = f (PolDec, ME, PublicServEfic);

4 This reasoning is *ceteris paribus*, which is to say that the other independent variables are constant. Consequently, it implies that the weight of the sector increases.

5 The numbering of the equations corresponds to their position in the matrix used to perform the analysis of the role of the variables. The construction of the matrix is explained in Annex. Equations are grouped and referenced in blocks, in order to facilitate the understanding of the structure of the model.

37) LeisureLitt = Offer of services and infrastructures for leisure activities on the Santa Cruz coast = f (PolDec, ME, PublicServEfic);
38) PublicInfrast = Offer of public infrastructure = f (PolDec, ME, PublicServEfic);
39) PublicServEffic = f (PolDec);
40) HistPatrim = Conservation and quality of the historic heritage and the degree to which it is accessible to the population = f (PolDec, ME, PublicServEfic);
41) CityClean = Cleanliness of the city = f (PolDec, ME, PublicServEfic); and
42) PolDec*

The meaning of these equations is that if problems such as cleanliness, delinquency, unemployment, etc. are reduced and employment and the productivity of labour rise, the quality of life of the city will increase. It is important to note that the improvement of the quality of life is, at the same time, an attraction to tourists and inhabitants of Tenerife, because it stimulates them to come to the city and to increase their purchasing.

Block IV. Budget and municipal expenses.

43) ME = f (DME, MRT, MRX, PolDec)

The rate of increase of municipal expenses (ME) depends on the increase in the value of the demands that the population makes on the municipality (DME), the revenues of the municipality obtained through taxes (MRT), other revenues obtained through transfers of external institutions (MRX) and on the implementation of municipal policies (PolDec). It is important to note that MRT depends on the general economic activity of the city, creating a feedback between the expenses of the municipality and economic development.

The other functions of this block are the following:

44) MRT = f (FP, AV), where FP = fiscal pressure = total value of paid taxes /AV;
45) FP = f (PolDec, AV);
46) DME = f (Prsc, Prnsc, VNR) where VNR = number of visitors to the city per year;
50) VNR = f (AV, LifeQ);
47) MRX*;
52) DissatDem = f [(DME-ME); -PublicServEfic)], where DissatDem = degree of dissatisfaction of Santa Cruz inhabitants with respect to the problems (delivery of services, reduction of pollution and traffic problems, etc.) that they want solved by the local government.

Block V. Population

48) Prsc = f (E, LifeQ). This means that the population of Santa Cruz depends on total employment and quality of life.
49) Prnsc = f(E) population located in zones near Santa Cruz is a function of employment in the city.

The model has some significant feedback between the blocks (or subsystems). The variables "Employment", "Total added value" and "Added value per capita" of Blocks I and II produce effects on Subsystems III (quality of life) and IV (the municipality budget). The increase (decrease) of the variables of the two first blocks affects the quality of life and the municipal budget and expenses. In turn, these variables react and affect the first ones. In respect to the population, it is determined by the economic development and quality of life of the city; in turn, its augmentation increases the demand for municipal expenses and the pressure on the city. This pressure aggravates some environmental problems, such as pollution, which require additional municipal expenses to be solved.

Analysis of the roles of variables in the system

A typology of variables may be distinguished[6]:

a) Leading variables, which produce strong impacts on the other variables of the system yet are not significantly affected by their changes – directly or indirectly;
b) Interacting or feedback variables, which both produce – directly or indirectly – important impacts over the others and are also affected by their changes;
c) Dependent variables, which are the contrary of the first group because they are very sensitive to the changes of the other variables but do not produce important effects over them; and, finally,
d) Variables that may be discarded, because they neither produce nor receive important effects.

The roles of variables in the Santa Cruz model have been detected by applying the methodology of analysis of leading and depending forces.[7] Their roles are presented in Figure 1, in which the horizontal axis expresses the dependency of the variables and the vertical, their leading force. If its horizontal value is high for a variable, this means that it is strongly affected by the changes in the other variables of the system; if its vertical value is high, this means that its changes produce strong impacts on the other variables. The leading variables have a high value in the vertical axis and a low value in the horizontal one; however, the dependent variables have a high dependency and a low leading force. The feedback variables have high values in both the vertical and horizontal axis.[8] They strongly interact and produce feedback processes in the system. Consequently, they may multiply the initial changes produced in one or some variables, pushing the system out of its previous state.

In Figure 1, the leading variables (LV) are in the first quadrant. They are the added values of a set of branches, between which three sub-groups may be distinguished:

a) LV1 (in green), that includes qualified "Services delivered to enterprises and real estate services" (AV-ServEnterp), "Transports and Communications" (AV-TranspCom), and "Financial services" (AV-FinancInst);
b) LV2 (in red), "Commerce" (AV-Com), "Construction" (AV-Const) and "Public administration" (AV-PA); and,
c) LV3 (in black), "Education services" (AV-Educ). In spite of the fact that they are not in the first quadrant, we consider that the added values of "Sanitation and other social services" (AV-SaniyServ) and "Hotel industry" (AV-Host) are leading forces, because they have important values in

6 See, for instance, Legna Verna, 2005: chapter I.2 and Roubelat, 1993: 258.
7 See Legna Verna, 2005: chapter I.2
8 See Annex

the vertical axis. Evidently, their leading power is weaker than the preceding ones. It is also important to note that "Financial services", "Transport and Communications", "Delivery of services to enterprises" and "Sanitation and other Social Services" have an important dependency and, consequently, they play an interacting role in the system. In fact, the role of these four variables is not easy to classify neatly. We may consider them both as "interacting variables with a high degree of leadership" or "leading variables with a high degree of interaction".

In the second quadrant are the strictly interacting variables (IV). In this model, there is only one variable pertaining to this category: the value added of the city, which has a very strong leading force and dependency.

Usually, in the leading and dependency analysis, the dependent variables (DV) are the ones that fall in the third quadrant. Nevertheless, in the study of the Santa Cruz model we have included in this category of variables some other ones that are in the fourth quadrant, because they have an important value in their horizontal. They are in the fourth quadrant because AV has a high value of dependency and displace to the right the vertical line separating the quadrants. The dependent variables have been classified into three categories:

a) DV1, the per capita added value of Santa Cruz (AVpc) and the quality of life ((LifeQ);
b) DV2), the demands that the population make on the municipality (DME), the revenues the municipality obtains through taxes (MRT) and fiscal pressure (FP);
c) DV3) the number of nights per year that tourists have been lodged in Santa Cruz (NightT), the number of visitors that came to the city per year (VNR) – an indicator of the external demand made on what the city offers, particularly on the commercial sector – and the purchases made by the inhabitants of Santa Cruz (PurchR).

The colours assigned to the abbreviated names of the variables have different meanings: green means that the productivity of the labour force working in the sector is superior to the city average; red means that the productivity is lower; and black means that it is approximately equal to the average. Productivity is defined as follows: AVi/Ei, where AVi = added value of the "i" sector and Ei = number of persons working in the same sector "i". Therefore, if the share of the employment of a green sector increases in respect to the total employment of the city, it produces an augmentation of the average labour productivity; and it decreases if a red sector has a higher weight.

The preceding analysis allows an understanding of the structure and functioning of Santa Cruz's system. The increase (or decrease) of activity in leading sectors – services to enterprises, transport and communication, finance, construction, commerce, public administration and education – augments (or reduces) the total employment and the added value of Santa Cruz. These last two sectors return the effects, producing an increase (decrease) of the activity of the leading forces, particularly in services to enterprises, finance and transport and communication, which have an important dependency value. However, these are not the only loops. The general increase (decrease) of economic activity and employment produces an increase in revenue for the city's public budget, which in turn satisfies the population's demands and improves quality of life. In turn, the improving quality of life generates a new wave of effects: because it is an attraction for foreign visitors, demand on the city's production sector increases. If the more dynamic sectors are the "green" ones, which have a high productivity, there will be a general increase of per capita revenue. It follows that policies oriented towards the increase in added value of services to enterprises, finance, transport, and communication are crucial; it is likewise important to increase the productivity of certain sectors, such as commerce, which have an important weight in the employment sector but do not have a high labour productivity.

2.2 Second step: identification of the main characteristics of the tendency scenario

The first step of the methodology detects the main variables that lead the system. On the basis of this result, the second step focuses on the analysis of the tendencies of these variables, to obtain information about the **direction** that the system is taking. If it is going in a negative direction, it will be necessary to design a strategy with the aim of changing this direction. If it is going in a positive one, the strategy will be orientated to reinforcing the direction.

The tendencies that affected Santa Cruz in the last decades produced a decline in the relative significance of the city, both in the context of Tenerife Island and of the Canary Islands Region (more information about this section can be found in Guirao 2007).

The ratio of Santa Cruz's population to the total population of its island and to the total of the Canary Islands has been decreasing. More importantly, according to the Statistics Institute of Canary Islands (ISTAC), the population of the city is projected to decrease in the future, from 203,795 inhabitants in 1996 (1st. January) to 184,430 (1st. January) in 2011[9]. The same tendencies affect both the number of persons who pay the revenue tax and therefore the fiscal revenues generated by it (Table 1). For instance, the number of persons who declared this tax increased in Santa Cruz by 29% between 1991 and 1998 while it increased more than 80% in Tenerife and in the Canary Islands during the same period. The same tendency is observed for the fiscal revenues generated by this tax. It is a good indicator of the general reduction of the weight of economic activity in relation to both Tenerife and the Canary Islands region.

Nevertheless, not all economic activities have been affected by the tendency to decline. Some have been resilient, as may be observed in Table 2, which shows the rates of increase in employment in Santa Cruz, Tenerife and Canary Islands, between 1999 and 2002. In this table, the sectors have been differentiated with colours according to their role and their rate of increase of employment. In the first column, the coloured ones are the leading sectors; green indicates that the labour productivity is higher than the average; red that it is lower than

9 The information of the ISTAC was obtained from its web page, on 09/02/2005.

Table 1: Increase (in %) of the persons that pay the IRPF (revenue tax on physical persons[10]) and of the fiscal revenues generates by this tax, between 1991 and 1998

-	Increase, in %, of the number of persons that pay the IRPF	Increase, in %, of the fiscal revenues due to the IRPF
Santa Cruz de Tenerife	29.43	9.20
Tenerife Island	88.10	31.51
Grand Canary Island	81.26	29.99

Source: calculations made on the basis of data of the "Avance del Plan Estratégico de Tenerife"

average; and black that it is similar to the average. In the other columns, green means a rate of increase of the employment higher than the average; light green that it is approximately similar to the rate of Tenerife and Canary Islands and red that the rate is lower in Santa Cruz.

Regarding the more productive leading sectors, it may be observed that Santa Cruz loses weight in "Hotel Industry" and "Financial Services"; but "Transports and Communications", and "Services provided to Enterprises and Real Estate Services", maintain their relative weight. This same behaviour is observed in two sectors with low labour productivity but that are important from the point of view of the generation of employment: commerce and construction. Finally, both "Public Administration" and "Education", which have labour productivity similar to the average, lose their participation.

Evidently, Santa Cruz is not going in the right direction. The third step of the methodology is oriented to study the effects of alternative strategy decision to lead the system to the desired scenario.

2.3 Third step: application of System Dynamics to the relationships of the qualitative model and estimation of the impacts of alternative strategies.

The qualitative model and the analysis of leading and depending forces allow the selection of the relevant variables

Table 2. Rate of increase of employment of the branches between the third term of 1999 and 2002

Branches	St. Cruz	Tenerife	Canary Is.
A. Agriculture and cattle	1.33	1.13	1.08
B. Fishing	0.60	0.75	0.70
C. Extractive Industries	1.36	1.18	1.24
D. Manufacturing industry	1.01	1.06	1.03
E. Prod. and distrib. of electric energy, gas, steam and hot water	0.87	0.98	0.94
F. Construction	1.22	1.25	1.21
G. Commerce, repairing of vehic. and other articles.	1.16	1.16	1.16
H. Hotel industry	1.04	1.12	1.14
I. Transports, storing and communications.	1.07	1.08	1.05
J. Financial services.	1.06	1.08	1.1
K. Serv. to enterprises and real estate services.	1.21	1.23	1.21
L. Public, administration, defence and social services	1.17	1.19	1.11
M. Education	0.94	1.04	1.04
N. Sanitation and veterinary serv. and other social services	1.02	1.1	1.15
O. Social activ., services to the community and personal services	1.14	1.23	1.25
P. Personal services provided at homes	1.19	1.14	1.18
Q. Employment in extraterritorial organizations	1.75	1.6	1.19

The calculations where made using the statistics of the ISTAC. The values in columns 3, 4 and 5 are equal to: Ei2002/Ei1999, where Ei2002 = employment in the sector "i" during the third term of 2002 and the same definition for Ei1999.

10 In Spanish IRPF = Impues to a la Renta de Personas Físicas.

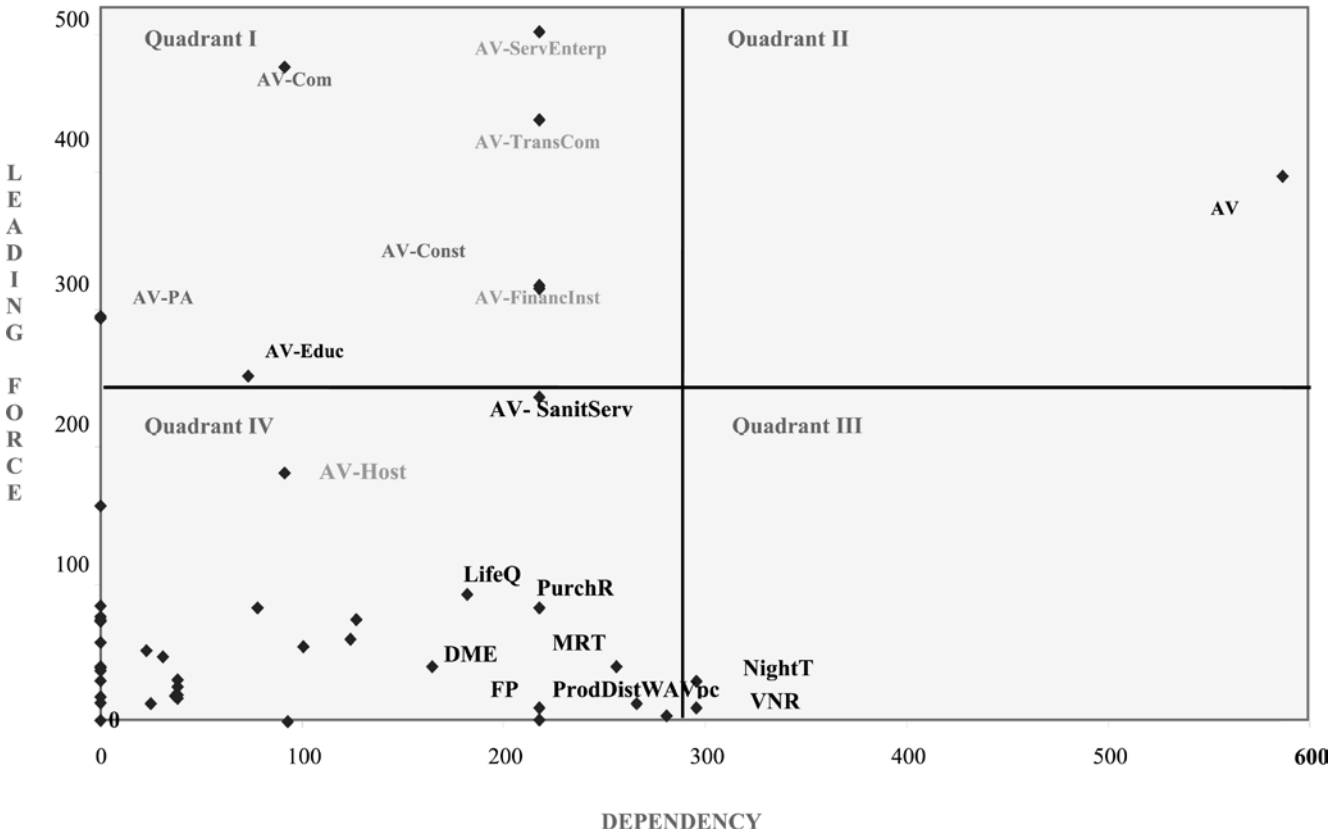

Figure 1: Variables leading and dependency force

and the detection of their role in the system. This is an important step in order to make decisions.

Figure 2 represents causal loop diagram (CLD) of aggregated model. The most important variable in the model is life quality, which is the main variable in the system. An increase in life quality increases the added value and quality of services above the level that it would otherwise have been. This positively influences the productivity and improves human capital as well as life quality. Life quality also positively influences the level of education, which contributes to the preservation of natural resources as well as the improvement of human capital. The described causal loop has a positive character which leads to self improvements of the system. However, one should also consider the limitation of natural resources, which are also shown in the diagram. An important strategic point that is revealed by the model is the following: to improve the quality of life of the citizens it is not only important from the point of the well being of the citizen but is important too from the point of view of the economic activity. So, the quality of the city (low pollution, crimes, transport problems, etc.) and its economic growth go in the same direction. There is no a trade off between environment and quality of life of the city and economic activity.

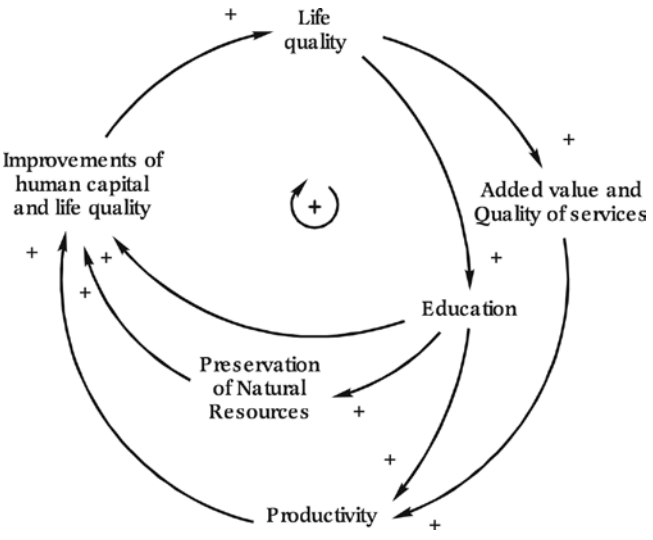

Figure 2: Causal Loop Diagram of aggregated model

A further step can be taken that consists of the application of system dynamics to the variables and the relationships of that model. Using Powersim software, the qualitative model was "translated" into a system dynamics model. Figure 3 presents the relationships that generate the increase in quality of life (LifeQ); Figure 4 in employment (E°); Figure 5 in per capita added value (AVpc°); and Figure 6 in total added value of Santa Cruz.

Simulations were conducted to estimate the effects of various decisions, each one implicating the adoption of a strategic option. For example: one option may be to opt for a higher specialization of Santa Cruz in the commercial sector; a second one is a higher specialization in qualified services to

enterprises; a third one is an increasing specialization in financial services, and so on.

If the first option is chosen as opposed to the second, the rates of increase in quality of life, the added value per capita, and the added value in the qualified services to enterprises sector will all be lower; in turn, the rates of growth in employment and the added value of the commercial sector will be higher. In other words, each strategic option steers the city towards two different scenarios: one characterized by higher qualified labour with elevated productivity and, another, by the opposite.

3 Discussion

The methodology that has been explained in this article helps to improve the decision-making process in a variety of ways. It permits a better understanding of the relevant characteristics of the structure of the social system and the role of the main variables in it. With this information, the specialists and the decision makers will know in which direction the changes of the variables will lead the system. Moreover, they will know which variables are strategic, because their changes will produce the strongest effects. If it is possible, the strategy has to implement policies to change the behaviour of these variables. In the case of the ones that are not possible (for example, the GDP of Tenerife Island is an exogenous variable that has an important impact on the evolution of Santa Cruz), the specialists and the decision makers know that they have to constantly predict their evolution. With this information, they will be better equipped to design policies orientated to mitigating the undesirable impacts of the evolution of these variables and to improving the positive effects. For instance, the present economic crisis has been producing a reduction in the number of tourists that visit Tenerife and, consequently, a decline of its GDP. In turn, it has produced a decline of the GDP of Santa Cruz and an increase in unemployment. Knowing these relationships, our team, working along with the authorities, has designed policies to reduce the negative impacts of the evolution of this variable.

With respect to the analysis of the alternative strategic decisions, it is important to emphasize that the methodology permits the prediction of the directions that the system will take as a consequence of these decisions. They are not quantified projections. They only provide the decision makers with information that allows them to visualize in which direction the system will move as the result of the implementation of a strategic decision. If the decision makers have selected a desired scenario, this approach allows them to determine if a particular strategic decision leads the system in the direction of it.

The application of system dynamics is also useful in estimating the effects of the hypotheses adopted and the changes of the preferences of the population with the purpose of selecting the strategy. Because of the lack of information, it was initially supposed that the population assigned the same importance to the level of employment and the per capita added value as variables that determine his level of quality of life (between others). The following step consisted of performing simulations that assigned different weights at these two variables. These simulations made it possible to appreciate that if the population considers the per capita added value to be more important than the level of employment, a strategy that accelerates the growth of sectors such as "Services to enterprises and real estate services" would be preferable than a strategy that accelerate the increase of "Commerce". On the contrary, it would be preferable to give priority to this sector if the population valued employment more than its per capita revenue. This approach allows performing analysis of the kind "What happens if…?" (for example, environment becomes a more valued variable, etc.). At present, these studies are being carried out in conjunction with the authorities of Santa Cruz.

4 Annex

The equations of these qualitative models may be written as a matrix. If they are the following: 1) A = f(2B; C), 2) B = f(C) and 3) C = f (3B) the associated matrix (M) is

	A	B	C	Σ
A	0	0	0	0
B	2	0	3	5
C	1	1	0	2
Σ	3	1	3	

For instance, column A has a 2 in line B and a 1 in line C, because A is affected by the changes of B and C (and it is

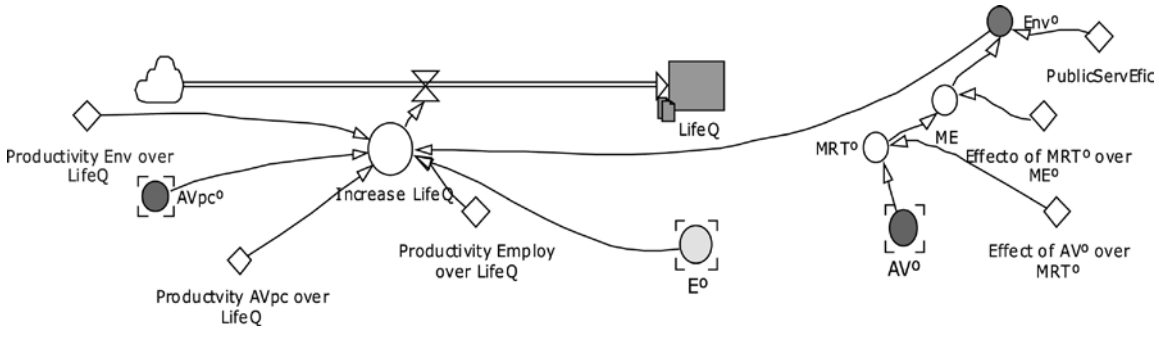

Figure 3: Relationships that generate the increase in quality of life (LifeQ)

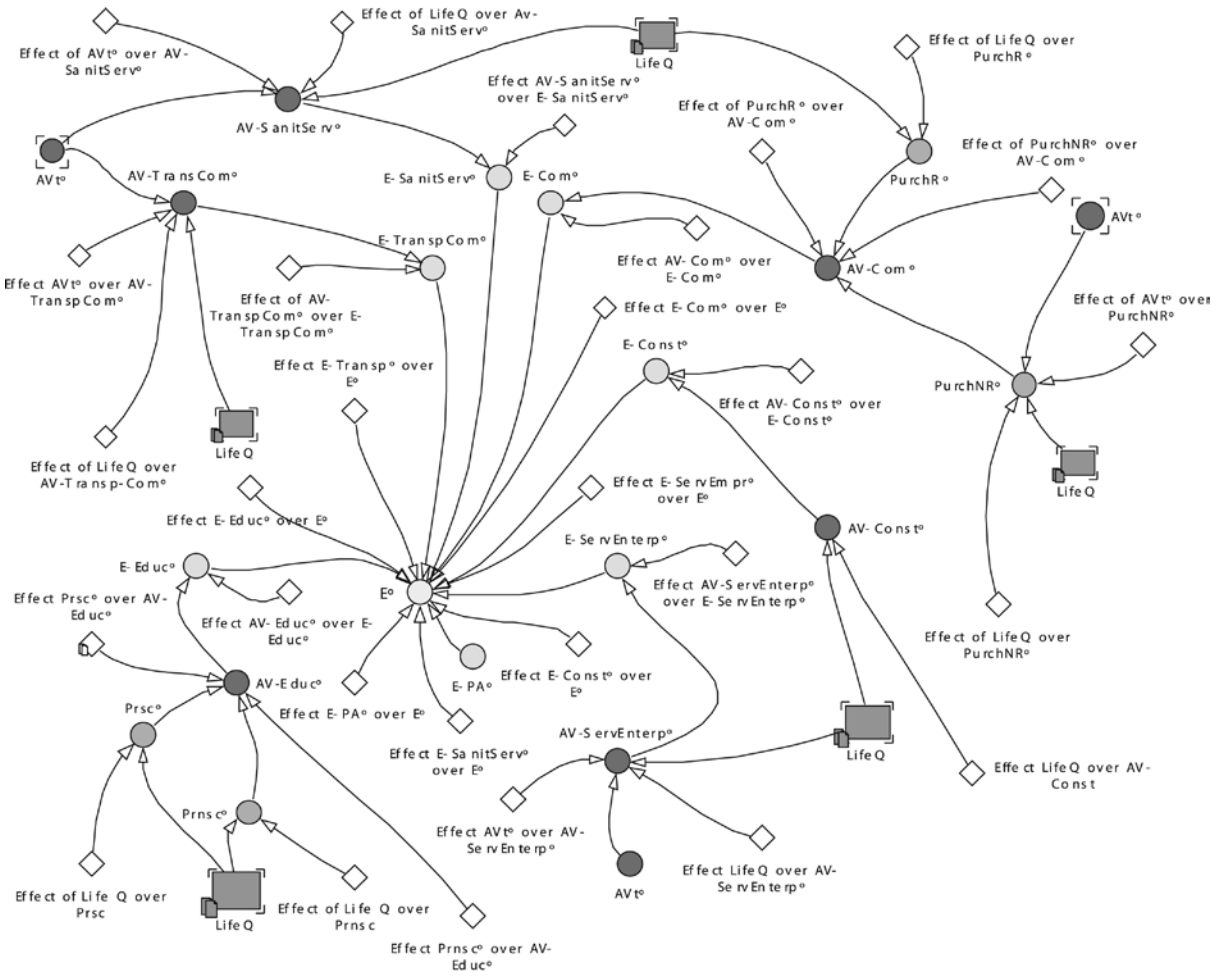

Figure 4: Employment (E°) subsystem

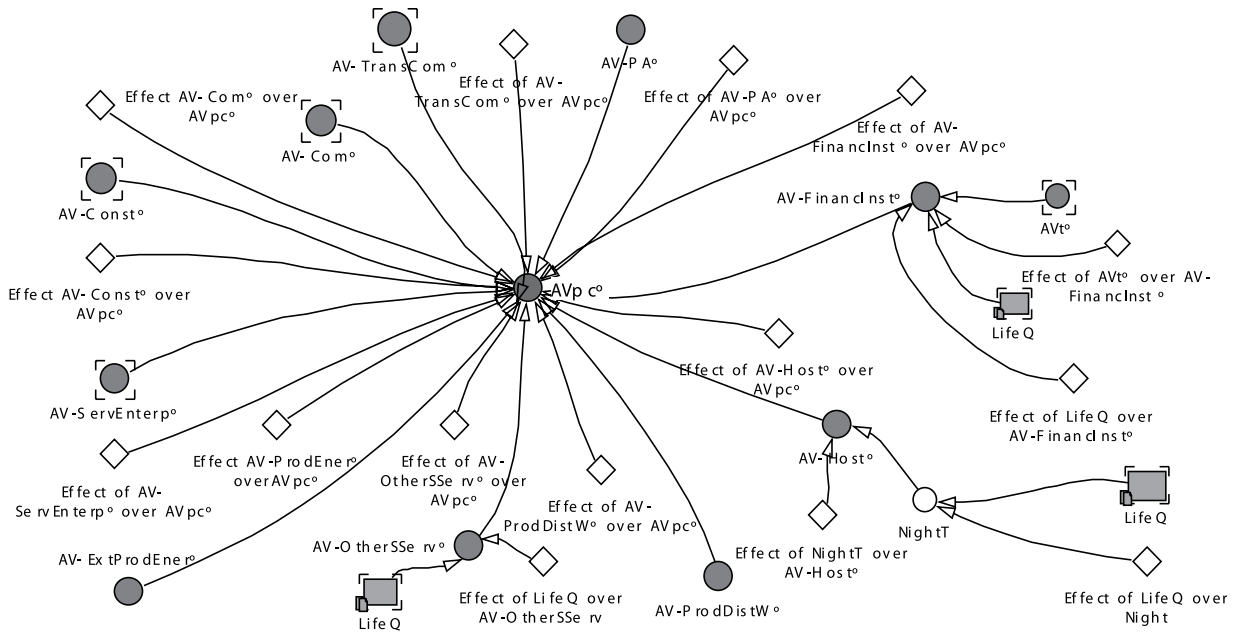

Figure 5: Per capita added value (AVpc°)

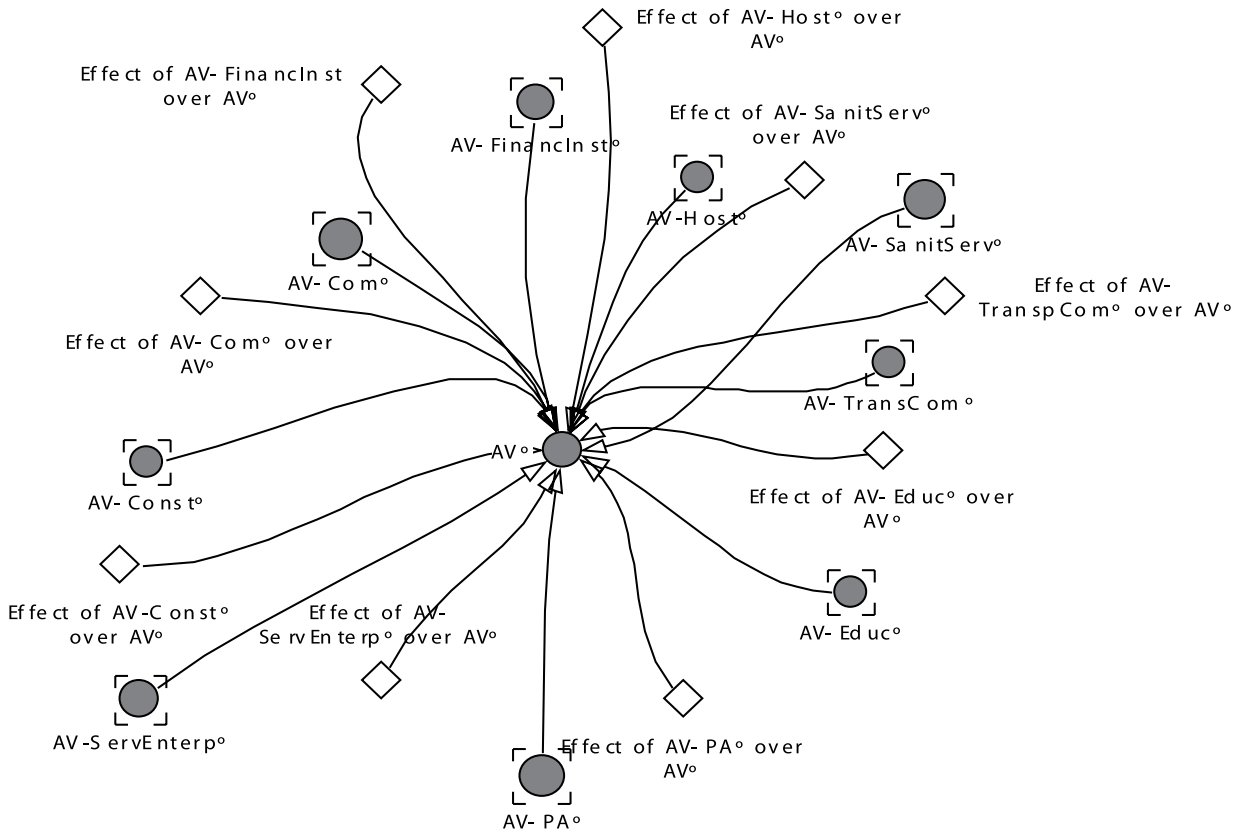

Figure 6: Total added value of Santa Cruz

estimated that a change of B produces a change in A that is double than the change in A due to a change in C). In general, if case $x_{ij} = 1$, it means that a change in variable i produces a change in j. If it is equal to zero, there is no effect from i to j. Consequently, the sum of the cases of the line of a variable is its leading force; the sum of the cases of its column indicates the dependency of the variable. For instance, variable A is essentially dependent, because the sum if its column is 3 and the sum of its line is 0; in contrast, B is a leading variable. Therefore, this matrix M allows the detection of the **direct** effects between the variables. Nevertheless, in social systems the **indirect** influences are important, which are detected by the multiplication of M. It may be demonstrated that if M is elevated at two, each case aij of the new matrix (M^2) 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 (Legna Verna, 2005: chapter I.2). If the matrix is elevated at four (M^4), it will reveal the effects that pass through three intermediate variables, and so on. In the case of this work, we elevated M at four. Figure 1 represents, for each variable, the sums of its line (vertical axis) and of its column (horizontal axis) in M^4. Consequently, the vertical axis of Figure 1 indicates the leading force of a variable and the horizontal its dependency. With regard to units, if a case of M^4 is $x_{ij}^4 = 1$, it means that there is one path $X_i \rightarrow X_u \rightarrow X_v \rightarrow X_w \rightarrow X_j$ that "transits" the effect of the change initiated in X_i until it produces a change in X_j. If it is 2, there are two paths, and so on. This result is valid only if the matrix M has merely values of one and zero. If the cases have other values (for instance, twos and threes) the figures of the cases indicates the relative force of the indirect effects of i over j.

5 References

Ayuntamiento de Santa Cruz de Tenerife. (2006). Plan General de Ordenación de Santa Cruz Tenerife. Mimeo, not published.

Jouvenel H. de., (1993). Sur la démarche prospective, *Futuribles*, Paris, 9, 51-69.

Godet, M. (1991a). *De l'anticipation à l'action*. Paris: Dunod.

Godet, M. (1991b). *L'avenir autrement*. Paris: Armand Colin.

Guirao Pérez, G. Hernández Hernández J., Legna Verna C. A. & Macías Hernández A. (2007). Navarro Ibáñez M. and Rivero Ceballos J. *Santa Cruz de Tenerife: capital insular y metrópoli atlántica. Tendencias y estrategias*. Santa Cruz de Tenerife: Delta Publicaciones.

Kljajić, M., Škraba A. & Legna Verna C. A. (2002). System Dynamics Model of the Canary Islands for Supporting Strategic Public Decisions. Paper presented at the annual international meeting for the System Dynamics Society. June 28-August 1st in Palermo, Italy.

Kljajić, M. Škraba A. & Legna Verna C. A. (2003a). Simulation Model of Canary Islands, preliminary results. Paper presented at the annual international meeting for the System Dynamics Society. July 20-24 in New York, United States.

Kljajić, M. Škraba A. & Legna Verna C. A. (2003b). Simulation Model of Canary Islands for Public Decision Support. Paper

presented at the International Conference on Applied Simulation and Modelling, September 3-5 in Marbella, Spain.

Kljajić, M., Bernik, I. & Škraba, A. (2000). Simulation Approach to Decision Assessment in Enterprises. *Simulation*, 75(4), 199–210, DOI: 10.1177/003754970007500402.

Legna Verna, C. A. & González González, C. (2004). An intelligent decision support system (IDSS) for public decisions using systems dynamic and case base reasoning (CBR) Paper presented at the annual international meeting of the System Dynamics Society, July 25-29 in Oxford, Great Britain.

Legna Verna, C. A. & González González, C. (2006). Application of System Dynamics and Case Base Reasoning (CBR) to build an Intelligent Decision Support System (IDSS) to improve Strategic Public Decisions. In *Intelligent Decision-Making Support Systems (i-DMSS): Foundations, Applications and Challenges, eds.* Jatinder Gupta, Guisseppi Forgionne and Manuel Mora, pp. 255-271. Bedford: Springer-Verlag.

Legna Verna, C. A., Kljajić, M. & Škraba, A. (2005). Development of Simulation Model of the Canary Islands for Strategic Decision Making. *Organizacija*, 38(5): 519-529 (special issue: Simulation-based Decision Support).

Legna Verna, C. A., Kljajić, M. & Škraba, A. (2005). System Dynamics Model of the Canary Islands for Strategic Public Decision Support. *Organizacija*, 38(5), 508-518 (special issue: Simulation based Decision Support).

Legna Verna, C. A. (2000). Knowledge and knowledge management for the improvement of strategic public decisions. In *Decision Support through Knowledge Management,* ed. Department of Computation and Systems Sciences of the Stockholm University and the Royal Institute of Technology Sweden, pp. 100-113. Stockholm: Royal Institute of Technology.

Legna Verna, C. A. (2005). *Gestión pública estratégica y prospectiva, con aplicaciones al ámbito regional*. Badajoz: Abecedario.

Roubelat, F. 1993. L'analyse structurelle. In *La Prospective, Pratiques et Méthodes eds.* Hatem, F. Cazes, B. and Roubelat, F. Paris: Economica.

Sterman, J. D. (1994). Learning in and about complex systems. *System Dynamics Review*, 10(2), 291-330, DOI: 10.1002/sdr.4260100214, .

Škraba, A., Kljajić, M. & Borštnar, M. K. (2007). The role of information feedback in the management group decision-making process applying system dynamics models, *Group Decision and Negotiation*, 16(1) 77-95.

Škraba, A., Kljajić, M. & Leskovar, R. (2003): Group Exploration of SD Models – Is there a Place for a Feedback Loop in the Decision Process?, *System Dynamics Review*, 19(3), 243-263, DOI: 10.1002/sdr.274.

Carlos A. Legna Verna has a Ph.D. in economics (Pierre Mendés France University, Grenoble, France). He was an expert of the United Nations Technical Cooperation for the development in Latin America and Africa. He has specialized in development theory and public decision-making, particularly in Decision Support Systems and Decision Making using System Dynamics and scenarios. He is a professor of Strategic Regional Planning, Regional Policy and Evaluation of Social Project at La Laguna University, Spain. He has published Gestión Pública Estratégica y Prospectiva, con aplicaciones al ámbito regional, and articles on public decision-making and System Dynamics. He's member of the System Dynamic Society.

Andrej Škraba obtained his Ph.D. in the field of organizational sciences from the University of Maribor. He works as a researcher and assistant professor at the Faculty of Organizational Sciences in the Cybernetics and DSS Laboratory. His research interests cover modelling and simulation, system dynamics, systems theory and decision processes. His recent interests have been focused on the analysis of nonlinear chaotic systems.