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Modeling Sustainable Location of Economic Activities

Carlos A. N. Cosenza - Ph.D.

Professor Emeritus, Federal University of Rio de Janeiro
Av. Horacio Macedo 2030, Centro de Tecnologia
Rio de Janeiro, RJ, Brazil
cosenza@pep.ufrj.br, cosenzacoppe@gmail.com

Cesar das Neves - Ph.D.

Full Professor, Federal University of Rio de Janeiro
Av. Horacio Macedo 2030, Centro de Tecnologia
Rio de Janeiro, RJ, Brazil
cdn@poli.ufrj.br

Ademir Clemente - Ph.D.

Full Professor, Federal University of Parana
Av. Lothario Meissner 632, Jardim Botanico
80210-170 Curitiba, PR, Brazil
ademir@ufpr.br

Abstract:*This article proposes an economic activity location model centred on the principle of sustainability. For this purpose the environment is considered in an ample sense, encompassing tangible and intangible components and their dynamics.This requires the use of the social entropy concept. The decision to insert a project into the environment generates a sequence of two-way effects,i.e., a long-term trajectory that is subject to a number of other decisions. A sustainable location decisionis the project-site combination that causes the lesser increase in socialentropy.The proposed model identifies the relevant variables and their relationships. It alsoindicates simulation and fuzzy logic to handle different technological paths, different sets of public and private investments, and changes in regulation. Despite the model is obviously not exact, it offers valuable information to public and private actors, so they can negotiate on a nearly objective basis.Finally, the model shows how to effectively enable decision makers to pursue sustainability.*

Keywords:*Location decision;Sustainability; Social entropy;Environment;Land use; Regional and local development; Spatial equilibrium.*

Abbreviations:

COPPE–Graduate School and Research in Engineering
CSR - Corporate social responsibility
MASTERLI - *Modello di assettoterritoriale e localizzazioneindustriale*
MIT - Massachusetts Institute of Technology
UFRJ – Federal University of Rio de Janeiro
UFPR – Federal University of Parana
SET - Social Entropy Theory
SOMEA -*Società per la matematica e l'economiaapplicate*

1. INTRODUCTION

The location decision is critical for every business organization. Such a decision is complex and mostly irreversible, requires large amounts of resources, and generates effects on costs and revenues over a long time period. The factors influencing costs and revenues associated with a specific location decision develop not only in the short-term but also in the long-term (Söderman, 1975). In brief, a company's location decision is usually expensive and risky.

Concentration and corresponding spatial disequilibrium derive from the nature of the location decision. The business decision maker, in addition to costs and revenues and their variations within geographical space, has to take into account the risk. It is intuitive that places and regions that already present prominent economic activity seem less risky and, for this reason, decision makers will prefer them unless their costs and revenues are clearly unfavorable.

The traditional location theory focused only on the effects of the environment on projects and neglected that projects also exert influences on the environment. Factors like raw materials, qualified labour force, transport infrastructure, and business climate exert influence on location decisions and are also influenced by them. A notable exception to the traditional approach is the Driving Company (or Industry) Theory by François Perroux. He considered the driving forces derived from a main investment as determining the growth pattern of the surrounding region (Perroux, 1961 and 1968).

From society's viewpoint, location decisions are important because they influence the labour market, create earnings and public revenues, and attract new investments. New economic activities change the socioeconomic structure and accelerate local and regional growth.

In the past, companies have made location decisions only on the basis of factors influencing their economic-financial results. Nonetheless,the present day society has adopted a new lifestyle and new patterns of consumption. Businesses face the challenge of adopting new methods of location and production. Regulation became essential to control the effects on the environment and the society. However, is not enough because the old habits are widespread and well established. By itself regulation by public authorities is not capable of redirecting society towards sustainability. This requires consciousness and concern of everyone, particularly business managers, who make the most crucial decisions affecting preservation, social outcomes, and sustainability.

A central question in this scenario is whether private and public goals should be combined towards sustainability. Problems like overused resources and spatial disequilibrium are not automatically mitigated by unrestricted earnings seeking companies. Sustainability is a result of complex inter-linkages and inter-relations among social and natural factors (Lozano, 2008) and requires specific methodologies of measurement (Korhonen, 2004; Veleva and Ellenbecker, 2001). In pursuing sustainability location decision analysis has to encompass effects on the natural environment and society.

A given spatial pattern results from earlier location decisions and exerts influence on present and future ones. Location decisions result from earlier ones and will influence future ones in the changing socioeconomic environment markedly affected by new technologies. So, public investments and regulations, in addition to technological advances, are basic forces in determining the rhythm and composition of local and regional development.

The preceding considerations make clear that the conventional concept of environment is no longer adequate for analysing location decisions. The interaction between projects and sites includes not just flows of materials and energy but also a variety of social effects. One needs a wide and complex concept of environment that includes tangible and intangible elements and contemplates their interaction with each other over time.

Considering that a project insertion in a site is an external action that gives rise to a complex long-term process of diversified mutual effects, optimal location decisions should cause the smallest impacts on the society´s ability to guarantee its future existence and well-being. Then, the present article focuses on the following question: What variables and relationships are relevant to sustainable location decisions of economic activities?

The aim is to develop a model capable of indicating sustainable location decisions of economic activities. Such a model deals with short and long-term effects, both from projects on their surroundings and vice versa, and pursues the smallest overall increase in social entropy.

Over the last thirty years, authors in different scientific fields have discussed sustainability and developed practical applications. Despite the obvious implication that location decisions exert on sustainability, both direct and indirect, via interaction with each other, the issue did not receive much attention. So far the efforts in developing recommendations and regulations towards sustainable location decisionslack a well-established theoretical support (Terouhidet al., 2012).

In medium-sized and large companies selecting a new location usually requires a qualified team of managers, significant time and effort, and implies high costs. Despite this, the results are heavily influenced by beliefs and feelings. The proposed model outlines the main factors involved and establishes the relevant relationships for sustainability. Thus, it provides business decision makers and public authorities with a comprehensive depiction.

Analysing location decisions under an ample concept of environment and considering the two-way effects over time help public administrators in planning local and regional development. This also helps in formulating and implementing public policies related to land use and preservation.

This article has five other sections. The second section drafts a historical review of location theory. The third section presents the concepts of environment, social entropy, and sustainability. The fourth section introduces the basics of the model. The fifth section presents the model, and the last section consists of concluding remarks.

2. BRIEF HISTORICAL REVIEW OF THE LOCATION THEORY

This historical review presents a summary of the traditional location theories and recent contributions.

2.1. Traditional Theoretical Approaches

Until the recent past prevaileda tradition initiated by Francis Bacon that science and technology were primarily sources of knowledge for dominating nature. Development was understood as the exploitation of natural resources and energy to provide comfort and security to humankind. Sometimes authors justified this by mentioning hunger and misery (Leiss, 1974). In this context,for nearly two centuries, economic activities, highlighting industry, grew and diversified focusing on costs and the market.

As a result, the traditional theory of location was directed to searching the more advantageous sites strictly from the companies' standpoint (Greenhut, 1956; Hoover, 1948; Isard, 1972; Weber, 1929). These theoretical approaches concentrated on selecting the location of minimum cost, except Lösh who devoted his model to the location of maximum profit (Lösh, 1954). All these theoretical models supposed the environment to be a limitless, passive supplier of resources.

In turn, urban economics concentrated on general patterns of land use and hierarchical organization of places. It paid less attention to individual location decisions. Thünen's model originally applied to agricultural location patterns and provided the basis for studies on land use. The celebrated model by Christaller furnished the guidelines to research place hierarchyand space organization (Christaller, 1933; Thünen, 1826). In brief, urban economics, in contrast with location theory, privileged studies and analyses at the macro level. One could say that individual location decisions seemed promptly predictable or unimportant from the urban economics standpoint.

The reasoning of the advantageous location strictly from the companies' standpoint had its climax with the model by the*Società per la matematica e l'economiaapplicate* (Somea, 1971), named *Modello di assettoterritoriale e localizzazione industrial* (Masterli). This model consists of two matrices: one matrix represents the industrial sectors' demand for a given set of locational factors and the other the supply of the same set of factors by predefined zones. A locational index was then calculated by comparing factors' demand and supply for each sector-zone pair according to the idea that the more supply satisfies demand, the better a location is.

2.2. Industrial Location Theory

Alfred Weber defined *industrial location factor*as a cost reduction derived from the industrial location choice. He considered labour cost and transport cost as the main factors influencing industrial location at the regional level. Inside regions, agglomerative and deglomerativefactors were responsible for concentration or dispersion (Weber, 1929).

Walter Isard associated transport costs with interest rate: for him the cost of transporting people and goods in space is comparable to the cost of transporting money over time (Richardson, 1979). He thought of transport costs as corresponding to resource allocation to overcome distances – the so called transport input. Although he gave some importance to market areas, transport costsplaid a central role in his theoretical approach (Isard, 1951[a], 1951[b], 1972).

August Lösh presented a very different concept. From his viewpoint, explaining a company's actual decision on location is a minor objective. His approach was devoted to model the way companies should select their locations. Instead of minimum cost, he elected maximum profitas the objective. By supposing a homogeneous and isotropic, large region, he derived the celebrated demand cone. Then, by adding competition between producers he obtained the ideal hexagonal market areas (Lösh, 1954).

These theories present, as a common feature, the focus on the effects the environment exerts on projects and presume that all the effects the projects exert on the environment are beneficial, favouring new locations, or do not exist.

Even though urban economics and industrial location theory never integrated, location decisions and land use are inextricably linked. Spatial patterns of economic activities result from regulations, public investments and individual decisions. Regulations tend to exert stronger influence in urban areas where land use is markedly regulated. At the same time, location decisions are interdependent, produce new spatial patterns, emphasize the existing ones and exert influence on land use regulation and public investments (Aladeet al., 2011; BodenmannandAxhausen, 2010; Camacho, 2012;Kim, 2010; United Nations, 2011).

2.3. The Location Decision Process

Companies' location decisions are crucial because present long-term effects, are mostly irreversible, present high costs, demand a lot of effort in terms of time and people andinvolve great amounts of investment. They are unavoidably risky, as available information is always incomplete and imperfect. Furthermore, if decisions related to products, markets, technology, and scale overlap the location decision;the process inside companies will be highly complex.

Söderman (1975), *apud* Clemente (1982), carried out a detailed empirical study on the industrial location process. Straight from empirical data, observation and interviews with executives involved in location planning he drew a model whose sketch is presented in Figure 1. Boxes represent variables; ellipses, factors influencing variables; arrows in the same direction, direct relation; and arrows in the opposite direction, inverse relation.

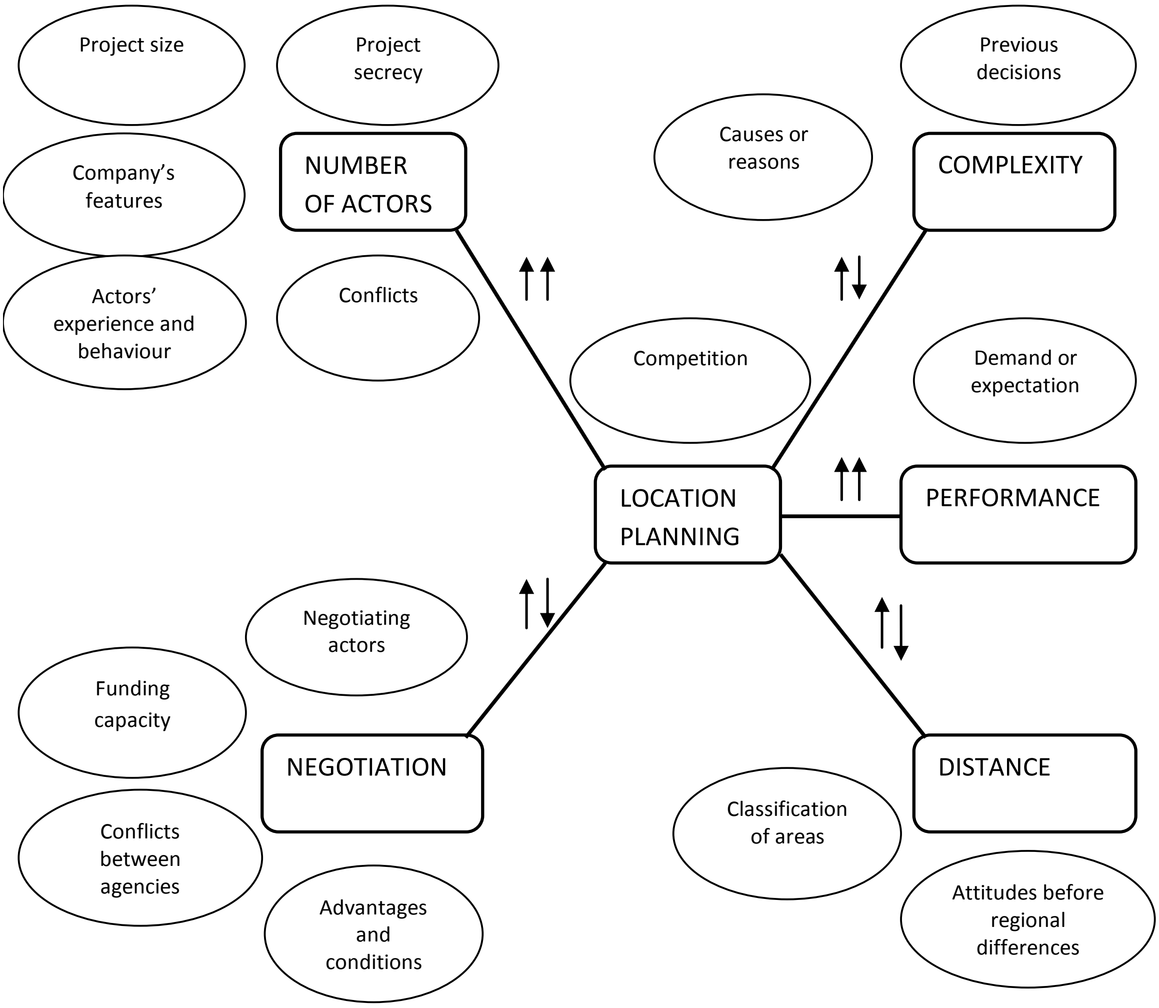

Figure1.*Söderman's industrial location model*

The Söderman's objective was to build a model representative of the location decision practice in industry. He studied Swedish and British companies and aimed at:1) Explaining how much location planning they do; and 2) Relating the quantity of location planning to performance.

2.4. The Coppe-Cosenza Model and New Concerns

The Coppe-Cosenza Model adopts a two-fold approach: rather than just meeting industry demands, or more generally economic activities' demands, the model also considers developing the geographic areas, named elementary or planning zones. In this case, the territorial units represent planning entities and no longer the exclusive passive function of input suppliers (Cosenza, 1981; Clemente, 1977, 2008). This conception brought about several applications (Carvalho, 2007; Chamovitz, 2010; Chamovitzand Cosenza, 2010).

Even though the Coppe-Cosenza Model represents an advance, two problems still remain: 1) A site's growth potential is solely assessed as its capability to meet the demands of a predefined set of projects, and 2) The demand and supply matrices represent only a given situation in time.

In fact, a whole range of exchanges starts when a project falls within the environment. Such exchanges derive from the effects of the project on the environment and vice versa. According to a dynamic process whose specificity depends on the project and geographic area in which the insertion occurs, it also depends on how the project and geographic area evolve over time.

The future trajectory of interchanges between a given project and a site will depend on future location decisions, future public investments, changes in regulation, and the technological progress. This means that theprivate decision maker, in view of company's established goals, should choose the location on the basis of probable future scenarios. This also means that the public decision maker should consider overall effects, presently and in the future, and therefore, stimulate or discourage new locations.

3. ENVIRONMENT, SOCIAL ENTROPY, AND SUSTAINABILITY

This section presents some theoretical considerations and definitions that sustain the proposed model.

3.1. Environment – A Broader Concept

The environment as usually conceived encompasses all natural and built assets. But these solely make up the physical environment. Human activities interact with oneother and act on the physical environment creating a dynamic process. To be precise, the environment includes both tangible and intangible factors which are in continuous,interdependent movement. In other words, the narrow concept of physical environment is not adequate for identifying and measuring the dynamic effects to which economic activities give rise. One needs a broader concept of environment to consider the economic, political, social and cultural effects that a location decision exerts on a given site and on a given project. Such a concept must encompass the human environment and the physical environment (GeorgievaandBurazeri, 2005; Palmer, 1999; United States, 2010).

Henceforth the concept of environment designates the diversified, complex and dynamic background in which an economic activity insertion occurs, including tangible and intangible factors and their interaction. In other words, the concept of environment refers to a dynamic process that involves natural and social dimensions. It is subject to external interferences represented primarily by business and government decisions.

3.2. Entropy

The First Law of Thermodynamics states the energy conservation. Energy cannot be created nor destroyed, only transformed. If processes were solely subject to the First Law, energy could be indefinitely reused.

The Second Law of Thermodynamics, however, asserts that the transformed energy always presents a lower capacity to yield work, i.e., is less useful. This is known as the Law of Increasing Entropy.

Entropy is defined as the ratio between heat and temperature (Eq. 1):

$$\Delta S = \int_a^b \frac{dQ}{T} \tag{1}$$

Where ΔS holds for entropy variation, and Q and T denote heat and absolute temperature, respectively.

3.3. System's Organization and Social Entropy

By the end of the Nineteenth Century, Ludwig Boltzmann established that the level of entropy of a system relates to the properties of molecules or atoms as follows: the more disorganized the system the higher the entropy level. Later, this was mathematically formulated by Max Planck. Since then, the level of entropy has been inversely associated with systems' internal organization.

By the middle of the last century, the Romanian economist Nicholas Georgescu-Roegen presented a revolutionary conception of the production-consumption process. He argued that economic process feeds on low entropy energy and materials, and returns higher entropy energy and materials (Roegen, 1971). This statement gave rise to an intense debate that extends to the present day involving the concepts of sustainable development, sustainability, zero growth and de-growth (Kerschner, 2010).

More recently the American sociologist Kenneth D. Bailey (1990 and 2006) developed the Social Entropy Theory (SET) involving originally six variables:

> The six key macro-sociological variables of SET are: population size (P), information (I), level of living (L), organization (O), technology (T) and space or territory (S). These PILOTS variables are key systems variables. Together, they determine the overall state of the system, including its entropy [...] make PILOTS more compatible with [Living Systems Theory] LST by adding energy (more correctly mater-energy) to it [...] to form EIPLOTS (2006, p. 297).

Social entropy represents the variation in obtainable efficiency in using the environment's available resources, both tangible and intangible. This means that social entropy relates to society's ability to follow a trajectory of perennial improvement of life quality. In other words, increase in social entropy is expenditure of society's potential capacity to meet its present and future needs in a given historical moment.

3.4. Carrying Capacity, Social Entropy and Sustainability

In history, the ancient civilizations that achieved greater levels of development were those that caused greater increases in thermodynamic entropy:

> Evolution and man's history indicate that the winners are the species and societies that act faster and consume more high-quality energy and materials: in other words, those which cause more pollution and faster growth of entropy (REBANE, 1995, p. 89).

Depletion of natural resources has been a common characteristic of economic development in history. This means that development as historically conceived implied a reduction in the carrying capacity of Earth and was not sustainable.

Though the idea of carrying capacity of Earth is not enough because society is able to improve the way natural resources are used and enlarge the set of usable resources. If a decrease in the carrying capacity of Earth is more than offset by technological progress and advances in social organization the net effect will be a decrease in social entropy and a corresponding increase in society's ability to survive and improve quality of life. Consequently, the concept of carrying support is not enough if one focuses on sustainability. This is true because it does not relate to environment as encompassing the interaction of physical and social factors in a dynamic process, as referred to earlier. In conclusion, the ample concept of environment and the concept of social entropy are necessary to assess the increase or decrease in the ability of humankind to survive and raise life quality in a given historical moment.

Then, the basic relationship between social entropy and sustainability emerges as follows: a strictly sustainable trajectory over time presents consecutive negative variations in social entropy. It occurs in such a way that society achieves increasing ability to survive and raise the standard of living. In other words, the higher the level of social entropy caused by mankind's activities in successive periods, less sustainable is a particular pathway over time and vice versa.

3.5. Technological Development and Social Entropy

From the thermodynamics standpoint Earth is an open system. It's strictly increasing entropy is constantly offset by the flow of new low-entropy energy coming from the Sun. However, this is not the case. The steady supply of low-entropy energy is a basic and necessary condition to the Planet's subsistence, but not enough. The environment - a complex and dynamic process of permanent interaction between natural and human factors - is a closed system because there is no continuous inflow of new low-entropy resources.

Is the technological progress able to guarantee increasing global efficiency and, therefore, lesser entropy increases? Can the new possibilities for incorporating new resources, replacing scarce resources, and increasing process efficiency guarantee decreasing social entropy? The Office of Technology Assessment of the United States Congress recognizes the role of technology:

> Technology can affect Sustainability in a positive way by reducing throughput and waste and by increasing efficiency and finding alternatives to scarce resources. Environmental benefits are not the sole measure of a technology's contribution to sustainable development. Appropriateness of scale, use of local resources, and equity are important considerations as well (U.S. Congress, 1994, p. 127).

The technological progress dictates new patterns of production-consumption and permeates the society as it gives rise to new values and new standards. For example, new technologies may promote individualism and competition, or organization and cooperation, and cause all subsequent effects. As technological advances configure new lifestyles and new thinking patterns, they also affect society's ability to efficiently manage all sorts of tangible and intangible resources.

Environment – the dynamic set of tangible and intangible resources - is a closed system and the social entropy variation is the main indicator headed for sustainability. Therefore, expectations about the strength of technological progress to ensure increasing social efficiency become magnified. The new possibilities created by technological development both in the technical and in the social fields will hopefully allow overcoming all sorts of shortages coming from a decreasing carrying capacity of Earth.

A thorough discussion on the extent to which technological progress could be able to guarantee increasing efficiency to the entire society is obviously far beyond the scope of this article. For the present purpose it suffices to acknowledge that new technologies may change markedly the pathway of mutual influences and interchanges between economic activities and environment.

3.6. Environment's Predictability and Risk

A complex system presents a variety of mutual influences among its constituents. These influences are mostly unknown and may present an accumulated effect originated from positive feedback. Andriani and Mckelvey (2006) argue that the Gaussian paradigm focuses on averages and finite variances and does not apply to many situations in which systems acquire a completely new nature. They suggest the Paretian paradigm to deal with such situations.

The Self-Organized Criticality Theory (Bak, 1996) states that the proportionality linking cause and effect that characterizes a complex system ceases at the critical state. Every system is governed by rules of interdependency among its components. These rules represent a pattern of diffusion of effects inside a given system. However, at the critical state, such pattern ceases to prevail and the system behaves in a completely different way. The well-known example refers to a sand pile to which sand grains are continuously added. The avalanches' sizes distribute according to a power law, presenting numerous small avalanches and a few big ones.

Environment, enclosing nature and society in a single complex system, involves multiple interactions about which scientific knowledge is still limited or does not exist. Actually, the Gaussian paradigm may not apply to predict chief environmental events. In brief, humanity faces limited knowledge on the environment whose complexity derives from interaction between natural and social forces. This limitation implies a critical uncertainty and underscores the importance of searching for strict sustainability in all decisions that may cause significant increases in social entropy, such as the location decisions of economic activities.

4. THE MODEL'S BASICS

This section presents the model's basics and main features.

4.1. Project and Site

A project is aneconomic activity unityspecified by a technological choice and a scale of production, such that onecould predict its interaction with the environment both qualitatively and quantitatively.

A site is a geographic area in which one considers the implementation of projects. Sites must suit estimating and forecasting the two-way effects between sites and projects, and should present sizescompatible with the geographic scope of the projects under consideration.

Given a set of projects and a set of sites, one wants to assess each possible combination in order to rank the locations for a particular project, and the projects for a specified site.

Every insertion of economic activity in the environment generates exchanges, that is, flows in both directions, represented by money, energy, materials, people and information. The interchanges between a givenproject and a given site exert effects on each other and give rise to a trajectory over time. Such a trajectory will bebasically subject to public and private decisions and technological changes,which should be considered in evaluating any location decision.

4.2. Two-Way Social Entropy Effects

A process involving interaction and exchange begins whenever a project falls within the environment. Such a process will draw a particular trajectory over time and will cause a variation in social entropy. So, a planner desires to forecast the change in social entropy associated with each possible combination of projects and sites.The best possible decision on inserting a given economic activity unityin a certain place is based on evaluating the predictable social entropy effects in both directions. That is, from the project on the environment and vice versa, but the two types of effect generally present diverse implications.

The public planner will compare the social entropy variation to possible enhancement in social welfare, and the private planner will compare the mentioned social entropy variation to potential earnings.Governmental authorities willprivilege public policy goals and attribute greater importance to social entropy effects that projects will develop on their surroundings; entrepreneurs may give greater significance to effects that projects will receive from the environment.Furthermore, public agents are supposed to decide by comparing social entropy increases to collective benefits, but private agents will not necessarily take into account social entropy increases in searching for earnings.

4.3. Corporate Social Responsibility (CSR)

Engaging with the environment where companies operate has become a common practice inthe business world.Thisbehaviour stems from a relatively recent approach that consists of a sense of responsibility towards society. So, in present days,an increasing number of business owners and executives does not wait for government to mitigate or solve social problems, instead, individually or through their organizations, they develop actions that were usuallyexclusive attribution of public authorities in the past,and even impose self-regulations (Desjardins, 1998; Lyon and Maxwell, 2008).

However the difficulties related to corporate social responsibility(CSR) practice are neither few nor small. There are five points to consider. First,one should note that diverse methodologies are commonly used for identifying and measuring problems like pollution and poverty. Second, projects designed to deal with social problems are also not standardized in respect to methodologies employed in preparing and managing them. Third, given the voluntary nature of CSR actions, their coordination generally faces serious difficulties. Fourth, the voluntary nature of social responsibility presents another important drawback related to the uncertaincontinuityof the offered services both in respect to quantity and quality. And fifth, the methodologies for evaluating CSR actions are also heterogeneous and as aconsequence comprehensive measurement of results and global measures of efficiency oftenbecome impossible (Auld et al., 2008; Jamaliand Mirshak, 2007; Prieto-Carrónet al.,2006).

Despite the mentioned difficulties, the concern regarding the limits of Earth growsquicklywhileretraction of governmental actions worldwide leaves major gaps. At the same time,many companies showincreasing ability to convert investments in CSR into economic outcomes (Porter andKramer, 2007). Thus, the most likely scenario for the coming decades presents significant,increasing volume and importance of CSR around the world. This means that CSR concerns will exert increasing influence on companies' strategic decisions, especially location decisions.

4.4. Sustainable Location Choice

The 1970 decade marked the beginning of a global concern about the finiteness of Earth and sustainability of human activities:

> […] economist Nicolas Georgescu-Roegen in 1971 pointed out that economic processes, as generally assumed, are not cyclical at all, and will in the long run lead to exhaustion of the world's natural resources and of the environment's capacity to absorb pollutants. Then in 1972,

> the Club of Rome published the shocking report, The Limits to Growth, followed byanother well-known book in 1989 by Jeremy Rifkin, *Entropy Into the Greenhouse World* (The Encyclopedia ofEarth, 2012, p.1).

Since decade of the 1970's,the economic progress as observed during the last two centuries is being widelyrecognized as not sustainable.Despitethis,a minimum consensus on the necessarysocial change is far from achieved.

At the micro level, the mutual effects between a given project and its environment represent onusesand bonuses for distinct stakeholders, including future generations. Then, one could theoretically conceive a balance involving costs and benefits, both in the short and long term for each stakeholder. This task requires considering current and future interests of each stakeholder in the most likely environmental scenarios. However, such procedure obviously does not guarantee lesser increases insocial entropy,norsustainable location choices.

These observations make clear the need for a new conception of the location problem. If the location problem is conceived in relation to social entropy, the best location is defined as the one that provides the best overall resultsfor society,given the characteristics of the project and geographic space. Given a relevant project, ifthe location that presents the minimum social entropy increase is not the more profitable one, public authorities should consider making the required investments to overcome such a situation. If necessary, government may subsidize the private investor to avoid socially undesirable locations. This way, private and public interests can converge to cause minimum increases in social entropy and achieve sustainability.

5. THE MODEL

The theoretical model whose general sketch is shown in Figure 2 represents location decisions and other social decisions in a dynamic process in which they are constrained by a given scenario and, at the same time, participate in creating a new scenario.

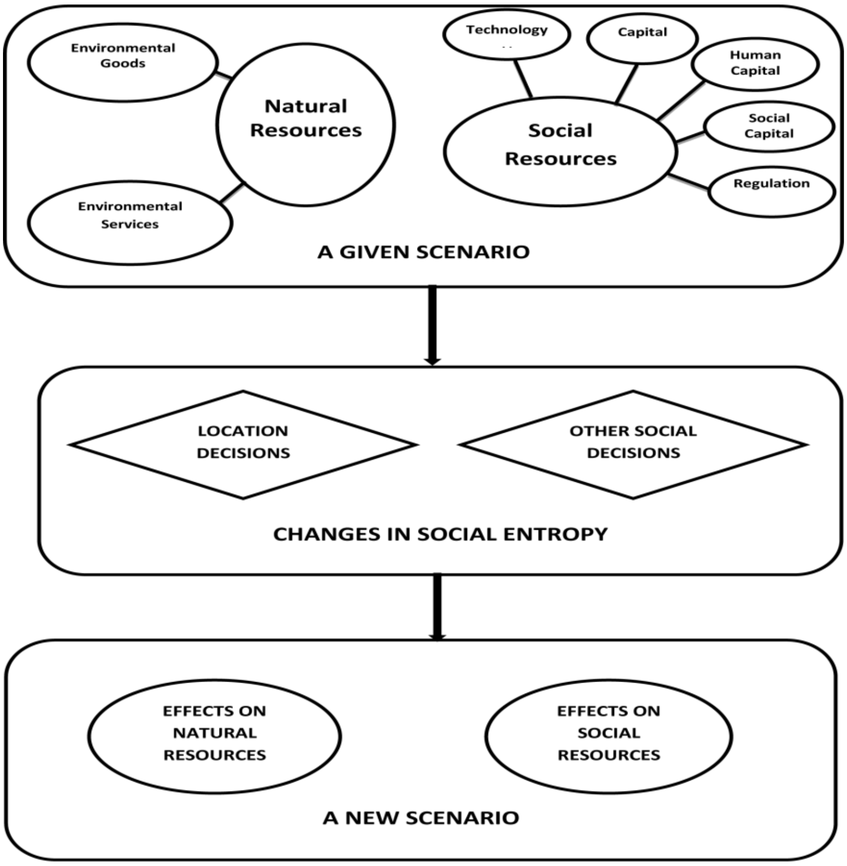

Figure2.*Model's general sketch*

In ancient civilizations the components of social resources were relatively weak and society depended essentially on natural resources to maintain and raise standard of living. In present days, however, technology permeates all social relations, mainly production and consumption, and is a major factor in determining the interaction between society and Nature. In addition, technological development continuously changes society and its relation to Nature.

Natural and social resources combine into succeeding scenarios as they interrelate one with the other. Each scenario represents a particular level of social entropy and is partly determined by the previous one. A scenario may substantially differ from the former depending on changes in social entropy caused by location decisions and other social decisions. These decisions exert effects on natural and social resources and a new pattern of interaction between their components will give rise to a new scenario.

Scenariosexert influence on location choice over time. In turn, location choices exert a variety of social effects, and also effects on Nature. New locations of economic activities participate inshapingsucceeding scenarios, namely, the environment's dynamic process represented by a particular overall trajectory.

Advantageous locations fora given project and environment may become disadvantageous, as time goes onfor the project, the environment or both.Contrasting, initially disadvantageous locations for a givenproject, environment or both may become beneficial in the long term, depending on the evolutionary trajectories of the project and environment. Therefore, in seeking sustainable location decisions one has to take into account the most likely future events, causal sequences, and resulting trajectories.

It is well known that a given project-site pair isviable from the private viewpoint if it presentsan attractive return on investments. This condition results from future cash flows generated by the project, and these cash flows depend on the mentioned succeeding scenarios. Even though, the governmental authorities may change the private return throughpublic investments and regulation. This means thata comprehensive analysis has to include the locations that may become attractive if governmentmakes certain investments, subsidises and changes the existing regulation.Therefore, the more sustainable location of a given project – the one that causes minimum increase in social entropy - will be among those currently profitable and those that may become attractive by means of governmental actions.

Each profitable project-site pair could originate a number of possible future trajectories and, therefore, numerouscalculations of social entropy variations. Figure 3 shows a flow sheet to avoid this.

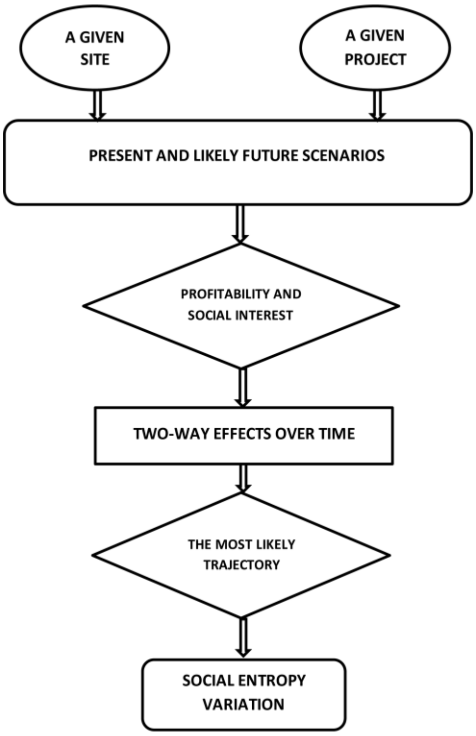

Figure3. *Assessment of social entropy variation*

Each project-site pair should be assessed in respect to profitability first. In case a pair is not profitable but socially interesting, the amount of governmental aid has to be compared to the social benefit as in the traditional cost-benefit analysis. Frequently public investments and incentives will favour a number of projects. If this is the case, projects may be considered together or a split criterion has to be adopted. As a result of this preliminary step, the set of project-site pairs shrink to those profitable or socially worthwhile.

An interdisciplinary team has to identify the two-way effects considering the present and future scenarios of the complex environment, considering particularly technological changes. Finally, the most likely trajectory of a viable project-site pair can be identified and the corresponding social entropy variation can be estimated.

The result of the procedure outlined in Figure 3 can be arranged in a matrix whose lines and columns represent sites and projects, respectively, and whose cells are the estimated social entropy variations. Empty cells obviously represent socially undesired combinations either because they require prohibitive amount of public resources to become profitable or because they represent unacceptable negative effects on environment or society.

There are three reasons why not evenanearly exact solution should be expected: 1) Location decisions involve many factors;2) Measurement of these factors frequently requires specific methodologies and; 3)These factors change over time. Clearly, none of the indicated calculationsof social entropy variation is exact. The model should be mostlyseen as a planning tool that can be continuously improved over time.

The estimations and assessments can be obtained by means of simulation or fuzzy techniques. Indeed, the information provided by the model should serve as a starting point for negotiation between public and private actors. This is because measurement of variables is not exact and other factors not included in the model are certainly involved.

6. CONCLUDING REMARKS

Despite the technological advances, the location decisions remain complex, costly and risky. These decisions are practically irreversible and have serious consequences not only to private investors but also to society. Optimal location decisions of economic activities should not relateany more to the minimum cost or the maximum profit resulting from sites' endowments as in the past. Sustainability requires considering impacts on social entropy.

According to the new patterns of production and consumption, one has to forecast the long-term trajectory of interactions that begins when an economic activity installs in a siteand preview not only the future cash flows, but also the increases in social entropy.Pursuing sustainability in choosing a new economic activity location is indispensable due to apotential disproportionate reaction of Environment associated with the caused increase in social entropy.A sustainable location is profitable enough to attract the required private capital and presents the lesser, total increase in the social entropy.

The proposed model focuses on the mutual influences and the two-way effects between projects and sites, both in the short and long term, and enables pursuingthe lesser increase insocial entropy among those project-site pairs that are currently or potentially profitable. Lessening expected social entropy increases is a safewaytoachievesustainability.

Applying the proposed model in reference to public policy goals may indicate the need for public investments, tax instruments, and favoured credit etc.In extreme cases, when the potential conflict between private and public interest presents high importancethe need for prohibition may arise.

Technological changes, public and private investments, changes in regulation and other major factors may be individually or jointly simulated and this will probably provide valuable information to private investors and public authorities. The model may provide relevant strategic information to private investors to the extent that profit will be increasingly dependent on companies' social and environmental role in the future. The model also seems to fill an enormous gap of information in public planning, as this is rarely based on actual comparisons of alternative courses of integrated actions involving investments, fiscal instruments, funding and regulation.

The succeeding social entropy variations are not discounted to their present values in the model.In general, the relative importance of short and long-term effects is a subject of difficult consensus. However, the presented model remains applicable if the analyst has adiverse understanding.

Some major difficulties still remain: 1) Estimatingsocial entropy variationis not strictly objective; 2) The impact of future technological changes onsociety is predictable only if one accepts wide variability; 3) Specialized people have to work together in multidisciplinary teams to feed the model and evaluate its results; 4) Natural and social forces not predicted may lead to divergent situations;and 5) The model requires a team of specialized people in a continuous work to improve over time.

Therefore, one should not take the results of the model as accurate or definitive. These findings should always be considered as the basis for negotiation between the actors involved, especially public authorities and private investors.

Although the proposed model was primarily developed for the location problem of economic activities, it also applies to virtually all human activities. It can handle activities like housing, leisure, education and others.

Finally, as the model explicitly considers social entropy increases in location analysis, it may help give rise to a technological development more concerned about sustainability.

REFERENCES

Alade, W. et al. (2011).Locational Analysis of Telecommunications Infrastructure in Residential Neighbourhoods of Lagos Metropolis. *CORP 2011 Proceedings*. Available at:http://www.corp .at/archive/CORP2011_42.pdf. Access: Oct. 20th, 2013.

Andriani,P.; McKelvey, B. (2006). Beyond Gaussian Averages: Redirecting Management Research Toward Extreme Events and Power Laws.*Journal of Financial and Quantitative Analysis.*Available at: http://www.dur.ac.uk/resources/dbs/faculty/working-papers/BeyondGaussianAverages19Jun06.pdf. Access: Oct. 20th, 2013.

Auld, G. et al. (2008). The New Corporate Social Responsibility. *Annual Review of Environment and Resources.* Available at: http://environment.yale.edu/files/biblio/ YaleFES-00000017.pdf. Access: Sept. 1st, 2013.

Bailey, K. D.(1990). *Social Entropy Theory*. State University of New York, Albany, NY.

______. (2006). Living Systems Theory and Social Entropy Theory. *Systems Research and Behavioral Science.* John Wiley, New York, NY. Available at: http://pt.scribd.com /doc/109455836/Living-Systems-Theory-and-Social-Entropy-Theory. Access: Oct. 21st, 2013.

Bak, P. (1996). *How Nature Works: The Science of Self-Organised Criticality*. New York, NY: Copernicus.

Bodenmann,B. R.**;** Axhausen, K. W. (2010). Location decisions of firms:A discrete choice model for the St. Gallen region, Switzerland. Zürich: *IVT and ETH*. Available at: https://edit.ethz.ch/ ivt/vpl/publications/reports/ab649.pdf. Access: Sept. 22nd, 2013.

Camacho, C.; Pérez-Barahona, A. (2012). Land use dynamics and the environment.*Pantheon-Sorbonne Université Paris.* Available at: http://halshs.archives-ouvertes.fr/docs/00/69/15/05/PDF/12012-2.pdf. Access: Oct. 1st, 2013.

Carvalho, L. P. C. (2007). *Seleção de localização industrial com base em método fuzzy de tomada de decisão multicritério:estudo de caso de uma empresa do setor de bebidas brasileiro*. Unpublished dissertation. COPPE/UFRJ, Rio de Janeiro, RJ.

Chamovitz, I. (2010). *Aplicação do Modelo de Hierarquia Fuzzy COPPE-Cosenza para a Avaliação de Grupos Operativos em Fóruns Educacionais na Internet.* Unpublished doctoral thesis. COPPE/UFRJ, Rio de Janeiro, RJ.

Chamovitz, I.; Consenza C. A. N. (2010). Lógica Fuzzy: *Alternativa viável para projetos complexos no Rio de Janeiro*.XIV PROFUNDÃO.COPPE/UFRJ, Rio de Janeiro, RJ.

Christaller, W. (1933) *Die Zentralen Orte in Süddeutschland. Eineökonomisch-geographischeUntersuchungüber die Gesetzmäßigkeit der Verbreitung und Entwicklung der SiedlungenmitstädtischerFunktion*. Jena: Gustav Fischer Verlag.

Clemente, A. (1977). *Modelos de Localização Industrial:aplicação ao Estado do Rio de Janeiro.* Unpublished dissertation. COPPE/UFRJ, Rio de Janeiro, RJ.

______. (1982). *Localização Industrial e Crescimento Regional: a influência dos transportes e da estrutura de mercado*. Unpublished doctoral thesis. COPPE/UFRJ, Rio de Janeiro, RJ.

______. (ed.) (2008). *Projetos Empresariais e Públicos*. 3rd ed. Atlas, São Paulo, SP.

Cosenza, C. A. N. (1981). *An Industrial Location Model*. Working paper. Martin Centre for Architectural and Urban Studies, Cambridge University, Cambridge, UK.

Desjardins, J. (1998). Corporate environmental responsibility. *Journal of Business Ethics;* (17) 8, 825-838. Available at:http://www.environmentalmanager.org/wp-content/uploads/2008/04/cer.pdf. Access: Aug. 15th, 2013.

Georgieva, L.; Burazeri, G.(eds.) **(**2005). *Health Determinants in the Scope of New Public Health: A Handbook for Teachers, Researchers and Health Professionals.*Lage, Germany: Hans Jacobs. Available at: http://www.snz.unizg.hr/ph-see/Documents/Publications/PH-SEE_Book3_Full_HealthDeterminants.pdf. Access: Oct. 20th, 2013.

Greenhut, M. L. (1956). *Plant Location in Theory and Practice.* The University of North Carolina, Chapel Hill, NC.

Hoover, E.M. (1948). *The Location of Economic Activity*. McGraw-Hill, New York, NY.

Isard, W. A. **(**1951). Distance Inputs and the Space-Economy Part I: The Conceptual Framework. *The Quarterly Journal of Economics*, 65(2),181-198.

______B. (1951). Distance Inputs and the Space-Economy Part II: The Locational Equilibrium of the Firm. *The Quarterly Journal of Economics*, 65(3),373-399.

______**. (**1972). *Location and Space-Economy.* The MIT, Cambridge, MA.

Jamali, D.; Mirshak, R. (2007). Corporate Social Responsibility (CSR): Theory and Practice in a Developing Country Context. *Journal of Business Ethics*. 72, 243–262. Available at: http://www.kantakji.com/fiqh/files/companies/w125.pdf. Access: Apr. 18th, 2013.

Kerschner, C. (2010) Economic de-growth vs. steady-state economy. *Journal of Cleaner* Production, 18, 544–551.

Kim, J. H. (2010). *Land Use, Spatial Structure, and Regional Economic Performance: Assessing the economic effects of land use planning and regulation*. Unpublished doctoral dissertation. University of Illinois at Urbana-Champaign, Urbana, IL.

Korhonen, J. (2004) Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology. *Journal of Cleaner Production*, 12, 809–823.

Leiss, W. (1974). *The Domination of Nature.*Beacon: Boston, MA.

Lozano, R. (2008). Envisioning sustainability three-dimensionally. *Journal of Cleaner Production,*16, 1838–1846.

Lösh, A. (1954). *The Economics of Location*. Yale University: New Haven, CT.

Lyon, T. P.; Maxwell, J. W. **(**2008). Corporate Social Responsibility and the Environment: A Theoretical Perspective. *Review of Environmental Economics and Policy Advance,* 1 (0), 1-22. Available at: http://www.erb.umich.edu/Research/Initiatives/colloquiaPapers/LyonMaxwellREEP.pdf. Access: Sept. 11th, 2013.

Palmer, S. (1999). *The Physical Environment: A review of trends in the natural and built environment.* In: Dargie C. (ed.). Policy futures for UK health. Available at:http://www. health.jbs.cam.ac.uk/research/cuhresearch/downloads/reports/environment.pdf. Access: Sept. 23rd, 2013.

Perroux, F. (1961). *L'économie du XXème siècle*. Universitaires de France, Paris.

______. (1968). Les investissementsmultinationauxetl'analyse des pôles de développement et des poles d'intégration. *Tiers-Monde*, 9 (34), 239-265.

Porter, M. E.; Kramer M. R. (2007). Strategy and Society - The Link between Competitive Advantage and Corporate Social Responsibility. *Harvard Business Review.* 1st article from the collection: Redefining Corporate Social Responsibility. Available at: http://www.google.com.br/ url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=2&sqi=2&ved=0CC0QFjAB&url=http%3A%2F%2Fwww.salesforcefoundation.org%2Ffiles%2FHBR-CompetiveAdvAndCSR.pdf&ei=2PSSUMTXD5KG9gSRxIHoCQ&usg =AFQjCNGAxIJ4xhxaf_wsFNTEXj3IU7LR0A&cad=rja. Access: Sept. 22nd, 2013.

Prieto-Carrón, M. *et al.*(2006). Critical perspectives on CSR and development: what we know, what we don't know, and what we need to know. *International Affairs.* 82 (5), 977–988. Available at: http://bdsnetwork.cbs.dk/publications/INTA82_5_09_ p977-988.pdf. Access: Aug. 15th, 2013.

Rebane, K. K. (1995). Energy, entropy, environment: why is protection of the environment objectively difficult? *Ecological Economics*, 13 (2), 89–92.

Richardson, H. W. (1979). *Regional and Urban Economics.* London: Pitman.

Roegen, G.N. (1971). *The Entropy Law and the Economic Process*. Cambridge, MA: Harvard University.

Söderman, S. **(**1975). *Industrial location planning: an empirical investigation of company approaches to the problem of locating new plants*. Stockholm: Almqvist&Wiksell International.

Somea(1974).*Modello di assettoterritoriale e localizzazioneindustriale*. Pizzi: Cinisello Balsamo.

Terouhid, S. et al. (2012).Towards Sustainable Facility Location – A Literature Review. *Journal of SustainableDevelopment*, 5 (7).

The encyclopedia of earth. (2012). *Approaching the world's environmental problems through the Second Law (Entropy Law) of Thermodynamics*.Available at: http://www.eoearth.org/article/Approaching_the_world%E2%80%99s_environmental_problems_through_the_Second_Law_(Entropy_Law)_of_Thermodynamics. Access: Oct. 26th, 2013.

Thünen, J. H. (1826). *Der isoliertestaat in beziehung auf landwirtschaft und nationalökonomie*. Hamburg: Perthes.

United Nations. (2011*). Population Distribution, Urbanization, Internal Migration and Development: An International Perspective.Available* at:http://www.un.org/esa/population/publications/PopDistribUrbanization/PopulationDistributionUrbanization.pdf. Access: Oct. 27th, 2013.

United States. (2010). *Healthy People 2020: An Opportunity to Address Societal Determinants of Health in the U.S. Secretary's Advisory Committee on National Health Promotion and Disease Prevention Objectives for 2020.* Available at: http://www.healthypeople.gov/2020/about/advisory/SocietalDeterminantsHealth.pdf. Access: Sept. 22nd, 2013.

U.S. Congress, Office of Technology Assessment.*Perspectives on the Role of Science and Technology in Sustainable Development, OTA-ENV-609* (Washington, DC: U.S. Government Printing Office, September 1994). Available at: http://www.princeton.edu/~ota/disk1/1994/9422/9422.PDF. Access: Aug. 16th, 2013.

Veleva, V.; Ellenbecker, M. Indicators of sustainable production: framework and methodology. *Journal of Cleaner Production*,9 , 519–549.

Weber, A. (1929). *Theory of the Location of Industries*. Chicago (IL): The University of Chicago.