Modeling Public-Private Partnerships

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Abstract
The present paper discuss and demonstrate arguments in the use of the System Dynamics as a main approach to a new research area here named of Territorial Engineering. More specifically the aims are help the main stakeholders involved in the process to decide about the bankability of infrastructure projects. It is also considered the possibility of using agent-based modeling in the form of a hybrid model. This new research area wish establishing a new focus on infrastructure funding, whereby it is argued that the investment decisions should not be taken based solely on the gains obtained by users and indirect beneficiaries, but should also consider the infrastructure's ability to accomplish an economic growth that may be captured fiscally. This proposition emerges from the limitations of the current funding approaches, both public (fiscal investment) and private (PFI and PPP), to cover the increasing construction and maintenance costs of infrastructure.

Key-Words: Hybrid modeling, Agent-Based-modeling, System Dynamics, Territorial Engineering, PPP bankability

Introduction

The decisions on infrastructure investments in a certain region are a complex task mainly when the public financial resources are scarce. There are a greater level of uncertainty and risk because the territory is a system composed by a great number of interdependent entities, with different degrees of relationships. In this situation is necessary to determine if a project is "bankable", i.e., to ensure (in anticipation) if it has capacity to create enough revenue to pay off loans or is able to produce financial benefits to attract private investors. To this is necessary examining a set of characteristics of these projects in a process known as "bankability".

The project presented here part of a new focus on financing infrastructure, called of Territorial Engineering, linking funding more firmly to economic growth provided by infrastructure and capturing the fiscal gains resulting, so that the contributions to public investment becomes fiscally sustainable. This solution includes the creation of an infrastructure funding, a set of business and industrial projects and integrative policies and facilities which are necessary to catalyze the growth process. However, this solution as explained in the next topics, increase the complexity of decisions related to the bankability. Comprehensive modeling tools as System Dynamics (SD) and Agent Based Modeling (ABM) could help to understand better the problem.

There is a vast amount of literature that recognizes the importance of infrastructure for economic growth (Aschauer 1989, The World Bank 1994, Lu 1996, Banister and Berechman 2001, OCDE 2003, Estache and Fay 2007). On the other hand the requirements of fiscal discipline, especially in countries in macroeconomic disarray (e.g., Brazil and other Latin-American nations) have burdened them with severe restrictions for making public investments that would be essential for their development and growth – see Reinforcing Loop R1 on Figure 1. (Carvalho 2007, Afonso and Biasoto Jr. 2007, Carneiro 2006, Ter-Minassian and Allen 2004). Once the traditional fiscal resources of these investments reached their limits, hope has been laid on private investments made by means of concessions and public-private partnerships (PPP) - see Reinforcing Loop R2 and R3 on Figure 1. However, even the international agencies that in the past strongly advocated for this kind of strategy have finally recognized that it cannot cover a significant part of the investment needs, given the hard requirements imposed by the financial market for its "bankability" (The World Bank 2007, Zulhabri and Abdullah 2006, Griffin 1999, GHK Research Training 2001, Spoehr 2002). Additionally, the private sector has more stringent limitations for assuming risks than the public sector (Beckers 2005).

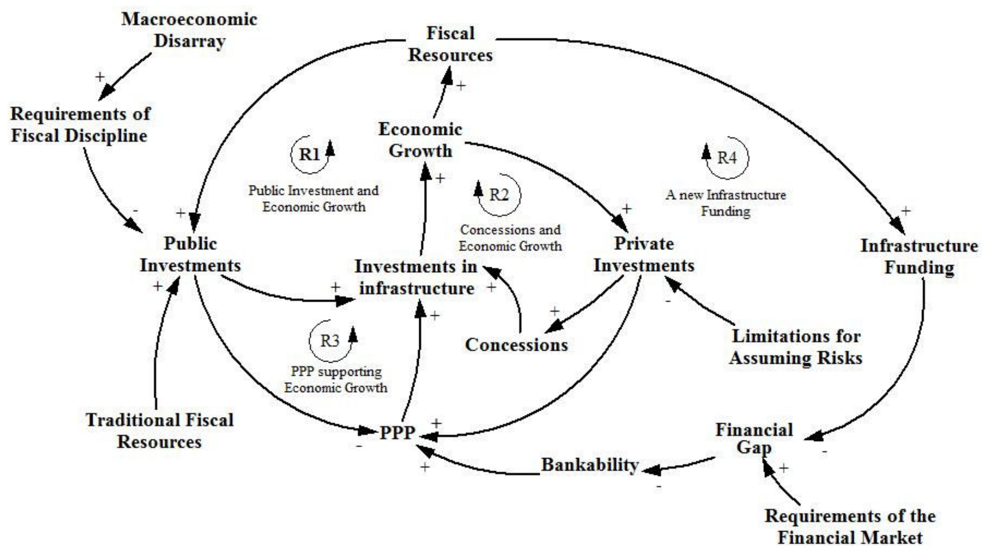

Figure 1 – The creation of an Infrastructure Funding to reduce the Financial Gap in PPP and become it "bankable"

R1 – As the Public Sector invests in infrastructure, the Economy grows and increases the Fiscal Resources for new Public Investments.

R2 – The concessions to the Private Sector reflects in more Investments in Infrastructure and Economic growth.

R3 – The Macroeconomic Disarray as in Brazil forces the Government adopt Requirements of Fiscal Discipline, which reduces the capacity of Public Investments. One of the solutions is the PPP as a way to invest in infrastructure. The Traditional Fiscal Resources represents here the traditional thinking about the Fiscal question.

R4 – The bankability for the PPP projects of infrastructure is constrained by a Financial Gap resulted of the hard requirements imposed by the Financial Market and the low investment capacity of the public sector. The creation of an infrastructure funding arises as a solution to eliminate the financial gap.

Thus, as fiscal funding of infrastructure investment is still the mainstream solution, much research has been devoted to analyze the straightforward links between investments and economic growth (Rivas et al. s.d a and b, Beckers et al. 2008, Department for Transport 2007 and 2009, Johansson 2007, Lakshmanan 2007, Vickerman 2007, Marshall and Webber 2009, Banister and Berechman 2001). One core aspect analyzed is the ability of some projects to foster growth so that the resulting accrued fiscal receipts could cover the financial costs of both the corresponding public investment and the participation of public funds for ensuring the bankability of PPP-schemes (fiscal sustainability approach; see Ter Minassian and Allen 2004, Vawda et al. 2001, Djevarajan et al. 1995, Belli at al. 1997, Schwartz et al. 2008). Further, projects that satisfy this condition should be excluded from the spending limits of the budget.

It may observed that the idea of putting public infrastructure investment in direct relation to economic growth and to the corresponding fiscal gains seems to be a prospective solution to resolve the feasibility gap of these investments. Such gap arises when traditional economic evaluation approaches of infrastructure projects deliver an economic justification of the project but are not able to determine where the financial resources for its execution will come from (e.g., COBA, multicriteria analysis, value engineering, among others). In turn, the fiscal sustainability approach could reflect the economic value of the investment – if this sustainability is the result of risen tax income due to economic growth attributable to the investment – and indicate the financial resources that could be raised for its funding.

1. Linking infrastructure investment to other industrial investments

Nevertheless, the link between infrastructure investment and economic growth is not so straightforward. Putting it more concrete terms, it is rarely possible to link regional economic growth results and the respective fiscal gains directly to a particular infrastructure investment (Kessides 1993, Boarnet 1997, Smith 1999, Raisuddin and Donovan 1992, Creightley 1993). Moreover, economic growth results from a combination of different factors, especially from industrial investment decisions, which are dependent upon a set of different considerations, such as strategic market location, local economies, and the political and regulatory environment. Of course, logistic costs are also important for investment decisions. However, as pointed out by the authors mentioned above, the more developed the existing regional infrastructure is, the less considerable a role it will play in diminishing production and logistic costs, and the less the logistic costs themselves can be accounted as an important share of the total production cost. At most, a tighter correlation between the infrastructure investment, the improvement of logistics, on one other side, and, on the other, industrial investment and economic growth will be more easily determined in lesser industrialized regions but with positive growth potentials (Banister and Berechman 2001).

As the fiscal sustainability approach presented above can not rely on isolated infrastructure projects because they are not the core factor for regional economic growth, the idea put forward here is to link infrastructure investment to other industrial investments in the region so that the whole regional investment package may prove directly growth producing. Other necessary policy actions and complementary infrastructure projects (waste, energy, education, health, and so on) shall be added to this regional investment package, which will from now on be referred to as territorial program.

The analytical problem to be solved is to prove that this whole package is fiscally sustainable, i.e., that it will produce enough growth as well as fiscal gains that are straightforwardly attributable to the package.

Certainly, the setup of such a complex program and its economic and financial evaluation is a complex task from both a theoretical and practical perspective. The aim of the present paper is to sketch the main points of this approach, which is called here Territorial Engineering. Hereby, the methodology of engineering projects will be used as a general guideline for its conception.

This comprehensive Engineering discipline would then have as its subject the conception, execution, operation and evaluation of programs consequently composed of public and private projects with the aim of delivering a determined target of economic growth which would be enough to cover its costs and financial reward needs. Generally, these projects would consist of a) infrastructure; b) industrial investments; and c) general public policy projects which are necessary to ensure the expected economic growth. Private projects are to be rewarded by the operational receipts obtained by their commercial operation (with an eventual participation of public resources), whereas the sum of resources involved in public investment and in financial support for private investment shall be covered by the fiscal gains from the resulting economic growth.

It also requires comprehensive modeling tools as System Dynamics and Agent Based Modeling. The System Dynamics methodology has proved its potential for decades enabling researchers understanding the behavior of Complex System as the proposed in this paper. Since the launch of remarkable books like Industrial Dynamics (Forrester, 1961), Urban Dynamics (Forrester, 1961), Limits to Growth (1972) and others many papers e books was written addressing questions direct or indirect related to the national or regional development. All this literature, research, models, hypothesis compound a set of references that can contribute significantly in building a dynamic and expanded model to test the infrastructure projects bankability. Obviously, the case studies should be tailored not only the objectives to be achieved as well as the Brazilian reality and others theories about the financial and fiscal processes developed and tested.

In some situations, the analytical methods may be not sufficient to give the answers necessary for some complex problems. One of the possibilities is the use of Agent Based Model - ABM. In Territorial Engineering, we found a rich ambient to explore the potentiality of this kind of approach. The dynamics of a territory results of the behavior of many interacting agents and an ABM model could capture the emergence of some dynamics which could difficulty using other methods.

2 – The Concept of Territorial Engineering

The use of the word Territorial Engineering is already diffused, albeit with different acceptations. Whereas in the USA different firms delivering topography and land survey services market their products as Territorial Engineering services, in Canada and France, associations of Territorial Engineers reunite government officials dealing with urban and public service engineering matters within a Territory or Province (Canada); and in a Region or Department (France). On the other hand, in France, Italy and Portugal, the term has received a more academic content. There, Territorial Engineering proposes an evolution of territorial planning toward integrating landscape designing and environmental issues more deeply (France and Italy) and joining different infrastructure engineering specialties into a broader, comprehensive framework (Portugal; see Rede Vivre s.d, Curso de Engenharia do Território - IST s.d., Covas 2006, Jacquemin e Pacitto 2004, Vaillant 2006, Universitá di Calabria s.d, Pascaru 2007). The acceptation proposed here leans on the academic ones, but with the difference that the territorial programs, their funding and the resulting economic growth are centrally focused, although the environmental, social and political issues are also integrated into the design process. This difference is mainly due to the special funding needs of developing countries like Brazil, which still have to reach a satisfactory growth and development level by means of diminishing social exclusion and damage to the environment.

Formalizing still stronger the proposed concept of Territorial Engineering, this discipline shall have as its subject the conception, the execution, the operation and the evaluation of programs composed of public and private projects for infrastructure, industrial plants as well other integrative policy projects, which are systematically and consequently fit together in order to produce, in a defined territory (here called as the program territory) a defined target of economic growth and development. The content of the respective projects consist basically of:

- the spatial configuration of the territory;
- the corresponding accessibility and mobility facilities;
- other infrastructure (water, sewage, energy, communication, emergency management etc.);
- a set of business projects which relate to the infrastructure projects (supplying industries and related services within the productive chain of the infrastructure project);
- a set of industrial projects which will benefit from the infrastructure projects and the integrative policy projects;
- a set of integrative policies and facilities which are necessary to catalyze the growth process, such as incentive policies for entrepreneurship, training and education, health, housing, culture, leisure, sports, public safety, social promotion and environment protection.

Territorial Engineering should not only define the rules and techniques for developing territorial programs, but it should also analyze and design the procedures for project management (technical management), financial engineering management, legal management, consensus building (political and advocacy management) and knowledge management.

One aspect that needs to be explained more clearly is the relationship between the proposed territorial engineering approach and the current territorial planning, since both aim at defining objectives, directives and actions for specific areas. Territorial

Engineering, in the acceptation proposed here, focuses on economic growth as a mainstream mean to fund the programs; thus it may serve as an instrument for improving the economic performance of territorial planning; i.e., as an actual "growth engine" added to the plan.

However, as it will be shown in the following sections, Territorial Engineering is not only about ensuring growth and funding. Because it integrates the financial viability with technical, legal and political feasibility by means of socially and environmentally sound programs within a spatial framework (landscape project), it shall help territorial planning to achieve its goals more efficiently. In any case, territorial programs are subject to the directives and priorities set by territorial planning, so there is a clear hierarchical subordination of programs to the plan.

2.1 – Formal description

The initial aim of this comprehensive project integration is to produce synergetic results in terms of income growth, which should be enough to fund the set of projects in a given term. Using a black box approach (see Figure 1), the territorial program is a system whose *inputs* are descriptors of the current situation in the territory, mainly related to the income and tax receipts (because this information is directly relevant for the funding strategy). In addition, descriptors include general economic and social indicators (per capita income, IHD, among others) as well indicators that have been adopted by the planning authorities. In turn, at the other end of the spectrum, *output variables* are the same as input variables, but measuring the desired end result in terms of the increase of income and tax receipts; of the improvement of the indicators regarding the general economic and social development; and of the achievement of the goals and targets set by governmental planning.

Thus, the central *black box processor* is the territorial program itself, which comprises the aforementioned projects and is the playing field where the engineering work has to work out the solution. This solution will combine the projects in an organic manner, starting from the projects that have already been scheduled. However, it will add new projects so as to help the whole set to achieve the desirable growth as well as other goals and targets (we may call these additional projects *growth* and *value driving projects*).

Consistent with the general engineering methodology (Krick 1978, Dym 1994, Ertas and Jones 1993, Pahl *et al.* 2005, Kemper 1975, Asimow 1970, Mitcham 1994), the solution of the program as an engineering project has to be developed based on decision and optimization criteria, which, here, are: a) the general economic growth result; b) the public and private cash flows (which have to attend the fiscal sustainability and bankability requirements); c) risk containment targets concerning macro-economic, business, social, political and environmental risks. In addition to these criteria, there are other conditions, which have to be attended as a) the currently decided projects within the program territory; b) guidelines and targets of the general territorial planning for this territory and for the whole nation; c) guidelines for the economic policy; d) the legal and regulatory rules in force; e) requirements, which are set up according to the political consensus building process; and f) the limitations each agent's management capacities.

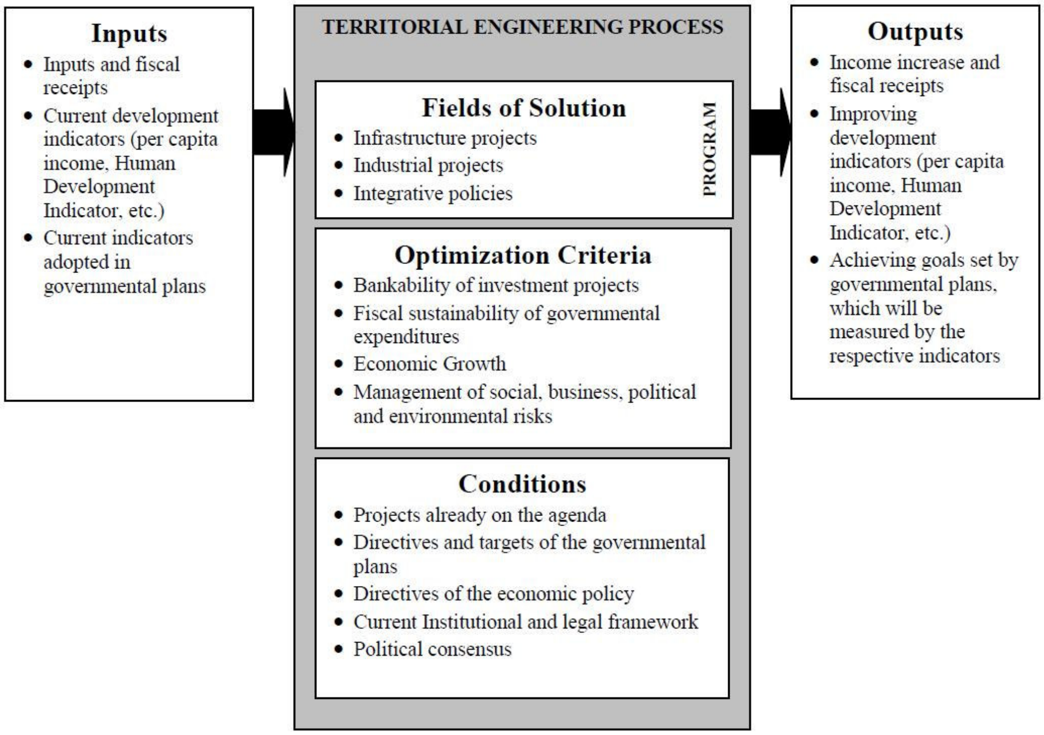

Figure 2 – Black-box scheme of The Territorial Program

2.3 – The setup process of a territorial program and the executive process

The consequent application of the principles of engineering methodology in the setup of territorial programs should follow these phases:

a) defining the initiating agents and the broad development area;

b) defining the development problem to be solved (program problem) as well the program territory and consolidating the list of requirements that the program should comply with;

d) analytical structuring of the problem and solution and development of the analytical tools (models);

e) designing the program (or program alternatives); and

f) analyzing and finishing the program.

The Figure 3 presents the generic activity flow for setting up territorial programs. Setting up a territorial program is the main initiative within the Territorial Engineering process. Other executive procedures need to be added to that process. In order for the program to be feasible, it is necessary to develop a number of things, namely:

- the program's *financial engineering*, which consists of selecting debt and equity instruments for private and public investments; and devising measures that should be adopted to ensure fiscal sustainability and economic growth;
- a proper *project management* process (technical or management engineering), which will ensure that the project is executed efficiently;

- the *political consensus building process* (political engineering), which will apply advocacy techniques and set up a social network composed of relevant agents to ensure the political hegemony in favor of the program;
- setting up of a *legal framework* (legal engineering), comprising a) a large contract framework between the different public and private agents which will rule rights and obligations; b) a reform program for laws and regulations; and c) the creation of the legal basis for new financial instruments (e.g., infrastructure bonds and government bonds linked to the foreseen fiscal gains and the like);
- setting up a *datacenter and of inter-and intranet tools* (knowledge management) to integrate the complex set of information and theoretical knowledge related to the different aspects of the projects and their management.

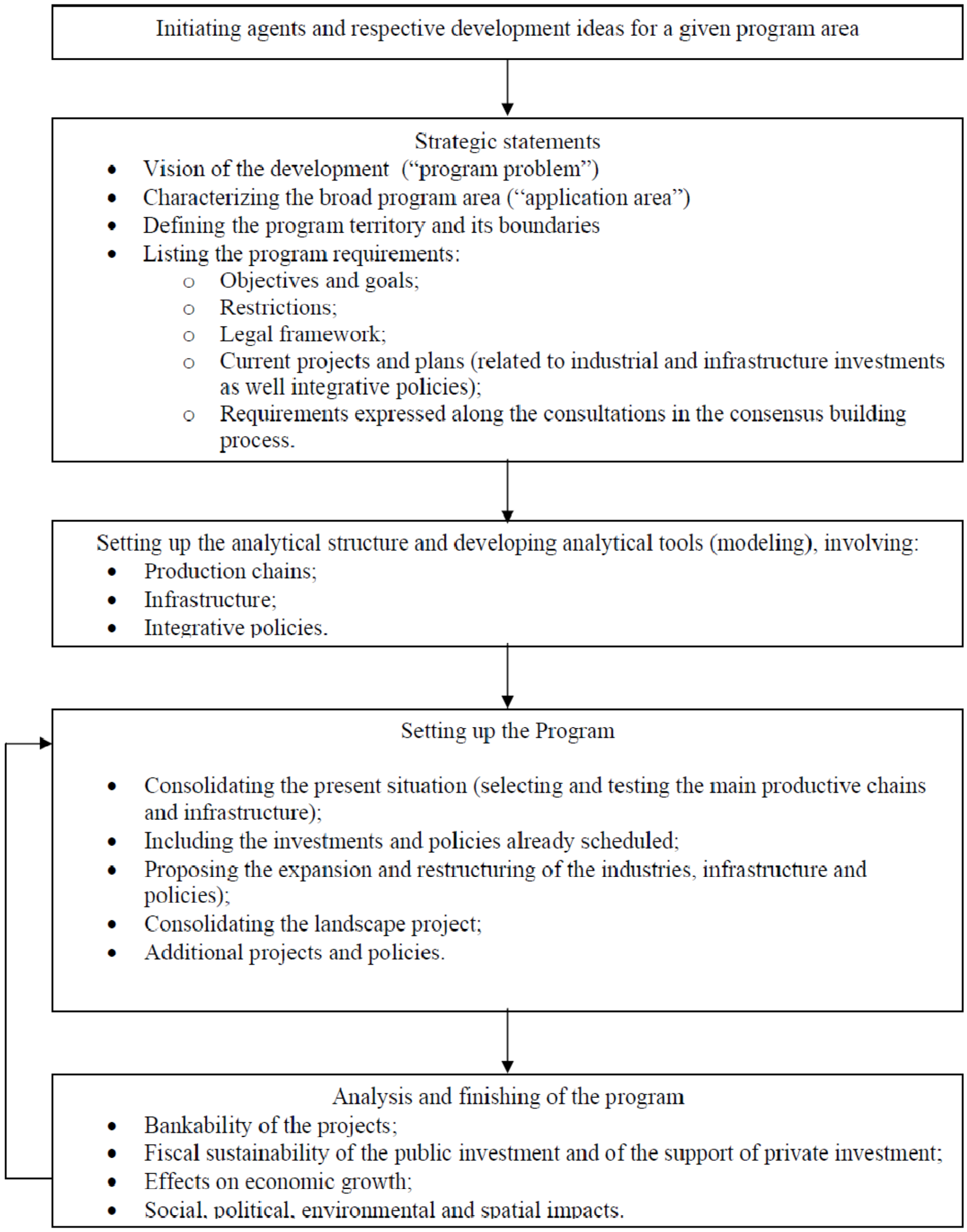

Figure 3 – Flowchart for the Territorial Program

As a common engineering process, Territorial Engineering embraces not only devising solutions, but also executing, monitoring and evaluating phases, thus closing a whole project cycle. In turn, the formulation phase includes the development and ex-ante analysis of the economic, financial, social, political and environmental results as well the financial engineering. Further, the execution phase will include the consensus building and the legal engineering. Finally, project and knowledge management accompany the whole cycle (see Fig. 4)

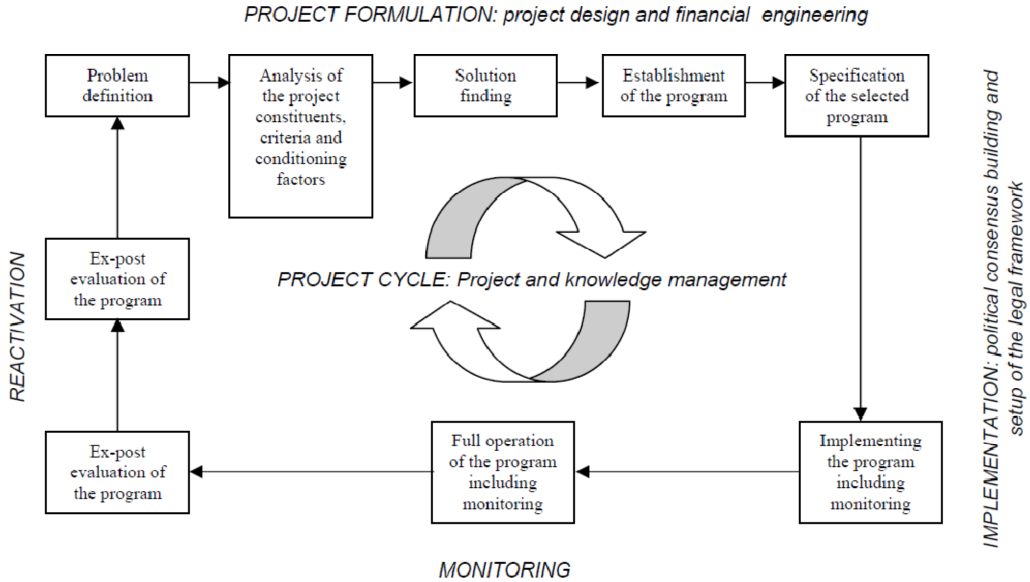

Figure 4 – Project cycle in Territorial Engineering

The list of problem categories is still far from exhaustive, and only the broad application and deeper development of the approach will bring a systematic categorization framework. Anyway, for terminological purposes it may be established that a programmatic problem arises when a given undesired situation is confronted with a desired vision, whereby the obstacles to be surmounted, the development targets and the basic set of actions are defined in order to achieve the desired transformation within an area. These constitutive elements lead to a more concrete problem definition, which in most cases will fit to one or other problem category discussed before. In some cases, however, the problem will appear initially as complex and undetermined, thus different logical tools as semantic networks, heuristic structures, models, etc. have to be applied.

Other considerations have to be made with respect to the programmatic problems and their definition. According to the rule, defining problems is not an exclusive task of planners and technocrats, but also of a set of relevant social agents, since the adoption of such comprehensive investment and action packages need a robust consensus building procedure. Frequently, the development and investment visions and options are already given by the social agents; and since Territorial Engineering has a self-conception as a tool for territorial planning (see above), the respective planning objectives and targets as well the already decided projects will deliver highly visible constituents for the problem definition. All these previous decisions have to be taken into account, and it will be the task of the “territorial engineers” to understand the desires and to meet with other planning prescriptions, and then to translate these inputs into a proper synthetic vision and into a programmatic problem which will be the base of the program. In general terms, the present situation will be the undesired situation, and the synthetic vision the desired one.

Once the synthetic vision is compound by the engineers and approved by the agents, the given application area will be submitted to deeper studies, whereby the financial, political, legal and knowledge bottlenecks to be surmounted will be recognized, leading to the final problem definition. This definition allows for advancing to the next steps, which are the more precise delimitation of the boundaries of the program territory (as shown below), the definition of the objectives, restrictions, targets, strategies of the program, all of them constituting the program requirements. Hereby, the objectives, targets and strategies already established by the official planning documents will have to be complied with; when such a strategic territorial planning is still not effective, it has to be caught up, beginning with the already decided projects (we could then speak of a kind of reverse planning). This step of problem formulation ends with a comprehensive diagnosis of the program area (application area), where the already existing industrial tissue, the infrastructure, the economic and social geography as well the political system will be scrutinized.

3.2 – The Program Territory

The definition of the programmatic problem and the preliminary characterization of the application area lead to the consolidation of the program territory. This territory originates from the application area, but it differs both conceptually and spatially from the latter (Aragão and Pricinote 2009). Initially, it must be highlighted that the term territory represents an appropriation of a determined area by a set of agents. In the case of Territorial Engineering, the public and private initiators of the territorial project are the protagonists of this appropriation. Subsequently, the program territory constitutes an appropriation strategy of a determined area by the agents which aim to implement the program, therefore, clearly differing from the common concept of study area used in planning studies.

A particular feature of setting up a program territory is that it is constructed from the inside outward: initially, the investment projects for the industrial plants in selected production chains are put on the map of the application area, as well the infrastructure network and projects and also the network of clusters and economic poles that are relevant for the program. According to the rule, these poles must be situated in or near the main cities (so there is a network of urban poles). This first territory will have a spatial configuration of a network and not of a continuous area. It will later be complemented by impact and resources basins, which, in turn, have a configuration of continuous areas. These basins have to be added as they consist of areas that may suffer from negative impacts which have to be mitigated (ecological basins, populated areas, production areas and the like); or areas which may deliver essential resources for the production which are not concentrated in discrete points of the space (water, soil, minerals, flora, fauna, etc.). In this second step, the territory will have a mixed configuration as it will be composed both of reticular and continuous elements, which will be articulated by the infrastructure and will be contained within the application area.

Notwithstanding, as this territory and the territorial program will not be isolated from the external environment, a third complementation will be necessary, whereby the territory will transpose the boundaries of the initial application area. This complementation will include a georeferenced network a) of strategic agents (composed of suppliers, buyers, makers of economic and political decisions); b) of external infrastructure links and nodes which will be relevant for the considered supply and commercial chains within the program (terminals, railways, roads, sea routes etc.); as well c) of continuous resource and market basins.

4 – Listing the program requirements

Every detailing of the program and even the construction of the analytical representation and modeling, which will support the setup of the solution, i.e. the program, has to be preceded by the effort to systemize the different requirements that it has to comply with. On the one hand, the formulated programmatic problem and the subsequent statement of the objectives and targets of the program are the first inputs to be considered. On the other, a whole pack of other requirements will have to be taken in account, and the setup of the complete list of requirements will be a time-consuming task to be fulfilled on the basis of an appropriated methodology.

To begin with, a system of requirement categories has to be adopted. Following the systematic established by Pahl et al. (2005), the requirements may be roughly subdivided in external and internal requirements: whereas the first ones represent the requirements imposed by the program clients, by regulations and legal statutes, by the official planning instruments and by inputs from other agents of the environment, the last ones derivate from the intrinsic features of the constituent elements of the program, as it will discussed further.

The main external requirements will consist of:
a) the objectives and targets which derive from the programmatic problem statement (see above);
b) the objectives, guidelines, goals and rules set by the official territorial planning documents
c) the rules established by national, regional and local legislation and regulations, especially those concerning regional, urban and infrastructure planning and construction; environmental protection; public finances and other legal matters encompassed by the program;
d) public and private projects that are already in the agenda regarding infrastructure, industrial plants, urban areas and integrative public policies;
e) requirements that have been mentioned throughout the political consensus building process between government, investors, industries and civil organizations;
f) other recommendations from studies on scenarios, trends of the global, national and regional markets relevant for the selected industrial clusters, as well as on possible new facts that may affect the program in the short-term.

Regarding internal requirements, these derive firstly from the inner logic of the Territorial Engineering, whereupon a territorial program should mainly achieve:
a) to rise the microeconomic efficiency of the productive chains, especially by creating value driving synergies by the complementation of the chains, by the improvement in their productivity and in the respective logistics processes and by fostering innovation processes;
b) to diversify, in an integrated manner, the pattern of the economic activities, to attract new anchor enterprises and private investment in general; to foster scale economies and to deepen the integration with external markets;
c) to consolidate the agglomeration economies by maturing the local industrial

clusters and growth poles and by raising the competitiveness of the territorial industries;
d) to ensure the bankability of the projects, and where the projects can not satisfy this condition and demand the complementation with public finance resources, to assure its fiscal sustainability, provided that they can satisfy the condition that they contribute to economic growth of the program territory and to the subsequent raise of tax incomes;
e) to generate general economic growth but by fostering human development and social justice, mainly by distributing income opportunities; and
f) to mitigate the environmental, business, political and existential risks to be identified.

Other internal requirements will result from the intrinsic technical features of the selected industrial activities, infrastructure and policies. For instance, certain agro-industrial activities are subject to specific environmental conditions, such as soil and climate, which must not be ignored when designing the program. Equally, the types of infrastructure involved have specific restrictions and technical peculiarities, so policies are subject to a set of institutional and legal restrictions that have to be observed.

Of course, the complete elaboration of a list of program requirements will turn necessary a strong effort in compiling and analyzing documents and in the organization of meetings and participatory procedures. After requirements are systematized, they need to be translated by means of a semantic network into a set of indicators, which will guide the setup, evaluation and selection of the projects of the territorial program.

5 – Designing analytical tools and models

5.1 – Main objectives of the models

Are the program requirements systemized, the setup of the analytical representations and of the modeling tools can be started; they shall help to understand the diversity of flows between the activities, as well their mutual relationships, and to design and analyze proposed programs. In a general manner, a territorial program has to be considered as a major undertaking and as a tool for the social and economic articulation or society; thus a more straightforward way to analyze the structure of the actions and projects is their description in terms of a network of interwoven productive chains which is supported by a network of infrastructures and urban polarities. This kind of texture would then represent the starting point for the tool construction.

At the present stage of the research, the setup of the tools, including the mathematic models, is still in its beginnings. What is expected from these models? Fundamentally, they shall indicate the evolution trends in industry and logistics, as well test to what extent the project proposals for the program are able to achieve the established targets as measured by the indicators.

The tools which are presently being developed start partly from the studies for the South American Regional Integration Initiative – IIRSA (Rivas et al. s.d. a,b), which aim at to connect investments in transport infrastructure with the economic growth, in a way similar to Territorial Engineering. From these studies it may be concluded that the setup of the tools should start from a preliminary and coarse sketching of the production chains and of the logistic systems. Following tasks are central:

- to represent the more representative products with respect to the GNP which are present in the territory;
- to reconstruct the respective productive chains and to analyze the profitability and competitiveness of the chain links which are present in the territory and of their respective industrial projects;
- to analyze their logistic process and to understand the links of the proposed infrastructure and policy projects to the value adding process of the industrial projects, so that the contribution of these projects to economic growth may be understand;
- to analyze the financial results of the project of the private sector with respect to infrastructure, industrial plants and even for the integrative policies (i.e. some private investments in housing, education and health sector), independently or dependently of governmental financial support (which can take the form of tax subsidies, of participation in equity, of subsidized loans by governmental development agencies, of governmental guarantees, and the like) and to test their subsequent bankability;
- to analyze the flows of the government finances subsequent to its direct investments and to its support to private investments in terms of the costs and also of the receipts directly related to the value addition and economic growth produced by industry, which will have been fostered by the infrastructure and policy projects;
- to measure the environmental, social, political, spatial and other relevant impacts and to compare with the established targets, deducing the respective risks they may bring to the success of the program.

5.2 – A preliminary sketch

Figure 5 sketches the general structure of the model and details the sequence different simulation tasks. This first high level of aggregation is in function of the project large-scale with the objective to identify subsystems and boundaries of the construction project as discussed by Sterman (2000). Based on the list of requirements that will be incorporated into the strategy for economic growth, the landscape project and a complementary list for other requirements; a set of infrastructure, industrial and policy projects is established, which will result in a system framework composed of industries, infrastructure and public services.

The output of this framework is decomposed into financial and nonfinancial results. With regard to financial results, the model will incorporate income, fiscal receipts and governmental financial support to achieve the bankability of the projects. These results will serve as input to bankability and fiscal sustainability tests. While the lack of bankability will result in seeking for governmental support, the lack of sustainability will imply in redesign of the project because additional growth driving projects according to the growth strategy will have to be inserted into the program. Nonfinancial results, on the other hand, will be decomposed in the different relevant impacts (environment, social, political, spatial and others) and their degree of achievement will be evaluated. In case of noncompliance with the established goals, the growth strategy, the landscape and other program requirements will be re-analyzed, and the program will subsequently be redesigned and then submitted to a new round of simulation and analysis.

The setup of this analytical system, which will lead to the development of an adequate (albeit complex) model, will be executed along the construction of the solution. These tools, the development of which is in the order of the day of the research efforts, shall verify if the already inserted elements of the program (basis scenario) are sufficient to comply with the program requirements and to achieve the defined targets, and in which degree additional projects will improve the performance of the set. Using the tool along this approach, it shall be able not only to analyze proposed scenarios, but also to indicate paths to the improvement of the program.

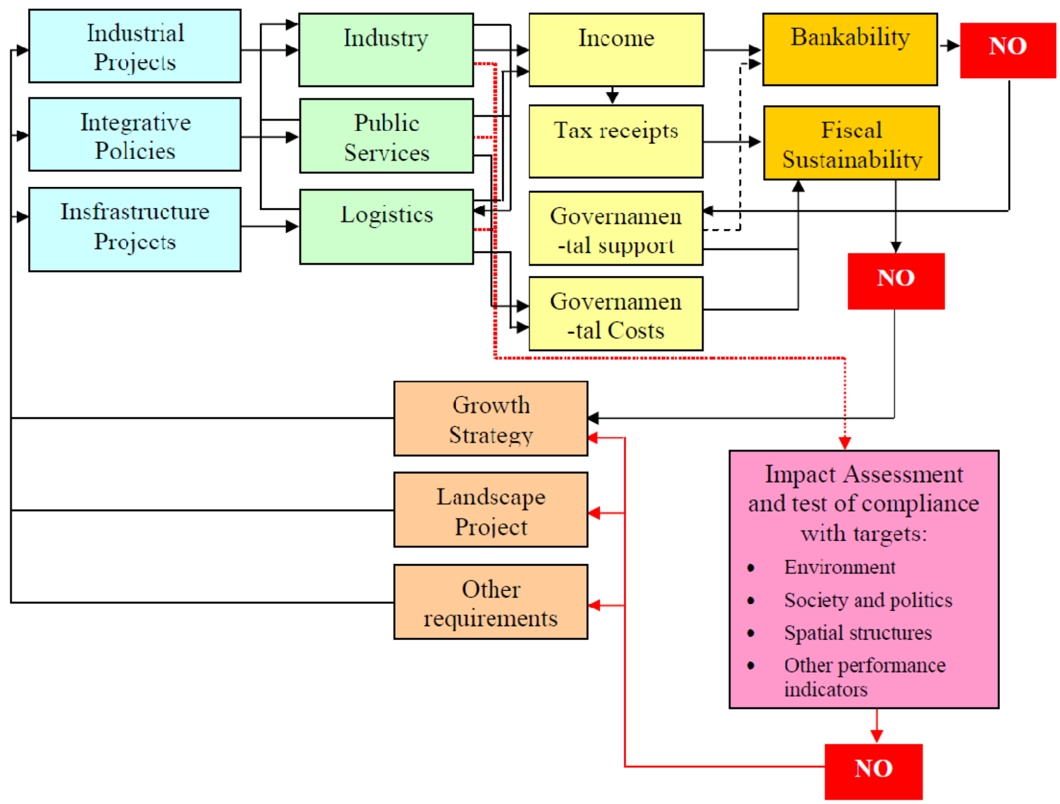

Fig. 5 – Broad structure of the analytical model for Territorial Programs.

5.3 – The first step: modeling project bankability

In practice, very complex models, such as the one proposed here, should be developed in different stages, based on a given set of priorities. It is noted that the issue of funding infrastructure had originally given birth to the concept of Territorial Engineering, although the value of this approach also as a strategic instrument for the execution of territorial plans and other benefits in terms of sustainable development has been recognized (see above). However, focusing on the first concern, the present modeling research efforts are being concentrated in developing modules to test the financial results, which are the bankability of the projects and the governmental supports. Supposing we have to examine the bankability of a highway construction project according to the Territorial Engineering proposed here we divided the problem in 3 subsystems (Figure 6).

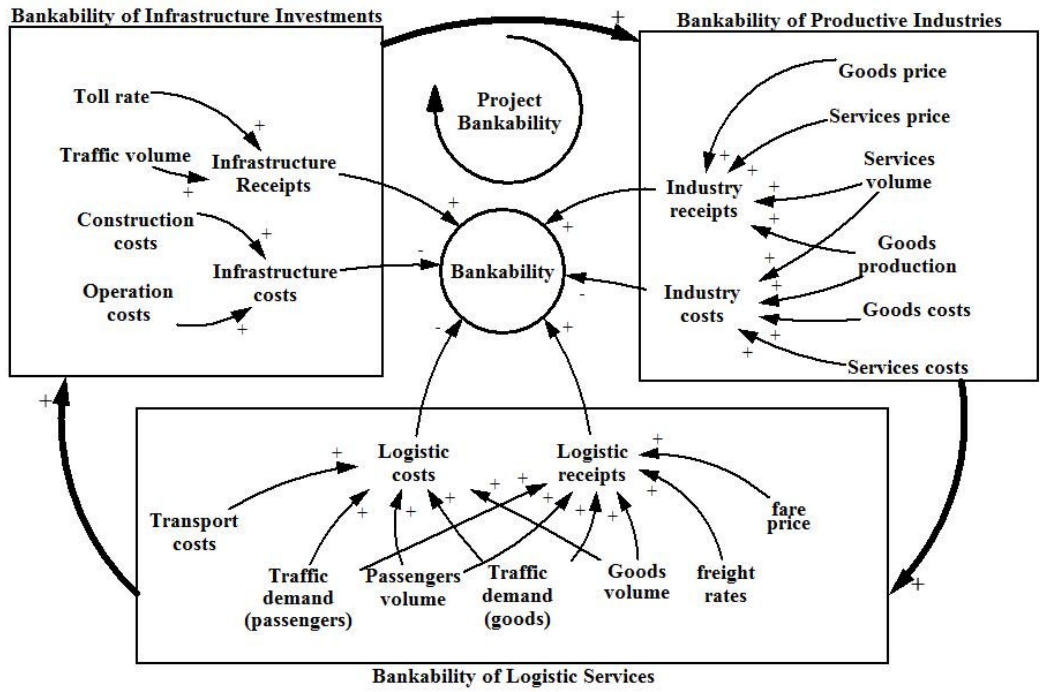

Fig. 6 – The three subsystem of an infrastructure project (Highway construction)

- Subsystem A (bankability of infrastructure investments): the construction plans, traffic demand and toll prices will produce the infrastructure costs and receipts, and the application of current criteria used by the financial market shall evaluate the bankability of the included projects.

- Subsystem B (bankability of logistic services): for analytical reasons, the logistic business has been separated from the infrastructure supply business. Informed by the traffic demand but also by the fare price (including freight rates) expectations of the client industries and of the passengers, the prices and services volumes are set, producing the operational costs and receipts. For analyzing the bankability of the respective investments, the criteria used by the financial markets are applied again, resulting in the bankability verdict.

- Subsystem C (bankability of productive industries): these industries include not only the production of goods, but may also include services that belong to the set of the integrative policy actions (e.g., education, health services, housing) as long they are commercially feasible. Informed by the sales targets and prices as well by the production volumes, the foreseen sales receipts and production costs (which include the logistic costs) build up a cash flow, which is evaluated regarding its bankability, based on the bankability criteria used by the financial markets.

It is fundamental observe that the three subsystem interaction (noted as a positive feedback loop) is which will create the bankability of the entire project not only the bankability of each subsystem in isolation.

The figure 7 shows a typical SD model for the Subsystem A (bankability of infrastructure investments) customized for Brazilian taxes and tributes.

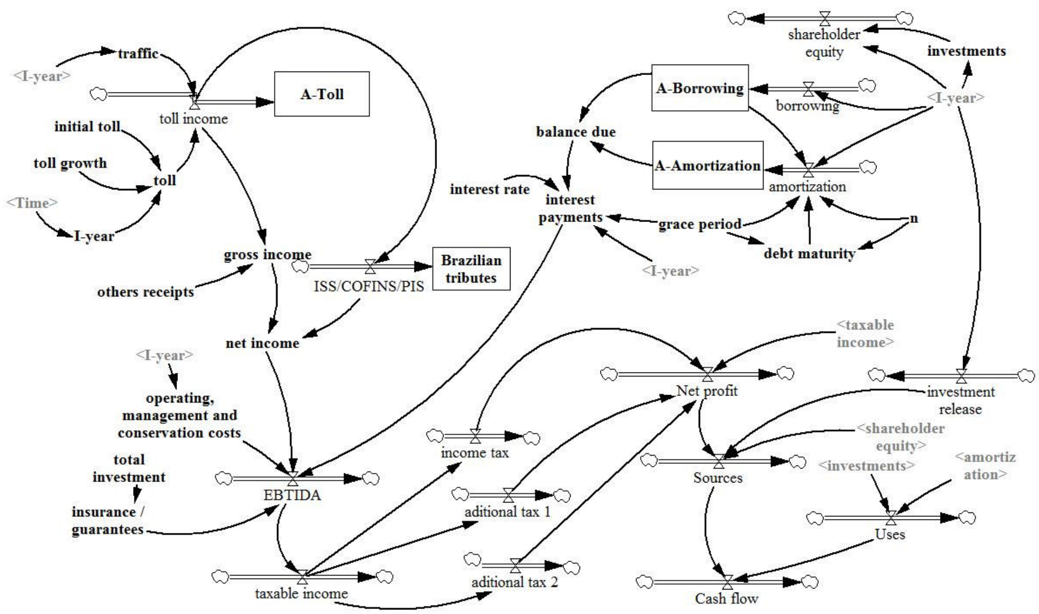

Fig. 7 – A typical SD model of bankability

Although this model incorporates key financial variables of a project, the proposal of Territorial Engineering is more comprehensive and is not limited to the analysis of infrastructure investment in itself. Therefore, this model is not sufficient to meet their innovative dynamic. The final model should be able to capture the complexity of interaction between the three subsystems, and the bankability as an emergent feature of the system. The decision to use a System Dynamics approach to the bankability issue is in function of the complexity and level of uncertainty when dealing with infrastructure projects like a highway and regional development.

For example, in Taiwan, since 1974, several transportation projects have been planned in order to enhance economic activities and achieve a more balanced distribution of population (Chiang and Chiang, 1991). Although the authors acknowledge a strong link between investments in transport and regional development, they observe that the regional disparities have not been reduced and the population migration to highly developed regions has never declined. In other hand, Chiang and Chiang (1991) developed a SD model to test scenarios including other social-economics variables as investments affecting the production and productivity of industry and infrastructure (industrial sites, public utility, social overheads, etc.). These scenarios intend to study the disparities between Northern and Eastern Taiwan regions. They conclude that the

"the transportation plays a key role to the development among regions, but is not the sole stimulator of growth. Only direct investment in economic activities originates real economic growth."

The aim of the ASTRA (Assessment of Transport Strategies) project was to develop a tool for analyzing the impacts of the Common Transport Policy (CTP) including secondary and long-term effects. The project started in October 1997 and planned to end in January 2000 (Schade et al, 1999). The authors justified the use of System Dynamics stated that interrelationships e.g. between transport and macro-economics or between location choices and the transport system are often treated as exogenous or not existing. To them here lies the field of application of system dynamics (Forrester, J. W.) because it is one of the few tools, which are able to re-establish these interrelationships and to tie together the elements of reality in one model again. The ASTRA System Dynamics Platform (ASP) integrates for sub-modules, which are regarded to be the most important systems of reality that have an impact on the assessment of the Common Transport Policy (CTP). The four real systems are:

- Transport system as a basis for modeling transport infrastructure and traffic volumes.
- Regional economics and land use because of the relationships between regional development (business, housing), transport and environment.
- Macroeconomics to integrate national or continental level influences into the model.
- Environmental system because of the relationships to the transport system and the importance for the national welfare position.
-

It is possible see that the approaches of the Territorial Engineering and the ASTRA are not much different (in a broad sense) in respect to the relationship between transport and environment issues, regional economies, and economic growth as well pointed by Chiang and Chiang (1991). The two papers cited also show that system dynamics is an appropriate approach to address complex problems like this. Of course, each project has its own goals, dimensions, and characteristics of what makes them unique but not closed to past and ongoing experiences.

5.3.1 Agent Based Models

The Territorial Engineering is a field of study that includes an extensive number of agents interacting each other in the real world. One advantage that calls attention when addressing the Agent Based Models is that they incorporate the action of various agents in mutual interaction in a single simulation environment (Castle and Crooks, 2006), which is very affordable considering the assumptions of the Territorial Engineering. In this method of modeling, the relations between the agents mutually linked and the environment are defined where the iterations are performed. The types of interaction are different: may be a simple reaction or actions based in strategies and objectives. In addition, the actions and behaviors can be synchronous or not.

In general, the multi-agent models have been applied to different types of situation, as listed by Crooks et al. (2007): reconstruction of ancient civilizations, understanding the development of national identities and state formation, biological models of infectious diseases, growth of bacterial colonies, size of companies and their growth rates, changes in prices on stock exchanges; behavior electoral spatial patterns of unemployment, and social networks of terrorist groups. In methodological terms, the construction of an agent-based model starts with the design of a conceptual scheme, where the basic goals of modeling, system elements (including attributes of agents and rules of behavior and its iteration, and the descriptors of the environment), and the results to be measured are defined. At the time of construction of the scheme, will be necessary also explain the simplifications to be adopted, which should not result in an unacceptable departure from reality.

The construction and application of agent-based models require coping with various challenges (Crooks et al. 2007). Given the variety of situations and environments, there are no standardized and replicable procedures. Every time is necessary to reconstruct the model in accordance with the specific goal of modeling. In addition, models should be based on theory and the traditional role of a model in the social science is a translation of theory into a form whereby it can be tested and refined. Other things to consider are the ability of the model to replicate different situations, the process of validation and calibration, the dynamic character of the iterations, the operational model, and the possibility of the model to be shared by different users.

Nevertheless, the challenges described above the possibility to apply Agent Based Models could offers more flexible to structure the models, which can be done in form of a hybrid model. A hybrid model combines in its structure elements from both system dynamic and agent based modeling. Using agent based modeling in conjunction with system dynamics offers many opportunities for researchers. The clearest addition to opportunities compared to basic system dynamic approach is the more flexible model structure (KORTELAINEN and LÄTTILÄ, 2009). In particular, agent-based modeling has provided good results when the behavior of individuals can not be defined clearly, when the description of this behavior can not be adequately expressed by equations, or when the complexity of differential equations becomes too much, and when the system is more appropriately built on activities that in aggregate and predictable processes, and when the behavior has a more stochastic.

Considering this information about agent-based modeling and hybrid models, the first tests are being conducted by this research program. Presently, the development of this first-stage model was assumed by the Center for Personnel Training in Transportation (Centro de Formação de Recursos Humanos em Transportes – Ceftru) at the University Brasília (UnB) as a long-term research program that will go along the development of other theoretical and technical branches of the Territorial Engineering approach.

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