Use of System Dynamics Models as Part of a Game-based, Urban Sustainability Course for Students in Higher Education (SUSTAIN)

ABSTRACT

The difficulty with sustainability arises from its abstract nature and the fact that these problems have long term horizons. The objective of the SUSTAIN course is to promote sustainability literacy among students of higher education through an innovative and student-centered education that makes use of system dynamics (SD) models embedded in game-based learning. In this project, as part of the SUSTAIN course, we try to develop small illustrative SD simulation models that will allow for experimentation in a consequence-free environment. These simulation models will then be translated to game elements, mechanics and potential playing scenarios for a table top / board game that deal with sustainability issues.

The purpose of this project under development is to help students of higher education achieve competences such as the ability of constantly assessing the environment, operating and adapting to it through continuous and iterative individual process of revision from their frames of reference, and to provide the material to comprehend systemic complexity. We expect these competences to allow them to deal with complex decisions and decision making processes in their future careers in private and public organizations, and provide insights into the complexity and the effort required to achieve the Sustainable Development Goals (SDGs).

INTRODUCTION

Currently in the EU, there is the need of not only raising awareness on the issue of sustainability, but acquiring a sustainability literacy, in the sense of a functional education that will provide the necessary skill and motives to cope with the challenges of and contribute to sustainable development.

Special attention is paid to means for the achievement of the SDGs, their universal application to all countries and the simultaneous address of the economic, environmental and societal dimensions of sustainability. The difficulty with sustainability arises from its abstract nature and the fact that these problems have long term horizons. Thus, there is the need of not only raising awareness, but acquiring a sustainability literacy, in the sense of a functional education that will provide the necessary skills and motives to cope with the challenges of and contribute to sustainable development. As a result, it is essential to provide an innovative pedagogy to students of higher education that will be the policy makers of tomorrow.

Developed conceptual models preceding the simulation models are provided in the annexes attached to this file.

SYSTEM DYNAMICS MODELS AS PART OF THE SUSTAINABILITY COURSE

The objective of the SUSTAIN course is to promote sustainability literacy among students of higher education through an innovative and student-centered education that makes use of system dynamics models embedded in game-based learning.

The field of simulation and gaming has acquired a growing relevance for quite a long time (Faria et al. 2009 and Crookall 2010 and 2012) and certainly has evolved over that time span. Nowadays, simulation and gaming is recognized as a field of research that supports learning (both individual and organizational learning) and is employed extensively in educational and management training programs (e.g., Crookall et al. 1987; Sauvè et al. 2007; Barnabè 2016). Notably, The field of System Dynamics has been traditionally close to the field of simulation and gaming, and various publications and special issues in the past two decades not only explored the interactions between the two streams of research (e.g., see Davidsen 2000; Davidsen et al. 2000; Alessi and Kopainsky 2015), but also demonstrated the benefits stemming from their combination in favoring learning and improved decision-making (e.g., Morecroft and Sterman 1992; Sterman et al. 2015; Davidsen and Spector 2015).

With specific reference to the SUSTAIN project, the main features of the game are as follows:

1. It will deal with transportation sustainability, societal metabolism and decision making under complex and inter-connected contexts. The purpose will be to teach students the definitions of those notions, how they are translated in everyday life, and formalize the mathematics necessary to make robust decisions.
2. The course will feature small, illustrative SD simulation models that will make the definitions more concrete and allow students to experiment in a consequence-free environment. The simulation models will be used to identify scenario exemplars on how we can achieve sustainable urban transportation and a balanced societal metabolism, while taking into account formal decision making process. Thus, greater insights will be provided to the policy makers of the future regarding the complexities of decisions in uncertain issues where many stakeholders are involved.
3. The approach of the SUSTAIN project is hybrid and as such the material explored up to this point would be translated in elements and mechanics of a Serious Game. The purpose is to allow students to learn about transportation sustainability and societal metabolism through playing. One important aspect of the design of the game is that it will avoid being just an informational/fact-delivering game; the core design principle will combine delivery of facts with experiential elements that will allow students to explore their own sustainability goals and the means to achieve them.

The developed models will be available in the project's website in the form of Interactive Learning Environments (ILEs, see Davidsen 2000) that will allow students (along with existing policy makers and non-experts) to experiment freely. This will allow students (and participants) to experiment freely and gain insights into which policies work best, which generate unwanted consequences and under which conditions urban systems present counterintuitive behavior.

CONCEPTUAL MODELS BEHIND URBAN SUSTAINABILITY ISSUES

The SUSTAIN CLD is composed by different variables, that represent areas of interest in a general modern urban system. The model, in fact, considers general aspects as GDP and population, as well as environment, transport, urban planning and waste and water management.

As the CLD (and subsequent Stock and Flow diagram) will be the basis for the future development of the game, which is the main outcome of the project, the core of the model is represented by the most important parameter for deciding who will win the game, i.e. the Attractiveness of city. This variable is the synthesis of multiple variables that belong to many aspects of urban system, defining the "wellbeing" of the population who lives in it.

The most important effect due to variations in Attractiveness of city is a variation of the number of people who lives in the city; this generates many impacts on different urban levels, triggering as many feedback loops. In fact, most feedback loops we identified passes through the "Population" variable. It's kind of natural that this happens as, in the end, urban systems exist because of its inhabitants, indeed.

Analyzing the CLD, the most important feedback loops were identified and then divided in three main groups.

The first group is composed by loops belonging to the "core" of the model, that is the relation between population, GDP and Industries and Services.

The first two reinforcing feedback loop (R1 – R2) trigger when a variation in city's attractiveness causes an increase in population, which generally has a positive effect in GDP; the more the GDP the more the development of industries and services, this generates a twofold positive effect on attractiveness: on the one hand, there is the availability of more services and developed industries; on the other hand more services and industries means more jobs for inhabitants. The former phenomenon is limited by the balancing feedback loop (B1), which depicts the saturation of jobs in the city. Finally, GDP and Industries and Services are tight together by a simple reinforcing feedback loop (R3).

The second group is composed by loops which belong to the "environmental" part of the model. Water, waste and transport have direct impacts on the total pollution and, in turn, on attractiveness of city.

As opposed to the reinforcing loops met previously, there are two balancing loops (B2 – B3) that stabilize the attractiveness of city through the possible increase in population which cause an increase in waste generation and water consumption, with consequences on pollution and water shortage phenomena.

The reinforcing feedback (R4) describes how traffic congestion has effect on usage of public transport and, in turns, effects on pollution. This loop is balanced by two loops (B4 – B5): on the one hand, the usage of public transport naturally reduces the problem of traffic congestion; on the other hand, external policies could increase the roads' capacity and length addressing the same problem.

The last group of loops concerns the "land availability". Cities cannot grow indefinitely, above all it is important to dedicate some space for green areas and parking space, which complete the viability of the city.

The three loops belonging to the third group are balancing loops which limit:

- Roads extension due to congestion (B6);
- Households construction due to population (B7);
- Industries and Services development due to GDP (B8).

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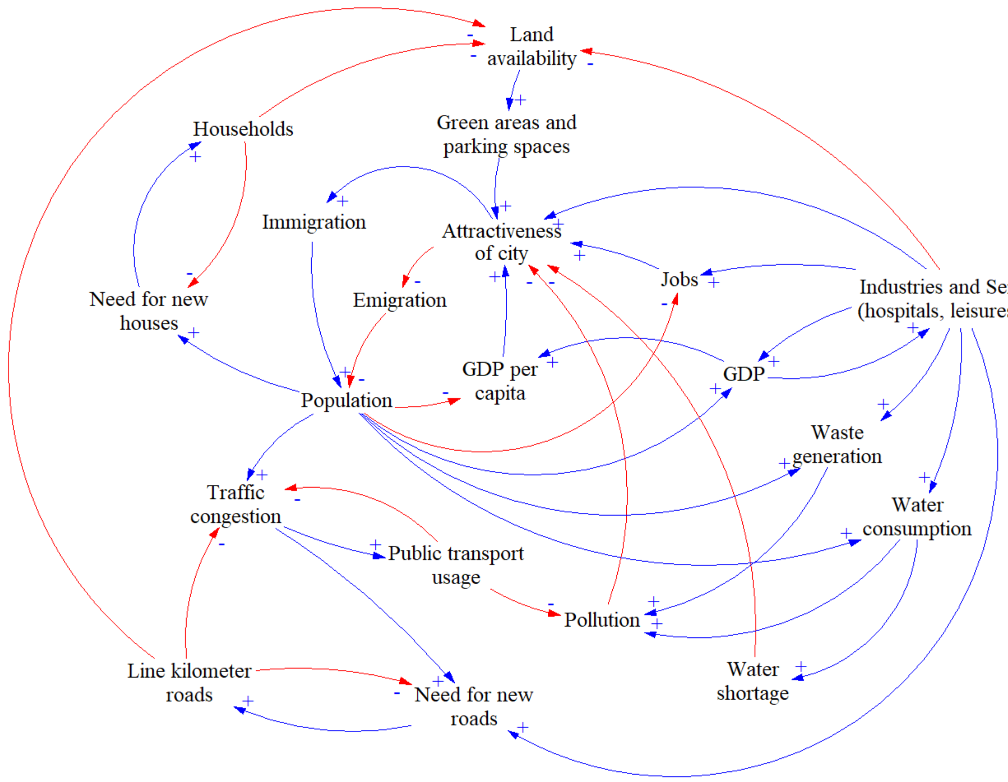
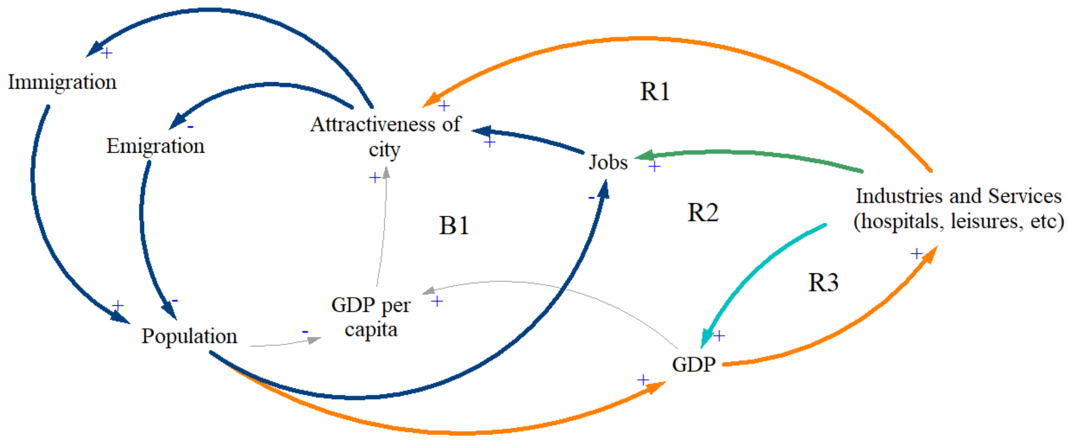
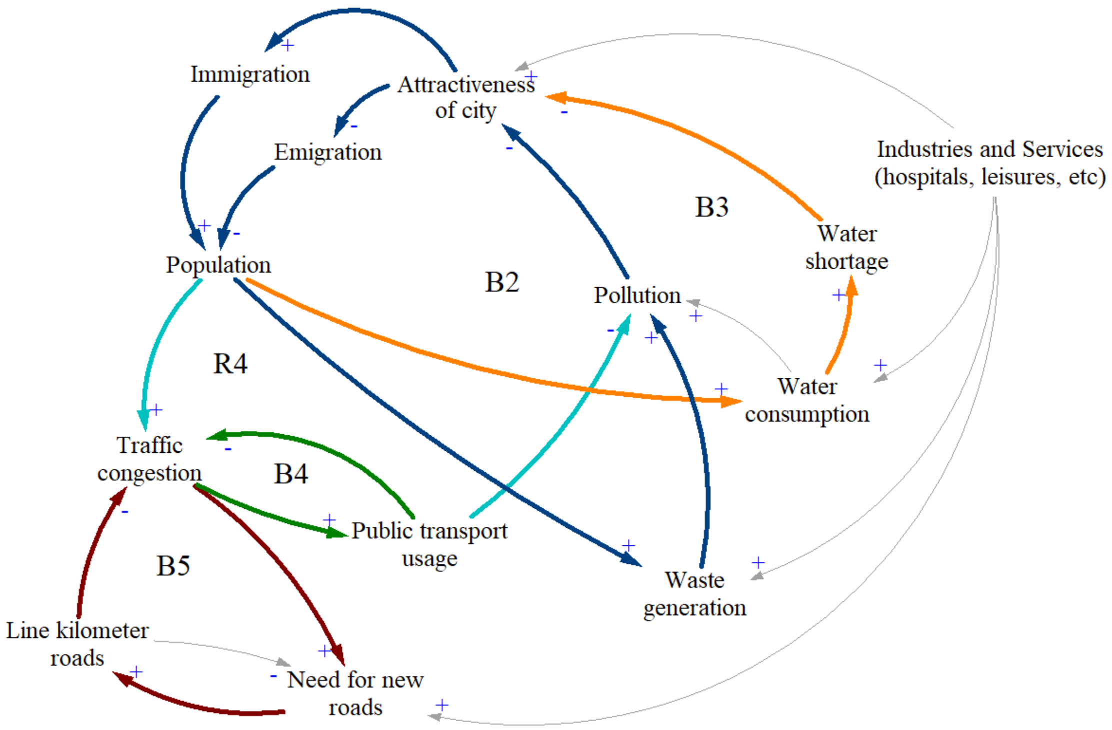
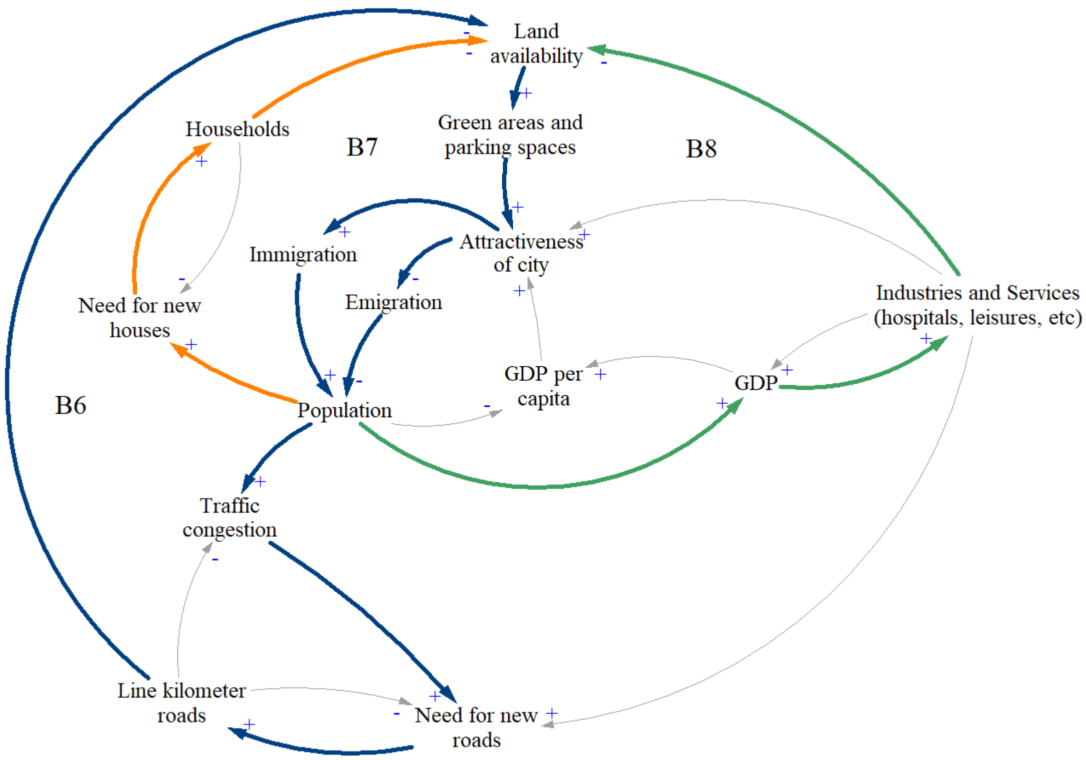
ANNEX


Land availability
Green areas and parking spaces
Households
Immigration
Attractiveness of city
Emigration
Need for new houses
Jobs
Industries and Services (hospitals, leisures, etc)
GDP per capita
GDP
Population
Waste generation
Traffic congestion
Water consumption
Public transport usage
Pollution
Line kilometer roads
Need for new roads
Water shortage


Immigration
Emigration
Attractiveness of city
R1
Jobs
B1
R2
Industries and Services (hospitals, leisures, etc)
R3
GDP per capita
Population
GDP


Immigration
Attractiveness of city
Emigration
Industries and Services (hospitals, leisures, etc)
B3
Water shortage
Population
B2
Pollution
R4
Water consumption
Traffic congestion
B4
Public transport usage
B5
Waste generation
Line kilometer roads
Need for new roads


Land availability
Households
B7
Green areas and parking spaces
B8
Attractiveness of city
Immigration
Emigration
Industries and Services (hospitals, leisures, etc)
Need for new houses
GDP per capita
GDP
B6
Population
Traffic congestion
Line kilometer roads
Need for new roads