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# An Innovative Game-Based Approach for Teaching Urban Sustainability

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## ABSTRACT
*This paper is based on SUSTAIN, an ERASMUS+ project with an innovative perspective on urban transportation, and its target is to promote the importance of sustainability on the everyday problem of urban transportation among the students of higher education (and not only), who are the policy makers of tomorrow. In order to achieve its goals, the research team is currently developing a course that will be based on an interactive serious board game with an analytical style of education. SUSTAIN's purpose is to create a game that will allow students to learn about transportation sustainability and societal metabolism through playing. The project partners develop small and illustrative simulation models, which will make the definitions more concrete and allow students to experiment largely in a consequence-free environment. The simulation models can be used to identify scenario exemplars on how we can achieve sustainable urban transportation and consequently a balanced societal metabolism, while on the same time taking into account formal decision making processes. In this paper, we are going to explain a Stocks & Flows Diagram for the above mentioned model, with a system dynamics approach.*

**Keywords:** *urban transportation, sustainability, serious game, decision making, system dynamics*

# INTRODUCTION

Sustainability and sustainable development have been recognized as the major challenges of the 21st century and to achieve this objective there is the need to think of education not as the traditional, analytic way of transferring knowledge, but as an experience that is centred on the student. Its purpose is to assist them in acquiring the necessary material/tools that will help them comprehend and tackle complexity that is inherent in sustainability.

The objective of the current paper is to present an effort in the context of an E+ project on Higher Education to use serious games as a means to teach sustainability. To achieve the objective a board game will be designed and developed that will utilize the principles of Systems Thinking for the game mechanisms and design.

## The SUSTAIN Model

The board game that will form the center of the new type of education, will be based on a simulation model that helps to contextualize and make more understandable the abstract notion of sustainability. The simulation model, named the SUSTAIN model, is developed with the principles of Systems Thinking and more specifically, using the methodology of System Dynamics. The following paragraphs, illustrate the basic aspects of the simulation model.

The SUSTAIN model that we are going to describe is a Stocks & Flows Diagram (SFD) (Forrester, J. W.,1971) without the definition of variables (Auxiliaries and rates) and constants. Over the following weeks, we will develop further the model by "quantifying" it, so that it can be simulated and experimented with. However, this delivery intends to convey the structure of the overall model, from which the SUSTAIN board game can be designed. Of course, we do not expect that all aspects in the model be implemented/accounted for also in the board game, but we have developed this model by keeping in mind the elements that were already considered in our preliminary designs as well as those found in the literature, so that we are not expecting big differences. What we would suggest now, to the game designers, is to review the model and carefully check especially the dynamics of stocks accumulations/decrease (with related timing) and the aspects of delays between actions and results (both very important aspects also for the game experience).

The model is divided in several sections:

- Investment-general variables
- Urban planning
- Waste management
- Water management
- Transport
- Environment
- Energy

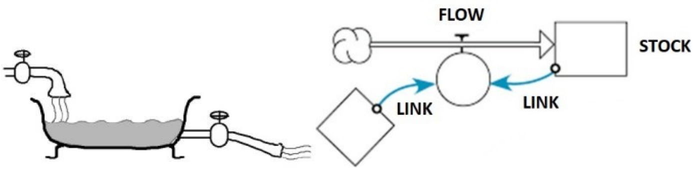
Each of them has its own variables and internal dynamics, but, from a systemic point of view, they can be seen as a whole big system which represents the concept of "city". In fact, there are many links and interconnections between variables belonging to different sections. For example, building a new school have impacts not only at urban planning level (because it occupies a portion of available land), but also on waste and water management and energy (new activities, additional consume of resources, additional waste).

The majority of them are not visible in the image because otherwise the model may become unreadable, but every time the visible link is missed, there is a shadow variable (in grey inside brackets <…>) that represents the link. For the right and effective understanding of model, we want to explain some very brief and easy concept about System Dynamics, in particular S&F modelling. The S&F model is a simulation model that represent the system under study from a quantitative point of view, allowing user for policy experimentation in free-consequence environment.

Furthermore, using computer simulation models is much cheaper in terms of cost and time, rather than experimenting with the actual system, to know if the targeted objectives could be achieved when a certain policy is implemented.

S&F symbolism (figure 1) consists of:

- the stock (represents things in the model that can accumulate, the stock will rise and drop depending on its flows and will remain constant while in equilibrium),
- the flow (is the rate of change of a stock. Inflows add to a stock; outflows take away from the stock. Equilibrium occurs when inflows to all stocks are equal to the outflows),
- and the information link (blue arrow in the model represent the direct influence of the current value on another).



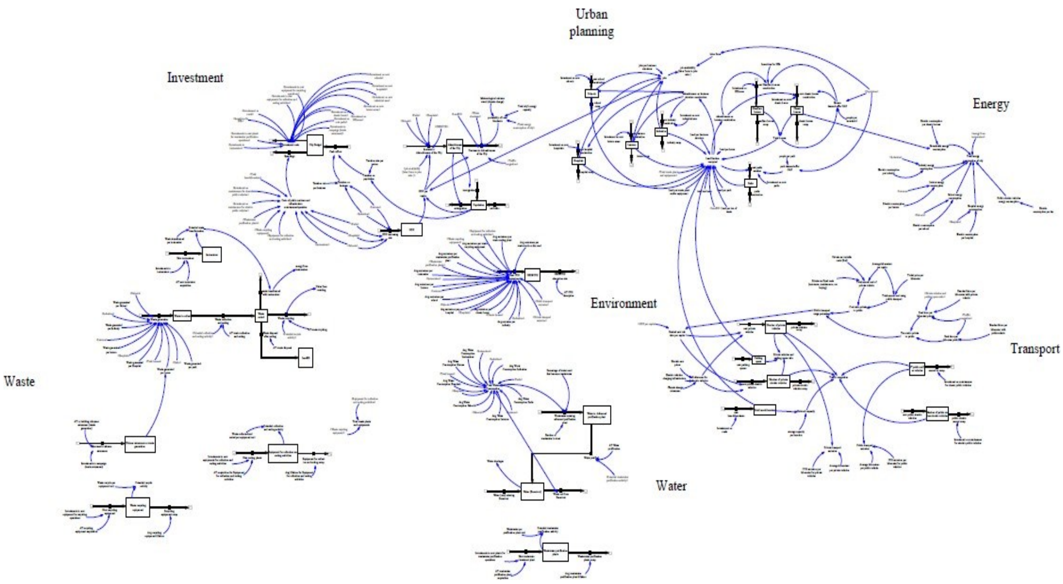




**Figure 1: S&F symbolism**

Investment-general variables

This first part of the model can be seen as the core of the model, because in this section there are the principal stocks that affect deeply the entire model, namely:

**Population.** A city exists when there are some persons that live in it. Every aspect of the city is affected by the number of persons that live in the city. The more the persons, the more the resources consumed, activities carried out, waste generated.

**Attractiveness of the city.** This stock represents the “wellness” and the satisfaction of the citizens and is led by many variables (e.g. job availability, schools, hospitals, GDP, etc.). Also, this level influences the people migration rates in and out the city, that define population level (Sanders, P., & Sanders, F., 2004)(Schroeder, W. W., 1975)(Haller, R., Emberger, G., & Mayerthaler, A., 2008).

**GDP**. GDP is a monetary measure of the market value of all the final goods and services produced in a period of time by a country or a city. It is guided by the economic wellness of the city, due to business activities.

**Liquidity.** This last stock represents the liquid assets for the city administration. Taxes from people and business activities increase the level, which is then (based on the availability) reinvested in different city sectors (e.g. new roads, more efficient facilities for waste and water, etc.)

## Transport

The transport sector in the model reflects a high-level description of transport dynamics inside a city (Jifeng, W. A. N. G., Huapu, L. U., & Hu, P. E. N. G., 2008). There are two transport choice for citizens: private vehicles or public vehicles. Based on the usage of one or the other mode there is a variation in number of private vehicles (i.e. new cars purchase), and therefore the car fleet in the city. There are also other variables outside the transport section which affect this variation (i.e. population and GDP per capita). The variation of private vehicles which circulate inside the city produce important feedback at section level as well as at overall model (Armah, F., Yawson, D., & Pappoe, A. A. (2010).
The modal choice is the core aspect in this section, for the reasons explained before, and is defined by two essential factors: Cost and Time. The cost factor is represented by cost ratio between annual cost for private transport and public one. Each citizen has an annual average kilometer per capita. Private transportation cost results from private car fixed costs (insurance, maintenance, car purchase) and variable cost (fuel) times annual kilometers. While public transportation cost results easily from price per kilometer and annual kilometers.
The time factor is represented by the ratio of time needed to arrive to the destination with both modes. Each of them results from standard time of transportation and traffic congestion, but only the private one is affected by time for finding parking, this latter is defined by the ratio between vehicle fleet and parking space.
Public transport fleet could be developed by investing both on traditional (e.g. petrol busses) and electric vehicles (e.g. trams). Each of them has its different costs of purchase and maintenance, also they have different impact in terms of GHG/CO2 emissions. Such sector is controlled by Urban planning sector through the planning of new parking spaces and new lane-kilometers. Another important factor is represented by traffic congestion, which is due to the number of private vehicles, public vehicles and network capacity. The congestion negatively affects the attractiveness of the city, and the related traffic emissions influences the sector Environment (then, again the attractiveness of the city).
Finally, such sector is controlled by Urban planning sector through the planning of new parking spaces and new lane-kilometers (Xu, Z., 2011), at the same time investment on roads and parking space have impact also at urban planning level, because they consume the city's land availability for other buildings and activities.

## Waste management

The Waste Sector is modelled as a long supply chain representing the whole cycle of waste from its generation to the landfill. In detail, the supply chain makes clear that waste is first generated (it depends on the number of the various activities in the city and the Average waste generated by each class of them) and needs to be collected subsequently. Therefore, the process entails phases (i.e., rate variables) of collection, sorting and recycling). The waste that cannot be treated is sent to Landfill or the Incinerators. Investments in this area can be carried out acquiring (or building) new equipment and plants needed for the whole supply chain.
The Water sector of the model is based on the main idea that any activity in the city consumes water and generates wastewater. Water consumption is modelled multiplying each category of stock for a

constant, representing the average consumption of water for that specific class: for example, the total number of industries is multiplied by the “average water consumption industries” to define the Water Consumption for this specific class. Part of the water that is used creates waste (i.e., the “total water consumption” multiplied by the “percentage of water used that becomes wastewater” gives the wastewater that needs to be purified and is subsequently treated in an advanced purification plant). Wastewater going through advanced purification plants is therefore purified and represent an inflow to (pure) Water in Reservoirs. Reservoirs are also increased by Rainwater naturally entering in it. Investments in this area can be carried out acquiring (or building) new wastewater purification plants.

## Energy

Cities consume energy based on the number of schools, hospitals, leisure structures, industries and households (Feng, Y. Y., Chen, S. Q., & Zhang, L. X., 2013). The total energy consumption of the city is an important factor to consider (Naill, R. F., 1992), because it defines the capability of the city to meet the need for energy of its citizens and business activities. In fact, concurrently with meteorological extreme event (due to climate change), there could be some local blackouts. The probability of this kind of phenomenon is due to the fact that the meteorological event “cut” the city’s energy delivering capacity and a high level of consumption causes the blackouts which have impact on city’s attractiveness. This kind of problem could be softened by the use of incinerators during the waste management process. In fact, incinerators provide city with additional energy, lowering the total level of consumption.

## Urban planning

The urban planning sector concerns the consumption of free soil for functional areas, dedicated to specific purposes or uses. The functional areas, for housing (NearZero houses and Classic houses), health services (Hospitals), leisure and recreation (Leisures and Parks), parking (Parking space) and education (Schools), and production or job creation (Industries) increase the attractiveness of the city, while they exhaust the available surface (Fong, W. K., Matsumoto, H., & Lun, Y. F., 2009). Each area or function also implies negative consequences on the quality of the city itself, in terms of waste, emissions, energy and water consumption, as well as influencing the transport sector. These negative consequences are modelled by other sectors such as Water, Waste and Environment. The distinction between NearZero houses and Classic houses allows to choose different type of buildings with different costs and associated consumptions (e.g. for cooling/heating). Such difference could be embedded in the board game using different weights such as “costs of building” or “environmental costs of functioning”.

## Conclusions and Future Research Directions

The purpose of the paper was to present the methodological aspects behind the design of a board game that will be used as a teaching tool in order to promote “sustainability literacy” in higher education.

The model uses the principles of Systems Thinking and Causal Loop Diagrams to create the system of a region/city and illustrate how the various elements are connected causally, how feedback loops are created and how these loops give rise to non-linear and complex behavior.

The next steps include the development of a quantitative model and the translation of the model’s variable to mechanisms and elements of a board game.

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