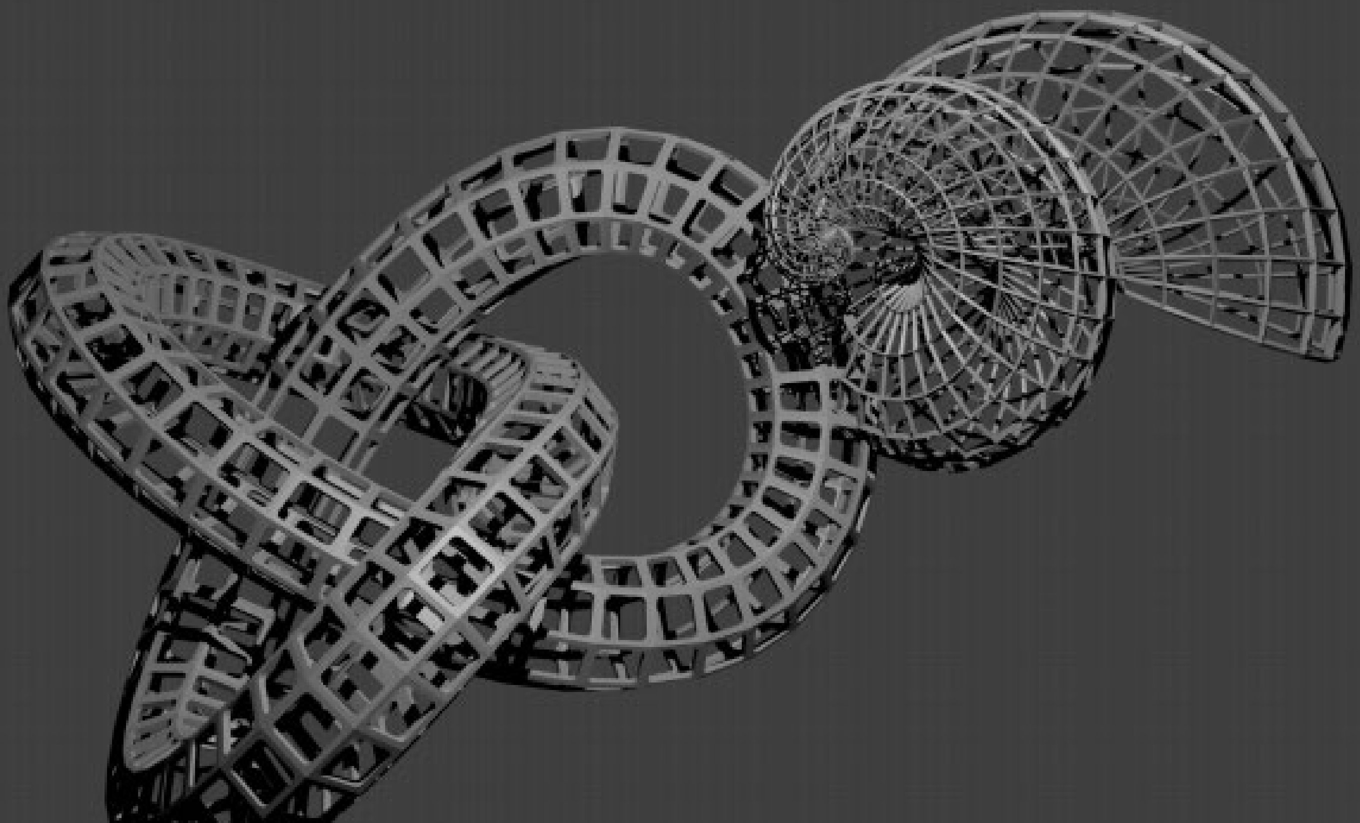
Workshop and International
Seminar on Complexity Sciencies



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Workshop and International Seminar on Complexity Sciences

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CONTENIDO

PREFACE

It is not easy to understand that high-level work can be developed to solve problems in complex systems such as social, environmental or economic ones, within the framework of sustainable development, without collaboration between people of different knowledge systems, from what has been called "the transdisciplinary bet". Although it is easy to understand that different systems of knowledge encourage different mental models that generate, not only the effort to understand the other, but misunderstandings of interpretation/translation of disciplinary knowledge and conflicts are triggered. The "transdisciplinary bet" seems to demand something more than interpretation/translation between disciplines, which could be closer to the attitudinal than the aptitudinal. It does not refer only to intelligence to understand a domain of knowledge and jump from this to another. It refers to the ability to associate the objective in its context and that is not something that can be learned in a formal course or by reading a book, it has a very high attitudinal component. In these circumstances, works have been developed in Colombia that seek not only the integration of knowledge systems, but also the proposal of solutions to essential problems of complex systems, in which interdisciplinary difficulties are overcome and social impacts are generated, promoting well-being. However, there are still few success cases. This document is a reflection of the cases in which the disciplinary integration has worked, taking as a guideline of connection: mathematics. It should be noted, however, that the mathematics developed here is in the context of what has been called "Applied Mathematics" and that the interpretation of what this may mean still generates discomfort, discussion and conflicts in communities, mainly purists. In personal conversations with the national prize of mathematics Jesus Hernando Perez "Pelusa" r.i.p., this expressed that the applied mathematics in any field of knowledge becomes that this field was also applied, because the applications are a give and a receive. He explained that it was a give because doing applied mathematics involved knowing well pure mathematics, but it was not enough because was also important to know how to communicate for everyone, so that it was not only a great capacity for discipline, but for the other disciplines that would like it or need to implement it. He said it was a reception because he demanded the opening of his own mental model to fully accept that of the other, so that his perspective could be captured and, now, if the application could be made. In more recent conversations with the distinguished Catalan mathematician Gerard Olivar Tost, who participates as an author in this document and who I know and appreciate for more than 10 years, we concluded that applied mathematics had become more of a lifestyle than a profession. Applied mathematics had led us to participate in areas that we would not have imagined in our training, generating scientific contributions to solve problems in complex systems, but particularly, giving us a wonderful perspective that in no way contradicted that for which we were trained. We concluded that this new perspective was complementary. The richness of this document is in the way in which the "transdisciplinary bet", the aptitude and the attitudinal, the giving and the receiving, and the lifestyles of a select group of authors of applied mathematics were intertwined. On the content, is presented dynamic systems represented in networks, smooth systems, piecewise-smooth systems and Filippov systems, which were modeled and simulated with systems dynamics, genetic algorithms, discrete event simulation and ordinary differential equations, to which were done life cycle analysis, bifurcation analysis, vaibility analysis and analysis of network measures, to study such diverse subjects as urban mobility based on socioeconomic differences of travelers, morbidity and mortality of the victims in the Colombian armed conflict, national energy markets, cooperation between rural communities to understand the sustainability of their development, allocation of mobile resources in the emergency systems, planning of the water resources in the production of bioethanol from sugarcane, management of projects in faculties of administration and management of socio-environmental conflicts for access to water. The multiplicity of social, socio-economic, socio-environmental and sustainable development issues, tackled from the diversity of modeling, simulation and analysis tools, show, not only the competences and qualities of the co-authors to tackle complex problems, but also, of the importance of community work for the resolution of essential problems of our specie. This document was written on the occasion of the Workshop and International Seminar on Complexity Sciences - CoSIAM 2018, held on October 02 and 03 of 2018 at the facilities of the National Open and Distance University UNAD in the city of Bogota D.C. (Colombia). The event invited 12 national researchers with research results about to be published in the world's top journal, with the purpose that these researchers could make a final discussion of motives and results among their peers before publishing. The event was accompanied by professors Gustavo Paccosi of the National General Sarmiento University (Buenos Aires, Argentina) and Enric Trullols Farreny of the Polytechnic University of Catalonia (Barcelona, Spain), who shared two workshops that were very relevant for the assistant researchers, to them thanks for the willingness and desire to share. The Workshop and International Seminar on Complexity Sciences - CoSIAM 2018 is an event of the Society for Industrial and Applied Mathematics - Colombian section, carried out for members of SIAM and entirely sponsored by SIAM, although this time it was counted also with the valuable contribution of the National Open University and Distance UNAD and its publisher. Thanks to SIAM for their support to the development of applied mathematics in Colombia. Thanks to the National Open and Distance

University for all the support provided. Thanks also to Gerard Olivar of the National University of Colombia, Rafael Rentería Ramos of the National Open and Distance University, Johnny Valencia Calvo of the University of Medellin, Carlos Arturo Peña of the Sergio Arboleda University, Laura Lotero of the Pontifical Bolivarian University, Danny Ibarra Vega of the Secretariat of Security, Coexistence and Justice of Bogota, Jorge Amador of the Humboldt Institute, Jorge Catumba of the International Research Center for Applied Complexity Sciences, Hernan Darío Toro and Carlos Trujillo of the University of Quindio, and Abel del Río Cortina of the EAN University, their work, willingness and effort were the soul of the event.

Johan Manuel Redondo PhD.

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EPIDEMIOLOGY, PUBLIC HEALTH AND COMPLEX NETWORKS

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ABSTRACT

Health differences across socioeconomic strata have always pointed out that poorer and minorities have higher mortality and morbidity than richer and majorities. This difference is exacerbated for particular populations such as the victims of ongoing armed conflict, who are also much harder to quantify due to the conflict itself. This study uses complex network analysis applied to a combination of three large administrative records for the health system and mortality records in the province of Risaralda (Colombia) between 2011 and 2016. We estimate the most common causes of morbi-mortality for both victims of violence and the poorest inhabitants of Risaralda, defined as those who qualify as recipients of subsidies from the Colombian welfare program, called SISBEN, in the categories of those with the highest need, levels I and II. Both populations show high morbidity frequencies for non-communicable diseases such as Type II diabetes, hypertension and hyperglyceridaemia, mostly associated with exposure to unhealthy lifestyles. However, these

mortality outcomes reflect the different treatments and lifestyles of both subpopulations. While the poorest replicate the same causes identified for morbidity, the victims of armed conflict die of additional causes including Type I diabetes, which reflects the even worse conditions they face.

1. Data and Methods

As mentioned above, we linked the records from three independent administrative databases for the province of Risaralda, for all the years between 2011 and 2016, by using a unique identification number. Using a sole year is a mistake for this study, as a particular year may record a mortality shock or bust for exogenous reasons. Hence, we use these six years pooled together. The first dataset is *Base de Datos Única de Afiliados* (BDUA, Unique Database of Affiliated [to the health system]), which contains individual records affiliated to the health system in Colombia. Second, *Registros Individuales de Prestación de Servicios de Salud* (RIPS, Individual Records of Health Services) holds the full medical records of all patients who are part of BDUA and who attended a regular medical visit, urgency care, and the follow-up of medical exams and treatments. The information holds symptoms, diagnosis and prognosis, as recorded by medical doctors. This information is essential for the morbidity profiles.

Finally, *Registro Unificado de Afiliación* (RUAF, Unified Record of Affiliation) holds vital records, including birth and death certificates that aim to be universal. One of the advantages of the vital registration system in Colombia is that death records include the main cause of death as well as the underlying causes of death, recorded under the International Diseases Classification in its 10th version (ICD-X).

2. Morbidity Network Analysis

We begin with the full information of the complex network, namely all diagnoses in the Risaralda province, for both populations under study. The population who qualify for subsidy programs in Colombia are ranked in the Identification System of Potential Beneficiaries for Welfare Programs (*Sistema de Identificación de Potenciales Beneficiarios de Programas Sociales*, SISBEN) classified at levels I and II. To define this network's nodes, we use both main and secondary medical diagnoses for each individual in RIPS. The edges are the relationships between the main and secondary diagnoses for each individual. As these relationships have a very high frequency, regardless of whether it is a main or a secondary 11 diagnosis, the edges do not have any direction resulting in a building scheme, as shown in Figure 1.

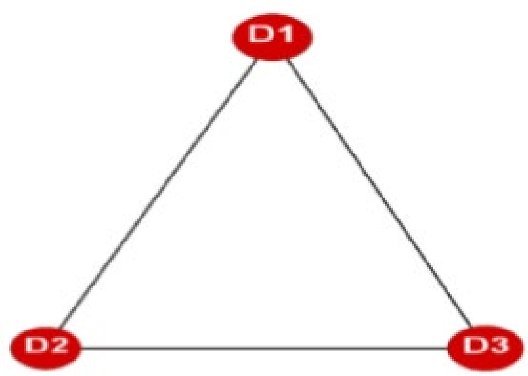

Figure 1. Structure for Building the Morbidity Network

For Figure 1, D_1 is the main diagnosis, while D_2 and D_3 are the secondary diagnoses, all following the ICD-X, as stated before. The strength of links W_{ij} is defined as

$$W_{ij} = \sum_{i,j}^{n} D_i \cdot D_j \, , with \; D_i \neq D_j \qquad (1)$$

where n is the total number of nodes in the network, namely the number of different diagnoses recorded in RIPS ($D_i \neq D_j$); $D_i \cdot D_j$ is the relation between each record for primary diagnoses ii and secondary diagnoses j. The total complex network from applying the above-described methodology to the data at hand, for all the years of study, results in Figure 2. The principal metric of nodes with the highest connectivity is in Table 1.

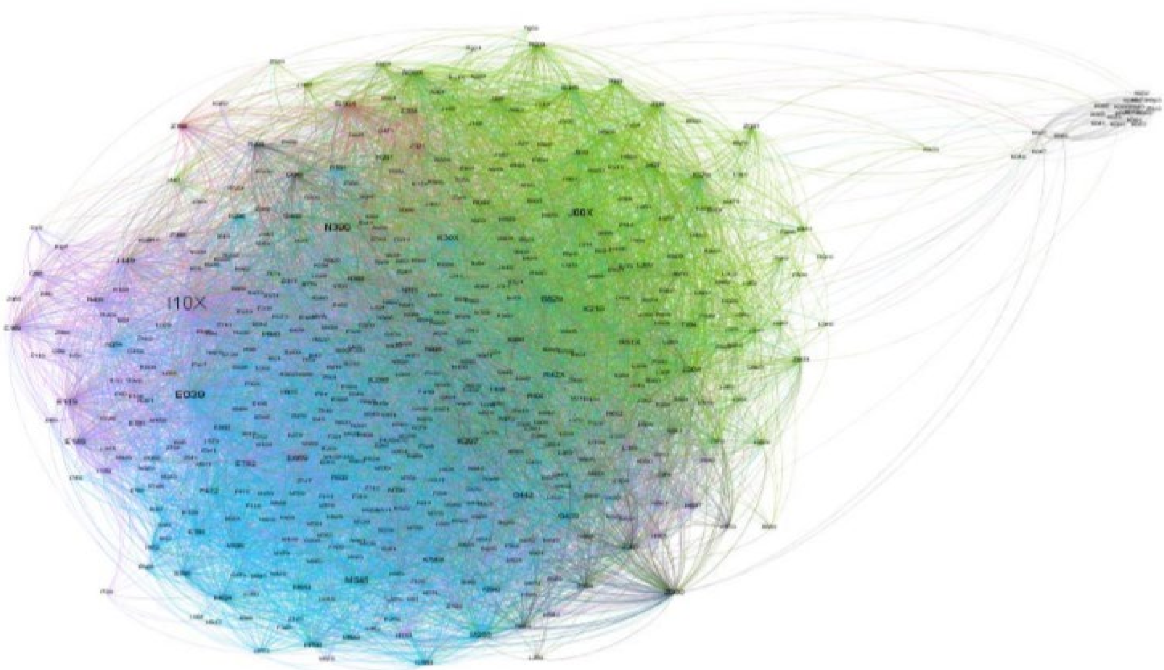

Figure 2. Graph of the Morbidity Network of Diagnoses in Risaralda, 2011–2016.

*Nodes are diagnoses and links are medical records from all kinds of medical visits: regular, emergency consultations, treatments and follow-ups.

3. Selection Algorithm for Detecting the Subpopulation

For this study, we need to fully identify both subpopulations of interest, namely victims of internal conflict and beneficiaries of subsidy programs, SISBEN I and II. To do so, we chose the k-communities algorithm of Fortunato (2010) and Palla et al. (2005), because this keeps the superposition of diagnoses in the subgraphs even though many individuals share the same initial diagnosis, but with different final diagnoses.

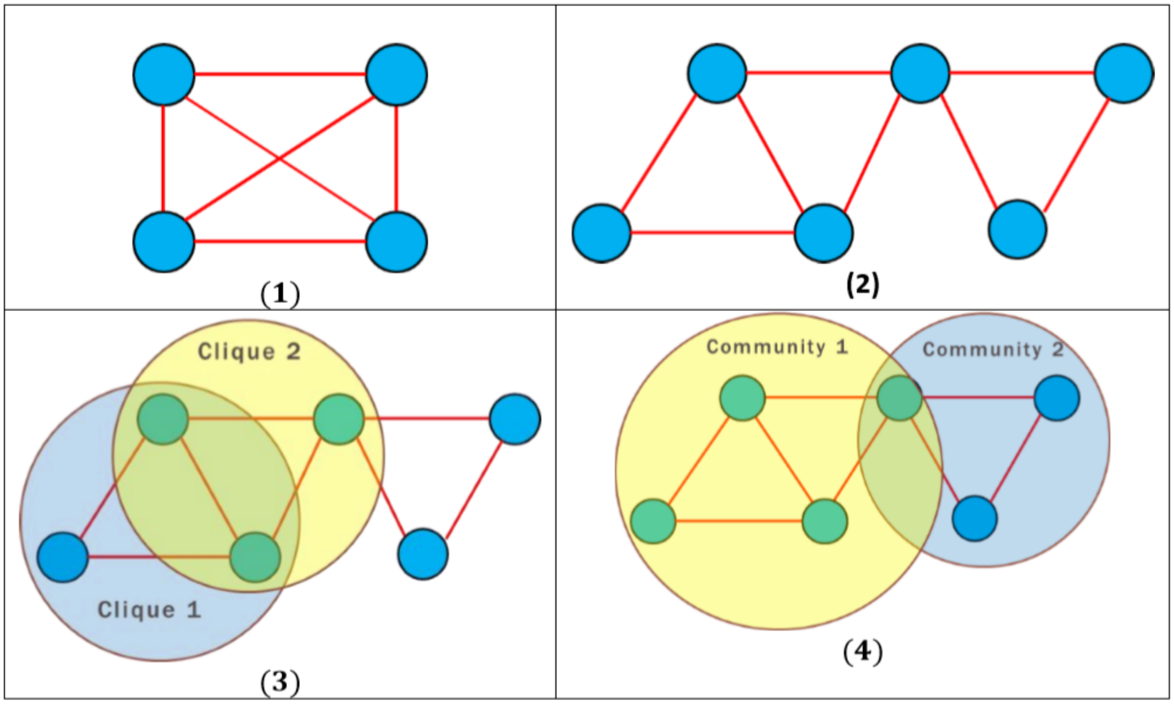

Figure 3. Detection Algorithm for the Detection of k-Communities

Source: Fortunato (2010) and Palla et al. (2005)

4. Intensity Analysis and Motif Coherence.

Motifs are interconnected patterns in complex networks with a much larger frequency than random networks (Milo, 2002). They are common in biology (Green et al., 2017; Smoly et al., 2017) and ecology (Delmas et al., 2017; 13 Rodríguez-Rodríguez et al., 2017), among other applications. Motifs have intrinsic characteristics that condition the probability of the occurrence of certain values in nodes, despite their application to particular cuts of the network (Milo, 2002). This permits them to generate a series of trends in the network circumvent information, such as nodes' consensus that control their flow. This characteristic is essential to associate diagnoses and illness related to lifestyles in the province of Risaralda.

Intensity, $I(g)$, for subgraph g with vertices V_g and edges l_g, as the geometric mean of their weights, or strengths, W_{ij}, is described in equation (1):

$$I(g) = \left(\prod_{(ij)\in I_g} W_{ij}\right)^{\frac{1}{|I_g|}} \quad (1)$$

The coherence $Q(g)$, which allows us to study the consensus between people at the edges inside motifs. Coherence takes values near to the most important unit in its subgraph to establish the association between subpopulations, and it is defined as the ratio between intensity, $I(g)$, and the geometric mean of their weights, or strengths, W_{ij}, as presented in equation (2):

$$Q(g) = \frac{I_g}{\sum_{(ij)\in I_g}^{n} W_{ij}} \quad (2)$$

Results

Results for the Victims of Internal Armed Conflict

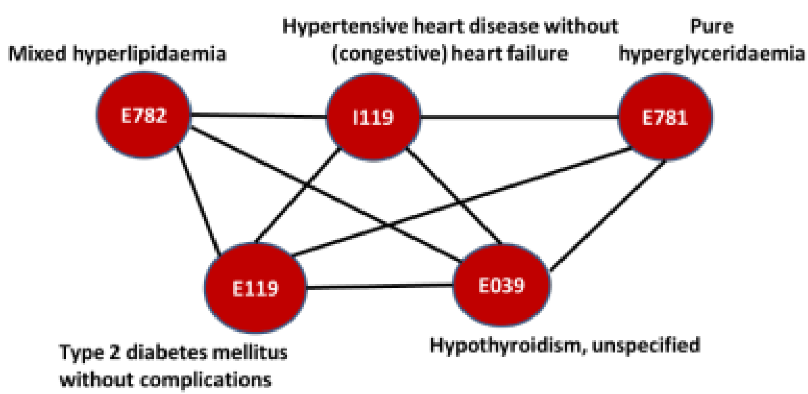

Figure 4. Community with the Highest Coherence Level. Morbidity Network of the Victims of Conflict in Risaralda, 2011–2016

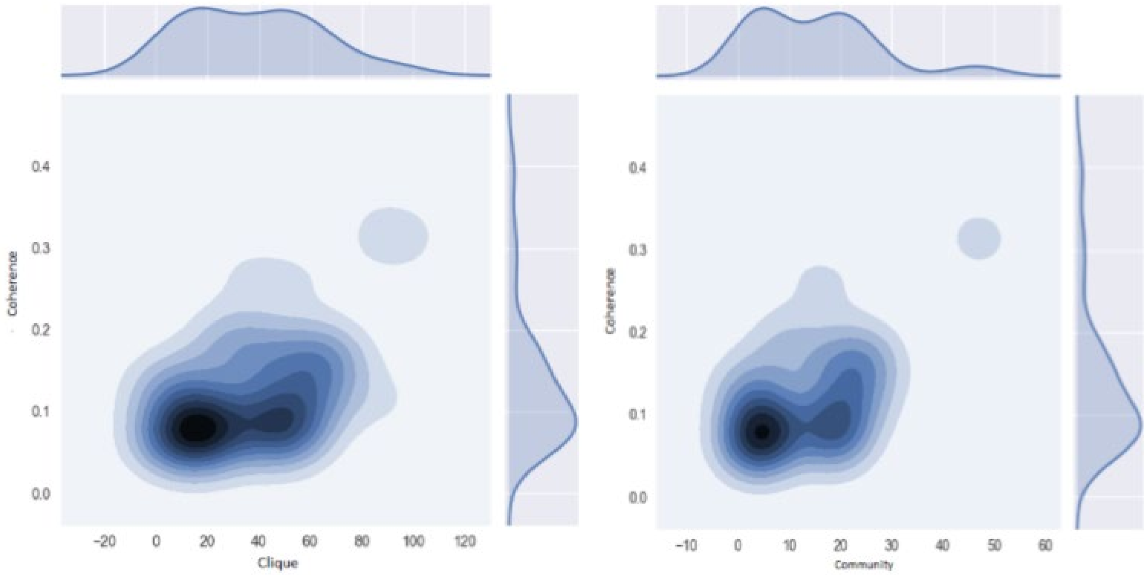

Figure 5. Motifs' Coherence in Cliques (left) and Victims of Conflict (right) for the Morbidity Network in Risaralda, 2011–2016

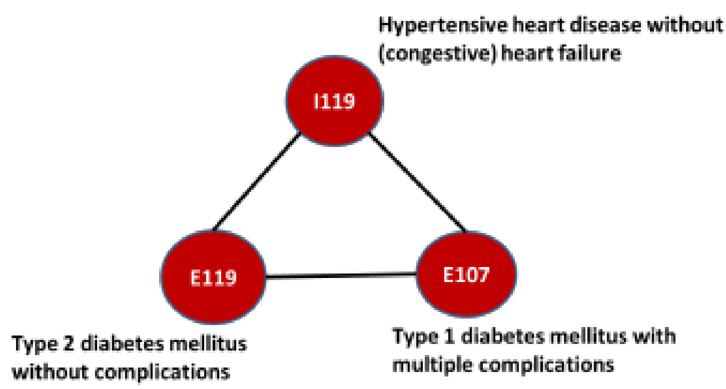

Figure 6. Clique with the Highest Overlapping in Morbidity and Mortality. Mortality Network of the Victims of Conflict in Risaralda, 2011–2016

Results for the Population Classified as SISBEN I and II

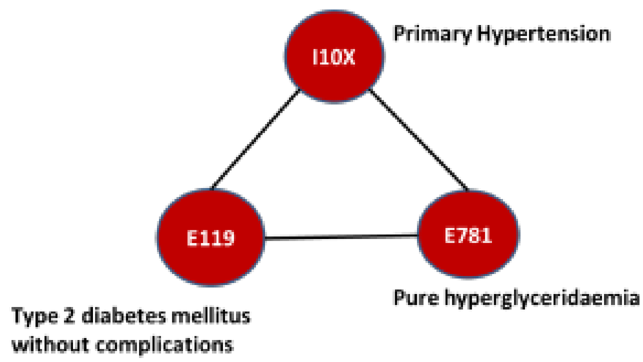

Figure 7. Highest Overlapping in Morbidity and Mortality. SISBEN I and II Mortality Network in Risaralda, 2011–2016

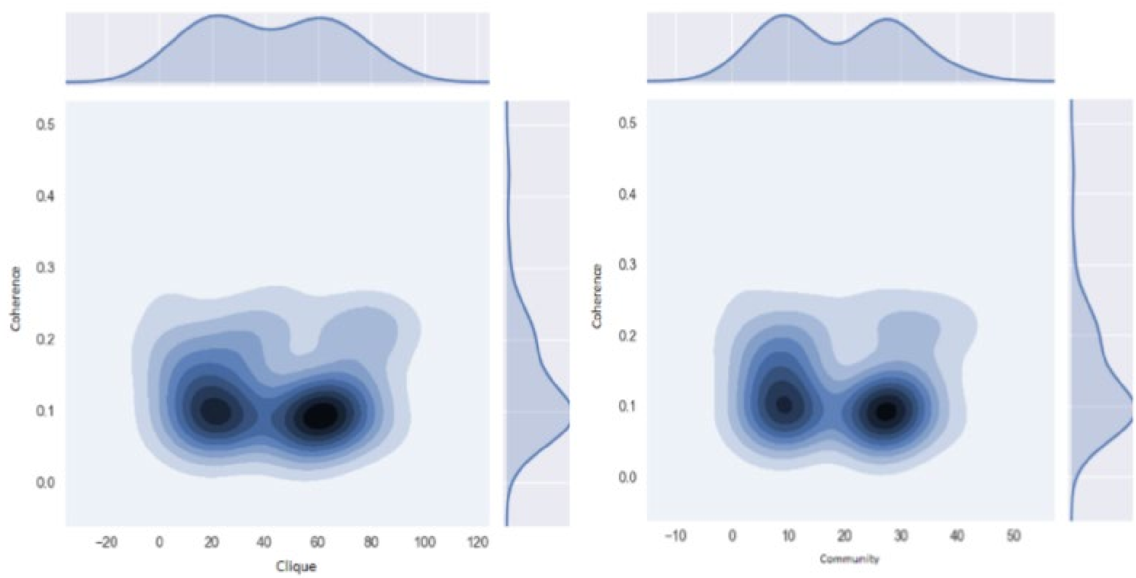

Figure 8. Motifs' Coherence in Cliques (left) and SISBEN I and II (right) for the Morbidity Network in Risaralda, 2011–2016

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ACTION PLAN THAT MAY CONTRIBUTE TO THE SOLUTION OF THE ENVIRONMENTAL CONFLICT GENERATED BY ACCESS TO THE WATER OF THE CHÍQUIZA RIVER IN THE MUNICIPALITY OF CHÍQUIZA – BOYACÁ

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ABSTRACT

This paper was carried out in the villages of Chiquiza Centro and Juan Díaz in the municipality of Chiquiza in Boyacá, Colombia; the social problems that exist in the southern sector of Chiquiza, especially as a result of the access to water from the Chiquiza river, has caused the inhabitants of this part of the municipality to be involved, for many years, in conflicts that have even reached human losses. The lack of a sense of cooperation in them has also caused a delay in the social and economic development of the area, as well as, family differences block the growth thus causing fear and anxiety due to the violence of the villagers that often nullifies the authority of the local government. By studying the characterization of the different actors such as the municipal administration, Colombia's Natural National Parks, Corpoboyacá, Ministry of Environment, neighboring Municipalities, community of Chiquiza, Environmental NGOs and financial entities in the socio-environmental conflict and, by using the stakeholder circle methodology, they were classified

according to their interest and influence, being the most influential in the participation in seeking a solution to the conflict; the municipal administration, the community of Chiquiza and Natural Parks were in order of greater to lesser. By knowing this information, the logical framework methodology was applied; this determined various viable strategies that were presented to the actors, thus allowing to identify and consider one of them, as part of the solution to this problem called the substitution of risk systems, for the benefits, installation times, implementation costs and, social and environmental impacts expected.

Keywords.

Stakeholder circle; logical framework; socio-environmental conflicto; sustainable communities; water resources; governance.

Introduction

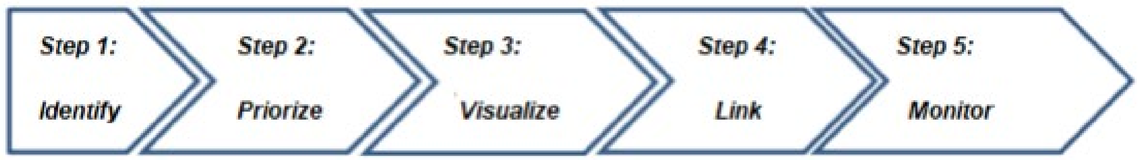
In the villages of Chiquiza Centro and Juan Diaz in the municipality of Chiquiza, the inhabitants live on the cultivation of onion Allium cepa, or better known as onion bulb or "big-headed onion"; the main source of water extraction for this is the Chíquiza River, which supplies this as well as other neighboring municipalities such as Sáchica and Villa de Leyva (Chiquiza, 2013, Chiquiza official site in Boyacá, Colombia).

Access to this resource has caused conflicts among its inhabitants, since those who have greater economic capacity, buy powerful motor pumps with hoses up to three (3) inches with which they extract large amounts of water, thus affecting the ecological flow of the river and the availability of this resource for other residents who make use of it. This situation has led to personal conflicts that have even resulted in physical aggressions between neighbors and also towards the authorities in charge of exercising environmental and police surveillance of the area. To date, this situation persists and threatens to intensify due to the marked climatic variations that occur in the sector and throughout the country, generated mainly by El Niño phenomenon and climate change.

In addition to the foregoing, there is the state neglect from which this and many other populations of the country suffer, which has led to impoverishment of the communities that have no other options than farming for their subsistence. This situation shows a bleak picture for rural communities that not only have to submit to the tough economic situation of the countryside, but also lack opportunities that allow them to obtain a better quality of life.

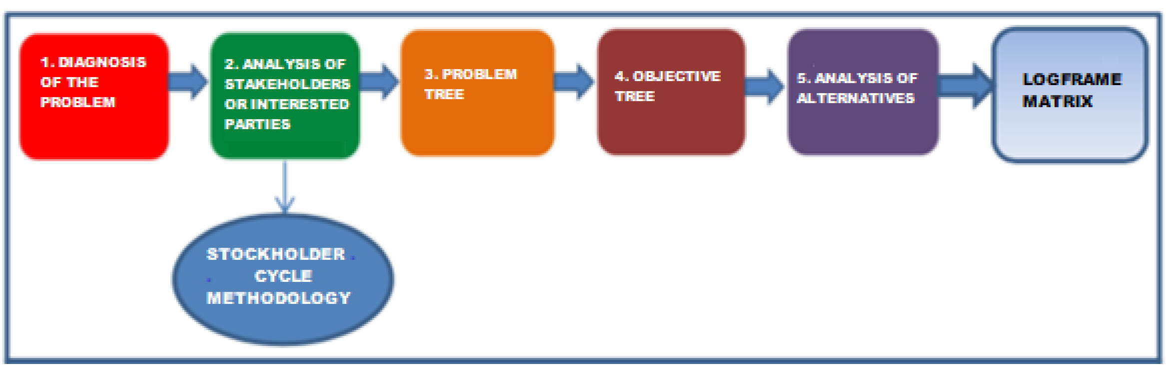
Methodology

In the development of this project two (2) methodologies were applied. The first is called Logical Framework, in which there are 6 stages: 1. Diagnosis of the problem; 2. Analysis of stakeholders or interested parties; 3. Problem tree; 4. Objective tree; 5. Analysis of alternatives, and finally it concludes with the Logframe Matrix. The second methodology is Stakeholder Circle, which develops the second item related to the analysis of stakeholders or interested parties. For the development of the analysis of stakeholders or interested parties, the Stakeholder Circle methodology was applied, due to its relevance in relation to this aspect. This methodology was developed by the project director and general director of Stakeholder Management Pty Ltd, Lynda Bourne (Strategic Management: A Stakeholder Approach, Bourne, 2013), a methodology focused on those actors who affect or are affected by the achievement of the objectives of any Corporation, understanding the corporation in this case not as a profitoriented organization, but as that person or group of people with interests that may affect others in their joint action; there, 5 stages can be noticed (Figure 1).



Fígure 1. Scheme of Stakeholder Circle methodology.

The Logical Framework methodology, also described by several authors as Logical Framework Scheme or Logical Framework System, comprises a sequence of steps that allow to give a global vision of the project. The methodology considers these steps, which enables to carry the logic of its structure. The logical framework scheme is shown below (Figure 2), which goes from the Diagnosis of the Problem to the structuring of the logframe matrix.



Fígure 2. Scheme of Logical Framework methodology.

Conclusion

In the execution of this project, an action plan was developed, which presented the steps that the interested actors can carry out in order to solve the socioenvironmental conflict that is being experienced in the neighborhoods of Chiquiza Centro and Juan Díaz in the municipality of Chiquiza, starting with the awareness of the problem, for its mere existence does not demonstrate that its participants explicitly accept it or recognize it in their daily lives.

Moreover, the identification of the stakeholders themselves was achieved, by knowing their influence, interest and power within the development of the project, and also, their willingness was known as well as what they can do by taking into account their functions and their links with the other regional, national and even international entities. Having been aware of this, alternatives were proposed that could contribute to the solution of the socio-environmental problem caused by access to the water of the Chiquiza River; by knowing these possibilities, the actors can evaluate how they can provide their contribution and management in the achievement of these objectives. Furthermore, in this project the actors were presented with the way in which they can finance the alternative they select; all this will depend on an in-depth study on which of them is the most viable depending on the initiative and capabilities of each stakeholder.

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WATER RESOURCES PLANNING IN BIOETHANOL PRODUCTION FROM SUGARCANE

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ABSTRACT

The biofuels industry has grown and has positioned itself in Colombia for national purposes, these come from biomass sources such as agricultural crops. Bioethanol is the most used in Colombia and is obtained from sugarcane. One of the main concerns of the sector and society, is the high water consumption associated with agricultural crops (9,000 m3 / ha-year), there are currently 232,000 hectares of sugarcane for the production of sugar and bioethanol. Given the aforementioned, the need arises to carry out a

planning of industrial increase of the sector taking into account as a main base the demand and availability of water resources for different activities in the Cauca river basin and the demand for sugarcane crops. In this document it is presented a mathematical model and the evaluation of different scenarios of the estimation of the trend of water consumption in the bioethanol production process in Colombia and in this way to establish scenarios of high risk of water shortage both for the population, interested parties and cane cultivation.

Keywords.

Bioethanol; System Dynamics; Water Resources.

1) Introduction

The production of bioethanol in Colombia comes from sugarcane, a crop widely positioned in the country around the Cauca river basin (232,000 Ha). The main impact in the supply chain of this biofuel is associated with the high consumption of water in the production and cultivation of sugar cane (9,000 m3 / Ha-year), which can generate supply risks in the face of a possible increase in production (Ibarra, 2017). In this paper a mathematical model of the bioethanol supply chain presented in (Ibarra et al, 2017) was socialized and a proposal was presented to develop a model with a growth limit based on the water consumption indicator.

2) Model for Use and efficiency of water Indicator.

According to the pilot evaluation of GBEP indicators for Colombia (FAO, 2014), more than 90% of sugarcane production is positioned in the Cauca River geographical valley, with irrigation activity being one of the most water-related in the production of bioethanol. For the evaluation of this indicator, two activities that generate water consumption (Cultivation and production) are taken into account. In this way, the following causal relationships for this indicator have been considered. Water consumption for cane cultivation increases with the amount of hectares (Ha) of cane planted. Similarly, the second activity that generates a water consumption is evident, which is in the production process, since the harvested cane arrives at a process of enlistment that includes washing and milling by means of mechanical pressure and water, for extraction of the juice that is sent to the bioethanol production process. Therefore, by increasing the quantity of cane to be ready, the consumption of water will also increase. Similarly, increasing the production of Bioethanol will increase the amount of water required in the factory. For this article only the modeling of water consumption by crop is shown.

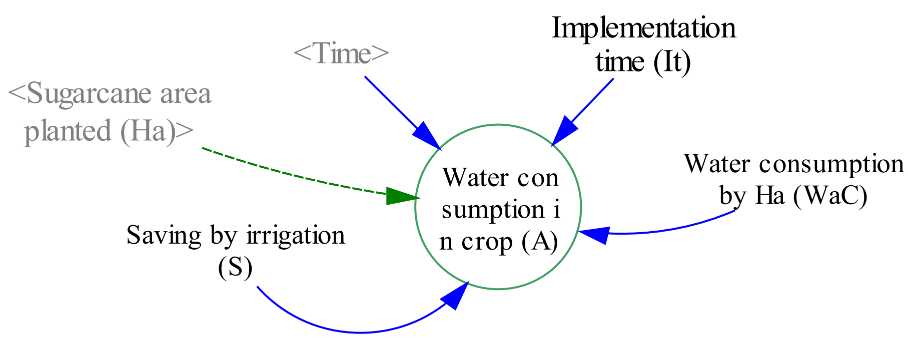

Figure 1. Use and efficiency of water Indicator.

Finally, the diagram that represents the use of water indicator in the production of bioethanol is drawn up, and is linked to the diagram presented in (Ibarra, 2017).

We proceed to formulate the equations to model this indicator. For the representation of total water consumption, the sum of the two main activities identified was taken, which obtained the following equation:

$$Y = A,$$

where flow A represents the consumption of water in the crop, and a saving parameter s is associated to it, which would represent savings strategies. The equation is formulated with a piecewise function that shows this decision in a time of implementation It:

$$A = \begin{cases} (WaC.Ha) * S, & si\ time \geq It \\ WaC.Ha, & si\ time < It \end{cases}$$

For the simulation of water consumption, which is mostly focused on the cultivation of sugarcane and the bioethanol production process, the consumption rate of 9,000 m3 of water per hectare of year crop and 0.005 m3 of water was taken as a basis. per liter of bioethanol produced (CUE, 2012). See figure (2).

In Figure 2. The simulation of the system is shown without any saving strategy and the water consumption behaviors are shown with different saving strategies (S = 0.2, 0.3 and 0.6), starting from the implementation for the year 2017. In the simulation the behavior is observed three irrigation techniques aimed at reducing consumption. Likewise, the restrictions of the defined regions were established based on the estimated use and concession rates for 2010 (Cenicaña, 2010), where they propose an irrational use of values higher than 2Gm3.

2.1) Irrigation techniques to reduce water consumption.

The amount of irrigation water depends on the irrigation technique. In general, open channels are used to irrigate water to crops. The frequency of irrigation is approximately 5 times a year and an annual amount of 5,000 to 9,000 m3 per hectare is applied. However, if irrigation pipe systems are installed, the amount of water can be reduced to 3,600 m3 (Cenicaña, 2010).

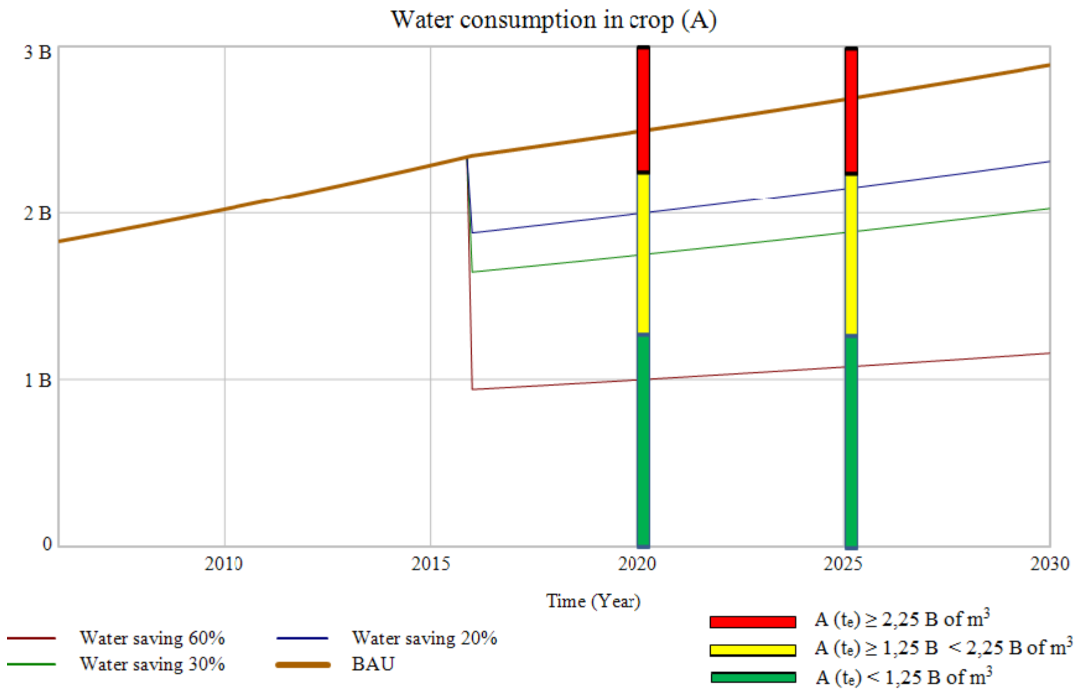

Figura 2. Prospective evaluation of the water consumption indicator.

3) Recommendations to public policy.

For planning in the bioethanol and other biofuels sector, it is necessary to define clear objectives, both for increased production and sustainability objectives, that is, if production is to be increased, agricultural crops for biofuels and installed production capacity, future scenarios should be measured and modeled to know what would be the impact of natural resources or sustainability indicators, in this case the amount of water available for this. It can be said that, Colombia does not have clear goals regarding the sustainability of the production of bioethanol from sugarcane and it is imperative that a national policy be defined to develop sustainable production schemes. The findings on the water consumption indicator show the need to guide policies with equitable allocation of this resource, that is, that the country manages to develop and implement a policy based on prospective consumption scenarios, so as not to generate shortage risks.

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MATHEMATICAL MODEL FOR THE EVOLUTIONARY DYNAMICS OF INNOVATION IN CITY PUBLIC TRANSPORT SYSTEMS

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ABSTRACT.

In this study, a mathematical model is formulated and studied from the perspective of adaptive dynamics (evolutionary processes), in order to describe the interaction dynamics between two city public transport systems: one of which is established and one of which is innovative. Each system is to be influenced by a characteristic attribute; in this case, the number of assumed passengers per unit it that can transport. The model considers the proportion of users in each transport system, as well as the proportion of the budget destined for their expansion among new users, to be state variables. Model analysis allows for the determination of the conditions under which an innovative transportation system can expand and establish itself in a market which is initially dominated by an established transport system. Through use of the adaptive dynamics framework, the expected long-term behavior of the characteristic attribute which defines transport systems is examined. This long-term study allows for the establishment of the conditions under which certain values of the characteristic attribute configure coexistence, divergence,

or both kinds of scenarios. The latter case is reported as the occurrence of evolutionary ramifications, conditions that guarantee the viability of an innovative transport system. Consequently, this phenomenon is referred to as the origin of diversity.

Keywords.

Technological Change; Public Transportation Investment; Public Transportation; Simulation Modeling

Introduction

The city of Bogotá, Colombia is on the cusp of becoming one of the new world megacities. While in 1960, only seven megacities existed, by 2010, this number had increased to 27, and by 2020, it is projected that this number will grow to 37. In this growth process, cities cannot ignore fundamental aspects of their own economic and demographic development, or the complex network of interactions generated thereby (Kennedy, Stewart, Ibrahim, Facchini, & Mele, 2014). One fundamental question is the relationship between population growth, demographic development, and public transport infrastructure. Bogotá, in particular, is going through a key decision-making moment regarding the possibility of incorporating a metro system as one of its leading forms of transport. In contrast, the current mass-transit system, Transmilenio, operates using articulated buses. There is a latent need to respond to the question: under what conditions could a mass-transport system invade, expand in the market, and coexist with current, established city transport systems, in the long term? This type of question is closely related to others studied from the standpoint of evolutionary biology, and which have permitted the development of adaptive dynamics as a useful mathematical theoretical framework for the study of these questions (Baccini & Brunner, 2012).

The formation of new species, called speciation, is one of the central points of evolutionary theory. It occurs through the genetic and phenotypic divergence of populations of the same species, which adapt to different environmental niches, either within the same, or in different habitats. In allopatric speciation, two populations are geographically separated by natural or artificial barriers, while in parapatric speciation, the two populations evolve toward geographic isolation, through the exploitation of different environmental niches in contiguous habitats. In either of these two cases, geographical isolation constitutes an exogenous cause of speciation, instead of an evolutionary sequence (Dercole, & Rinaldi, 2008; Butlin, Galindo & Grahame, 2008). On the other hand, sympatric speciation considers a population in a single geographical location. As such, it is disruptive selection that exerts selection pressures, which favor extreme characteristics over average characteristics. This phenomenon may result, for example, from competition for alternative environmental niches, in which specializing may be more advantageous than being a generalist. Consequently, the population divides into two groups which are initially similar, but which later diverge on separate evolutionary paths (branches), each driven by their own mutations, undergoing what is called evolutionary branching (Butlin et al., 2008; Doebeli, & Dieckmann, 2000).

Human evolution shows empirical evidence of this evolutionary phenomenon. Humans form part of the hominidae family, which includes great apes (bonobos, chimpanzees, gorillas, and orangutans) and other extinct humanoid species. Since Darwin and the publication of The Descent of Man (1871), countless fossils have been found and dated, which show that humans and great apes shared a common ancestor approximately six or seven million years ago. The causes of the evolutionary branching which led to humans are a source of great debate. However, one of the most intriguing potential causes is the evolution of articulated language, thanks to fine control of the larynx or the mouth, which is regulated by a particular gene (Dercole, & Rinaldi, 2008; Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001).

Generally speaking, the basic units capable of evolution through innovation and competition processes are not limited to living organisms. Multiple examples of evolutionary branching can, in fact, be found in material products, ideas, and social norms (Dercole, Dieckmann, Obersteiner, & Rinaldi, 2008; Dercole, Prieu, & Rinaldi, 2010; Landi, & Dercole, 2016). In particular, commercial products are replicated each time that a product is bought, and services each time they are used. They go extinct whenever they are abandoned by users. Thus, improved versions are occasionally introduced, which are characterized by small innovations. These interact in the market with the prior, established versions. Said interactions are usually competitive, and involve rivalry between products from both the same and different categories.

With the information discussed up to this point, it is possible to respond to the question of what constitutes the theory of adaptive dynamics. In general, it is a theoretical backdrop which originates in evolutionary biology, and links demographic dynamics to evolutionary changes. It further permits the description of evolutionary dynamics in the long term, considering innovations to be small and rare events (Dercole, & Rinaldi, 2008; Dieckmann & Law, 1996; Geritz, Metz, Kisdi, & Meszéna, 1997; Geritz, Meszéna, & Metz, 1998). This theory focuses on the evolutionary dynamic of quantitative adaptation attributes in the long term, and disregards genetic details, through the use of asexual demographic models. Among the most relevant aspects is that it recognizes interactions as the driving evolutionary force, and considers feedback between evolutionary change and the forces of selection experienced by agents (Dercole, & Rinaldi, 2008; Dercole, & Rinaldi, 2010; Doebeli, & Dieckmann, 2000).

Model description

In this investigation, the question of whether conditions exist for the origin of diversity in a competitive market, among the principal public transport systems (TS) in a city, is addressed from the perspective of adaptive dynamics. Additionally, the average number of passengers transported per unit is considered to be a characteristic attribute of each TS. The model proposed here allows for determination of the innovative TS fitness function. *Invasion conditions* are established therefrom in a market dominated by a conventional TS. Later, based on theory, the *canonical equation of adaptive dynamics*, which reveals the long-term behavior of the characteristic attribute and its impact on the TS market, is determined and studied. Finally, a scenario, in which *evolutionary branching* occurs, is simulated. This phenomenon is called the *origin of diversity*, as it implies that the market can be diversified. On the other hand, a scenario in which *terminal points* occur during attribute evolution, in the case that diversification is not possible, is also presented.

Consider a city with an established transport system, which is characterized by a particular attribute, u_1, which is assumed to be positive and associated with the average number of passengers who are transported in each mobile unit. Denote $x_1 = x_1(t)$, with $0 \leq x_1 \leq 1$ the proportion of people who adopt the transport system characterized by attribute u_1. Suppose that a TS innovation occurs, which corresponds to some technological modification which physically affects the established TS, characterized by the value of attribute u_1, and leads to the appearance of an innovative TS characterized by the value of attribute u_2. In general, it is assumed that the innovation is small, and will have a minimal effect, which permits the interaction between transport systems to occur below the same conditions, and on the same market platform. The innovative TS gives rise to a small proportion of users $x_2 = x_2(t)$ who compete with the established TS. Explicitly, the fourth-dimension system will exist as follows:

$$\dot{x}_1 = [\alpha(u_1)y_1 - \delta(u_1)](1 - x_1 - c(u_1, u_2)x_2)x_1$$

$$\dot{y}_1 = l(u_1)(1 - y_1) - \epsilon(u_1)\alpha(u_1)x_1y_1$$

$$\dot{x}_2 = [\alpha(u_2)y_2 - \delta(u_2)](1 - x_2 - c(u_2, u_1)x_1)x_2$$

$$\dot{y}_2 = l(u_2)(1 - y_2) - \epsilon(u_2)\alpha(u_2)x_2y_2.$$

In this case, the $y_i = y_i(t)$ state variable, for $i = 1$ or 2, represents the proportion of the budget invested for TS expansion, such that $0 \leq y_i \leq 1$. This model goes by the name *resident – innovative system.* Note that, for the model characteristics, must be satisfied that $0 \leq x_1 + x_2 \leq 1$.

Table 1. Description of study variables and of the coefficients used in the model

State description	
x_i	Proportion of people who use system i
y_i	Proportion of the budget available to the expansion of system i
Parameter description	
u_i	Value of the characteristic attribute which describes TS i
$\alpha(u_i)$	Rate of instant TS *i* adoption
$\delta(u_i)$	Rate at which TS *i* is abandoned by users
$l(u_i)$	Rate of investment in new resources for the expansion of TS i
$\epsilon(u_i)$	TS *i* efficiency of "converting" the investment into new users
$c(u_i, u_k)$	Rate of interaction between systems i and k.

On the other hand, $c(u_i, u_k)$ is the interaction rate between systems *i* and *k.* A number of situations are then obtained:

- If $c(u_i, u_k) > 1$, inter-system competition prevails over intra-system competition. A simple example of this is that, if system *i* corresponds to a city taxi system, while system *k* corresponds to a public bus system, then $c(u_i, u_k) > 1$ implies that taxi competition with buses is stronger than the competition between the taxis themselves.
- If $0 \leq c(u_i, u_k) \leq 1$, then intra-system competition prevails over inter-system competition. Returning to the public taxi and bus example, in this scenario, competition between the taxis themselves is stronger than competition between taxis and buses. Particularly, $c(u_i, u_k) = 0$ indicates that there is no interaction between the two transport systems, and $c(u_i, u_k) = 1$ indicates that the interaction between the two transport systems is symmetrical, or affects both equally.
- If $c(u_i, u_k) < 0$, the interaction between transport systems does not correspond to competition, but rather cooperation, a situation which can describe integrated TSs.

In order to numerically study the previous system, it is considered that the proportion in which new resources are invested for transport system expansion is $l(u_i) = l$, that the TS efficiency to "convert" the investment into new users is given by $\epsilon(u_i) = \epsilon$, and that the rate at which the TS is abandoned by users $\delta(u_i) = \delta$ are constants for $i = 1,2$. On the other hand, it has been assumed that the rate of instant adoption depends on characteristic attribute u, through the function:

$$\alpha(u) = a \exp\left(-\frac{1}{2a_1^2} \ln^2\left(\frac{u}{a_2^2}\right)\right).$$

For a TS characterized by attribute u, the $\alpha(u)$ rate makes perfect sense when x_1 is small, and has no competition from other transport systems (Dercole et al., 2008). A maximum of a occurs when $u = a_2^2$, in order to indicate the value of the attribute which is easiest to absorb. On the other hand, for a transport system with a very low or very high number of users, $\alpha(u)$ tends to cancel out with sensitivity controlled by a_1. Suppose that $a > 0$ and $a_1, a_2 \in \mathbb{R}$ (see Figure 1-left).

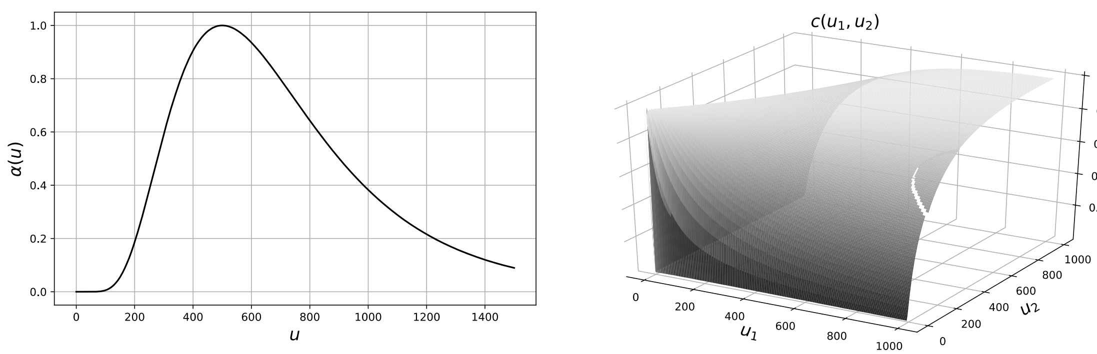

Figure 1. Left: Function $\alpha(u)$ chart for parameters $a = 1$, $a_1 = 0.5$, $a_2 = 22.36$. Right: Chart of function $c(u_1, u_2)$, for parameters $f_1 = 0.96$ y $f_2 = 2$.

Additionally, the interaction rate between TSs is represented in the following form:

$$c(u_1, u_2) = \exp\left(\frac{\ln^2 f_1}{2f_2^2}\right)\exp\left(-\frac{1}{2f_2^2}\ \ln^2\left(\frac{f_1 u_1}{u_2}\right)\right)$$

Observe that the interaction rate between TSs $c(u_1, u_2)$ depends on the u_1/u_2 reason, and tends toward zero when said radius tends toward zero, or when it tends toward infinity, which reflects that TSs which are very different compete weakly. A graphic representation of the function is shown in Figure 1-right (Dercole et al., 2008). If $f_1 > 1$, the TSs that move the greatest average of passengers tend to have a competitive advantage. On the other hand, if $0 <$

$f_1 < 1$, the TSs that move a lower average number of passengers will be those which have the advantage. A large f_2 value implies that very different TSs also compete strongly. When $f_1 = 1$, competition between TSs is symmetrical.

At the time in which innovation occurs, the city established TS its assumed to be in a nontrivial equilibria $\bar{x}_1(u_1)$ and $\bar{y}_1(u_1)$. In other words, it is assumed that this equilibria is LAS. When the resident – innovative system is studied, it may be of interest to determine the conditions under which the innovative TS of attribute u_2 can "invade" the market. For this, stability conditions at the equilibria: $E_1 = (\bar{x}_1(u_1), \bar{y}_1(u_1), 0,1)$, must be studied. The zero and one values in the last two coordinates of E_1 indicate that the innovative TS has not yet entered the market, and that the entirety of the budget is available for investment. In order to determine local stability, a small disruption is created around it, and the behavior of the linear system associated is studied (Perko, 2013).

The values selected for simulations correspond to the belief that innovation involves a TS that is in conditions to transport a higher number of passengers. For this reason, it has been assumed that the value of the established TS attribute is $u_1 = 200$, and that the value of the innovative TS attribute is $u_2 = 800$. Although this value is far above the current capacity of the Transmilenio's bi-articulated buses, it is well below the capacity of other mass TSs. For example, a three-car train from the Medellin, Colombia metro has the capacity to transport up to 1220 passengers at a time.

A simulation of the transport systems is shown in Figure 2, both before and after innovation. The curve shown as a dashed line is the simulation of the resident system before the innovation ($x_2(t) = 0$ and $y_2(t) = 1$, for all t), respectively, for the x_1 proportion of users (left), and for the proportion of budget y_1. Once the innovation occurs, the innovative TS enters the market (dash-dot line), which competes with the established TS (solid line). Observe that Figure 2-left corresponds to *diversification*, or what here has been called the *origin of diversity*. In effect, initially, there was just one TS established in the market. After the innovation, however, both TSs can expand and coexist in the market as two transport options for users. In particular, it should be noted that $f_1 = 0.96$ implies that the TS which mobilizes a lower number of passengers has the competitive advantage. However, innovative transport is able to expand and establish itself in the market. Similarly, in Figure 2-right, a substitution scenario is shown. The only variation that has been performed with respect to the simulation of Figure 2-left is the $f_2 = 2$ value, which indicates that, in the market, the TS with the capacity of transporting a higher number of passengers is favored.

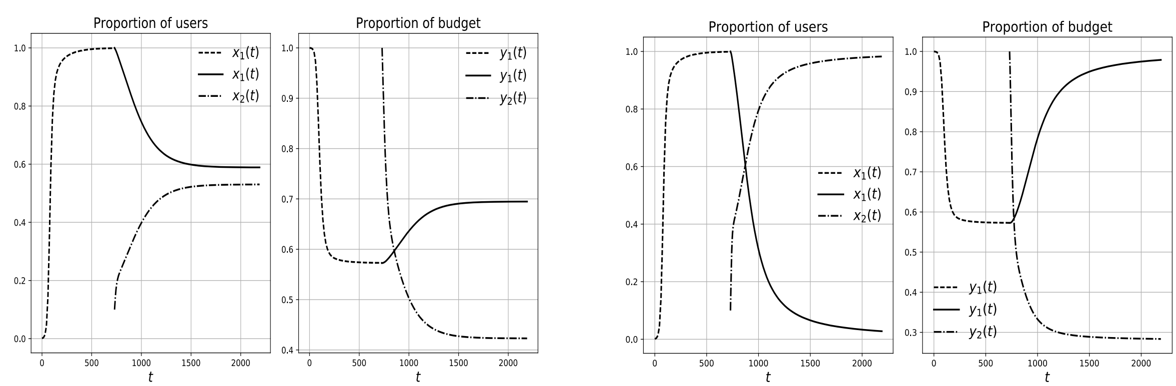

Figure 2. Diversification (left) x_1 solutions before innovation (dashed line) and after innovation (solid line) and for x_2 (dash-dot line). Right: y_1 solutions before innovation (dashed line) and after innovation (solid line) and for y_2 (dash-dot line). The following have been used: $a = 1$, $a_1 = 0.5$, $a_2 = 22.36$, $\delta = 0.1$, $\epsilon = 0.1$, $l = 0.025$, $f_1 = 0.96$, and $f_2 = 2$. The attributes are $u_1 = 200$ and $u_2 = 800$, thus, $l^*(u_1) = 0.0215$, $l^*(u_2) = 0.01184$, $R_p(u_1) = 1.8653$, and $R_p(u_2) = 6.4287$. **Substitution** (right) the same values have been used for parameters, except $f_1 = 2$.

The dynamic of the attributes, henceforth called the *evolutionary dynamic*, will help to explain the characteristics of the innovation and competition process which acts on the market. Dercole et al., 2008, succinctly describes the processes which should be considered for rigorous formulation of the *canonical equation*, which describes the evolutionary behavior (in the long term) of attribute u. This equation takes the general form:

$$\dot{u} = \frac{1}{2}\mu\sigma^2\,\bar{x}(u)\frac{\partial\lambda}{\partial u_2}\,(u,u),$$

where μ is innovation frequency, and σ^2 is the variance. In other words, the canonical equation considers the frequency with which innovations are presented in the public TS market, and the size of the variations obtained in each innovation. The $\bar{x}(u)$ value corresponds to the equilibria in which the established TS stabilizes before the innovation. On the other hand, partial derivative $\frac{\partial\lambda}{\partial u_2}\,(u,u)$, is called the *selection gradient*, and is associated with the forces of selection which are exerted from the market, by the same TS users, on the long-term dynamic of the characteristic attribute; here, $\lambda(u_1, u_2)$ is the fitness function given by one of eigenvalues of the system's Jacobian matrix at the invasion equilibria E_1 (Dercole et al., 2008).

When an evolutionary equilibria solution $\bar{u}_i$ for $i = 1$ or 2 is LAS, this means that successive innovations which replace those previous, direct attribute u toward the value of equilibria $\bar{u}_i$. It is important to consider that, in the case of diversification, or when, after innovation in the market, both TSs can coexist, each characteristic attribute will be described by a canonical equation like that described previously. The equations which correspond to this situation are not reported here, as the explicit expressions are quite long and do not significantly contribute to the discussion. However, they may be handled via symbolic calculation.

In Figure 3, the behavior of characteristic attributes u_1 and u_2 are shown, before and after innovation. It is evident that both attributes diverge in their values to different evolutionary equilibria. While the established TS from attribute u_1 is maintained below 200 passengers per mobile unit, the innovative TS progressively increases its capacity until reaching an average of over 1400 passengers transported.

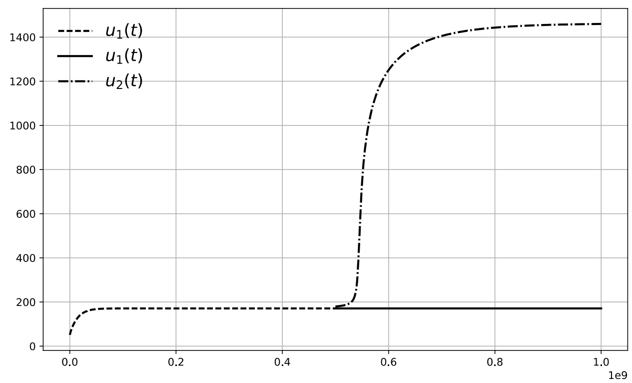

Figure 3. The solutions to the canonical equation for u_1 shown before innovation (dashed line), for u_1 canonical equations (solid line) and for u_2 (dash-dot line) after innovation. The parameters used are the same as those in Figure 9 for the diversification scenario.

Conclusions

The resident model proposed here is an initial approach to the phenomenon, the resident model permits the study of the dynamics of a city's TS in various scenarios, and learn under which conditions it may be expanded in the market, and a partial or total adoption equilibria could be found, although this would imply transporting the entire population of the city.

The innovative-resident model allows for the establishment of the conditions under which an innovative TS can invade and expand in the market. This information is obtained from study of the sign of the fitness function for specific model coefficient expressions. Additionally, the approach through adaptive dynamics permits establishment of the long term dynamics the quantitative attribute (average number of passengers per mobile unit). The study of this evolutionary dynamic permits the classification of the evolutionary equilibrium in ramification points (diversification) or terminal points (those in which the evolution definitively halts), like the points where substitution takes place.

Particularly in the case of diversification, with the functions defined in this study, and for the values of the parameters considered, it was observed that the established TS should maintain a low number of users transported (< 200 passengers per unit), while the innovative TS should attain a high number of users transported (> 1400 passengers per unit). The above indicates that, in a scenario of coexistence between the two transport systems, it is necessary for each one of them to use a different strategy, in regards to the number of passengers that they decide to transport. One of them should focus on mobile units with few passengers, while the other system should focus on mobile units which can transport passengers massively.

Diversification is impossible when both transport systems use the same strategy. For example, if both TSs design a strategy that permits them to transport over 1400 passengers per unit, the effect would be that the innovative TS would absorb all users and substitute the established TS.

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SADDLE-NODE BIFURCATION IN THE DYNAMIC ANALYSIS OF A NATIONAL ENERGY MARKET

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ABSTRACT.

This article presents preliminary results of the mathematical analysis of a national energy market. The modeling of the studied system was made from causal relationships between the supply and demand of a national energy market, obtaining a system of ordinary differential equations of the first order of the electric power capacity in construction, the electric power capacity installed and the price of electricity in the market (Redondo et.al, 2018). In the dynamic analysis of the model, a saddle-node bifurcation was identified for the case in which the elasticity of the price with respect to the reserve margin is considered null, which allowed establishing two prospective scenarios of the system: absolute disappearance of the supply of electricity or tendency of growth of the supply to the attention of the demand of the market

Keywords

National energy markets; equilibria point; saddle-node bifurcation; Dynamical Systems.

The national energy market is one of the main issues of economic activity in any country. To study its behavior, some models have been constructed that link the most important variables of these markets. The Ceiba Center and the National University of Colombia, have been using the Systems Dynamics methodology with conclusive results for the formation of a regional market (Ochoa, 2010). Different approaches can be used to establish a model of electricity markets, to illustrate, consider the price of electricity. Authors have used statistical techniques (Angelus, 2001, Deng, 2000a, Deng, 2000b, Ethier, 1998, Ethier, 1999, Knittel, 2001, Silva, 2001), neural networks (Velasquez, 2001, Pulgarin, 2001, Rabbit, 2005; Ramsay, 1998; Szkuta, 1998), computational intelligence models (Souza, 2002), fuzzy systems (Medeiros, 2003) and recurrent neural networks (Hong, 2001). In this document we analyze a case of the system of equations obtained for the modeling of an electricity market presented by Redondo et.al. (2018).

The main purpose of this article is to show the preliminary results of bifurcations found in the mathematical model of national energy markets proposed by Redondo et.al. (2018), to conclude on its prospective possibilities in practice.

Mathematical model for the energy market

The mathematical model of the system considers a system of ordinary differential equations of the first order of the electric power capacity in construction x, the installed electric power capacity y, and the price of electricity in the market z (Redondo et.al, 2018):

Equation 1: Mathematical model of a national energy market.

$$\dot{x} = max\left\{0, a\left[1 - \frac{c}{p}\left(\frac{yz^{\varepsilon}}{dq} - \frac{1}{q}\right)^{\beta}\right]y\right\} - \frac{x}{k_1}$$

$$\dot{y} = \frac{x}{k_1} - \frac{y}{k_2}$$

$$\dot{z} = \frac{1}{k_3}\left[p\left(\frac{yz^{\varepsilon}}{dq} - \frac{1}{q}\right)^{\beta} - z\right]$$

where $0 \leq a \leq 1$ is the investment rate in new energy capacity, $c \in \mathbb{R}^{+} \cup \{0\}$ is the unit generation cost, $k_1 \in \mathbb{R}^{+}$ is the construction time, $k_2 \in \mathbb{R}^{+}$ is the average useful life of the generation plants, $k_3 \in \mathbb{R}^{+}$ is the time of adjustment of the real price to the price assumed by the consumer, $p \in \mathbb{R}^{+} \cup \{0\}$ is a reference value of the unit price, $q \in \mathbb{R}$ is a reference value of the reserve margin, $d \in \mathbb{R}^{+} \cup \{0\}$ is a reference value of demand, $\varepsilon \in \mathbb{Q}^{+} \cup \{0\}$ is the elasticity of demand with respect to price and $\beta \in \mathbb{Z}^{+} \cup \{0\}$ is the price elasticity with respect to the reserve margin.

Planar case analysis

To analyze Equation 1, we can consider different cases associated with the value of the elasticities ε and β . For example, if the elasticity of the price with respect to the reserve margin is zero, $\beta = 0$, the 3-dimensional differential system becomes a planar system of the form:

Equation 2: Simplification of the differential system of Equation 1 for the case in which the elasticities are zero

$$\dot{x} = max\left\{0, a\left(1-\frac{c}{p}\right)y\right\} - \frac{x}{k_1}$$

$$\dot{y} = \frac{x}{k_1} - \frac{y}{k_2}$$

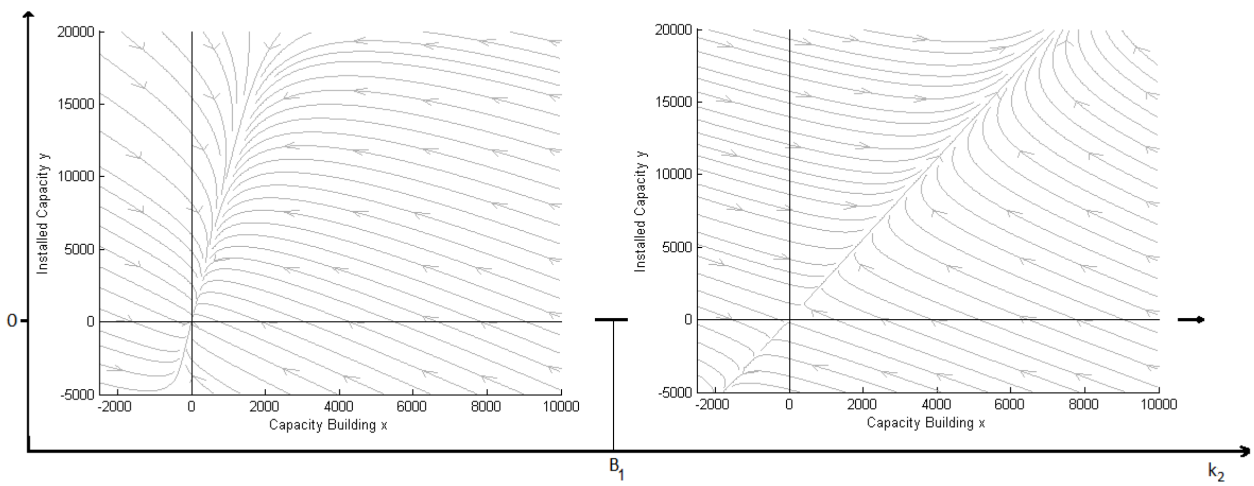

Figure 1: Bifurcation saddle-node under the parameter k_2 for the case where the elasticities are null and the maximum in Equation 2 is not zero.

For this system we have the following proposition.

Proposition 1: When the maximum in Equation 2 is zero, the system has a stable equilibrium point at the origin. When the maximum is not zero, that is, the reference value of the unit price is greater than the unit generation cost: $p > c$, the origin has a saddle-node bifurcation in $k_2 = B_1$, with $B_1 = p/(a(p-c))$. If $k_2 < B_1$, the origin is stable. If $k_2 > B_1$, the origin is a saddle node.

Figure 1 shows the simulation of the system showing the sadle-node bifurcation that occurs due to the variation of the parameter time of adjustment of the real price to the price assumed by the consumer k_2 under conditions of price elasticity with respect to the margin of zero reserve and price unit greater than the cost of unit generation: $p > c$.

Other cases from the elasticities can be considered for the bifurcation analysis of Equation 1. However, in the context of this paper the discussion of this found bifurcation case is intended.

Conclusions

The hypothetical case presented, in which the elasticity of the price with respect to the reserve margin is null, is the case in which the market does not react to the variations in the supply and demand relationship, which can occur when there is a regulation that fixes the price, considered here the reference value p or when the substitute in the market can supply in the same conditions the demand of the users.

Clearly it is an ideal case that has more theoretical than practical character, however, it is identified that the realization of investments, given by the positive maximum in Equation 2, is not enough to guarantee the supply of electricity to the national market. The system must maintain the adequate and non-trivial relationship between the reference price and generation costs in order to maintain supply growth proportional to the growth in demand.

This is the case in which the investment must reach a non-zero minimum to be viable for the system. This viable minimum was identified in the system as the bifurcation value B_1, for the special case studied.

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NON-SMOOTH ANALYSIS IN A NATIONAL ELECTRICITY MARKET MODEL: A COMPLEX APPROACH

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ABSTRACT.

In this paper, we show the preliminary results in a proposed a model for the supply and demand of electricity in a domestic market based on system dynamics. Additionally, the model indicates piecewise smooth differential equations arising from the diagram of flows and levels, using dynamical systems theory for the study of the stability of the equilibrium points that have such a system. A bifurcation analysis approach is proposed to define and understand the complex behavior. Until now, no work has been reported related to this topic using bifurcations criteria. The growing interest in personal ways of self-generation using renewable sources can lead the national grid to a standstill and low investment in the system. However, it is essential to preserve the national network as a power supply support to domestic and enterprise demand. To understand this scenario, we include an analysis of zero-rate demand growth. Under this hypothesis, a none smooth bifurcation appears related to a policy which involves the variation of the capacity charge. As a first significant result, we found that it is possible to preserve the investments in the market since, through the capacity charge parameter, the system dynamics can be controlled. Then, from a business approach, it is necessary to know the effects of the capacity charge as the strategic policy in the system generation price scheme.

Keywords.

Electricity market, modeling, simulation, complexity, non-smooth dynamic, supply and demand.

1. Introduction

To study the systems in the particular case of this document, we start with modeling of system dynamics. The concept of qualitative has had different connotations in the field of modeling. It would be expected that the information contained in the causal diagrams has this nature. That is not the meaning of qualitative that is discussed. The qualitative term refers to the different phenomena that a system exhibits, that is, the tendencies of its dynamic flow over time. For example, when in the system a level variable increases, decreases, oscillates or reaches a point of equilibrium. And, besides, if this dynamic is determined by a specific parameter (leverage points) or set of decision rules that affect it, boundary conditions, discontinuities, among others.

The dynamics of systems is structured so that it has a part of mathematical modeling and another that focuses on numerical methods of simulation. For this reason, a model based on systems dynamics is a mathematical object (Aracil and Gordillo, 1997). Hence, it deserves a mathematical analysis of its dynamics. From the above, it turns out that there is a wide range of strategies to model and simulate electricity markets (Ahmad et al., 2016, Foley et al., 2010, Gary and Larsen, 2000, Jebaraj and Iniyan, 2006, Ponzo et al., 2011; Ventosa et al., 2005). However, regarding the exploitation of these models, the contributions are lower, perhaps because of the interests with which the modeling and analysis were developed.

There is a wide range of strategies to model, simulate and formulate policy elements in electricity markets. If, on the contrary, the differential equations that emerge from them are explored, to a lesser extent reports will appear in this sense. Now, what is the need for this approach? According to the methodological synthesis proposed in (Valencia, 2016), the relevance of the qualitative analysis of models based on systems dynamics is recognized. For scientists who are familiar with the subject, they will know that formulating a system of differential equations that represent the complex behavior of an economic or social system is not as simple as for real physical systems. Specific variables that can be endogenous, or on the contrary, evaluate their effects exogenously to reach some conclusion, are indeed in the air. Well, if the formulation based on systems dynamics is used, arriving at this type of representation and obtaining a system of differential equations is more straightforward and more systematic.

In the case of this article, the interest focuses on the use of this dynamic wealth, to make decisions that involve elements of electric power policy. Therefore, in a systematic way it is possible to formulate models that start from a mental schema and use other tools that are not generally used for these cases of study. The implementation of asynchronous mappings in social systems is then proposed (Di Bernardo et al., 1997). The proposal that never before had been present to study the transients in dynamic social systems that model electricity markets. In this same sense, the implementation and analysis of stability of differential equations systems, despite its high degree of discontinuity and non-linearity, gives modelers a set of parameters that determine leverage points and shows which settings affect in a significant market dynamic.

Then research questions arise around the subject. What variables could induce a specific dynamic? And, if indeed, these leverage points represent, in a certain way, real information for the regulators. If the elements of energy policy are understood as control elements. Operators can then, based on systems dynamics models, that with a qualitative analysis provide additional information, formulate investment policies in the reliability charge instead of increasing the price of scarcity, for example. It is worthwhile to use in addition to the sensitivity analysis offered by the simulation packages; sensitivity analyzes that are structured as asynchronous mappings since for this type of systems it is much more interesting to explore what happens in the transient state.

The modeling of electricity markets is of great interest to the academic community, such as society in general. Especially since what happened in the 90s, the process of liberalization of the electricity market, as well as regularization, increases its analysis complexity. For example, (Gary and Larsen, 2000) argues that traditional econometric models do not provide market information and that in this conventional way it is not possible to represent their complex behavior. However, interest has also focused on deregulation, concerned about the effects that any external or political event could have on them. Following work such as (Cárdenas et al., 2015, Ford, 1999, Ochoa and van Ackere, 2009), there is an overview of the modelers' interest and the study of the energy market. These studies have analyzed the impact of different policies associated with investment decisions and the short and medium term effects that any change in the system could face.

2. Methodology

The complementarity between systems dynamics and mathematical analysis, with the help of the modern theory of nonlinear dynamic systems, allows establishing the qualitative behavior. However, sometimes, it is difficult to distinguish between qualitative and quantitative. Therefore, starting from a mental scheme, which is fundamentally the root of systems dynamics, it is possible to reach quantitative models that describe the system in question. In this way, it is possible to use non-linear modeling schemes of soft or discontinuous systems (PWS of its acronym in English Piece-Wise Smooth), which represent in a high degree the phenomena present in real situations. This is how the dynamics of systems allows, with a high level of detail, to study substantially complex aspects, which in the long run are no more than a set of soft and fragmented systems, carefully interconnected by functions or mathematical laws. The models based on systems dynamics are the translation of a type of mental model in the language of dynamic systems (Aracil, 1999).

To write the methodological synthesis proposed here, the methodological schemes offered by Aracil are considered in their document on Systems Dynamics (Aracil and Gordillo, 1997). In this one, it is shown in a general way how, from a mental scheme and using the theory of systemic thinking, it is possible to take advantage of a model based on systems dynamics. Also, another reference is the work of Sterman Business Dynamics (Sterman, 2000), where it is possible to identify different tools and systemic methods to validate and evaluate a model.

3. The problem definition

In this stage, a series of dynamic hypotheses are presented that reflect the influence of the different components of the system to be studied. For example, how the increase or decrease of a variable could affect other system variables, and what type of variables should be included in the model. In this phase, all part of a mental scheme. It is assumed then, five main variables that affect the behavior of a national electricity market. Already in work presented by Dyner et al. (Dyner, 2000), the structure of a national electricity market was defined, which includes the supply and demand side as the leverage points of the same. Likewise, the reserve margin of the system was set as the bridge that unites supply with demand and allows measuring the effects on the price that this signal would have. It is possible to understand this market, like any other market in which the availability estimated through the reserve margin affects the price and investment in the system, a scheme that remains valid today and you can see other ways to use it in (Cárdenas et al., 2015; Castañeda et al., 2015).

In this sense, it is necessary to evaluate what happens when the growth rate of demand k is equal to zero, the case study in this article. It was found that, under this condition, the variation of the reliability charge produces a discontinuous bifurcation, causing market equilibria to go from being real to virtual and, in the case that all are virtual, arise through a line of equilibria strange oscillatory behaviors.

4. Conclusions

From a mathematical point of view, it has been demonstrated that there is a non-soft bifurcation when the parameter b varies. In the qualitative analysis carried out throughout the work, it was possible to arrive at the detail of all the behaviors associated with each of the boundary conditions that determine the behavior of the system. On the other hand, the approximations and numerical schemes used were adequate to solve the problem. Besides, again, the theory of dynamic systems associated with soft systems by sections facilitated recognizing each of the phenomena present there. By the same token, when a point of equilibrium is real, efficiently using some method of numerical integration, one can understand its behavior.

Now, from systems dynamics and national electricity markets, the result is even more interesting. First, there is a discontinuous bifurcation for a national electricity market, so far there are no reports in the literature on this. And second, under the conditions in which the bifurcation appears, for the operators it could mean the permanence response of a specific technology if the growth rate of demand is zero. That is, the conditions under which the investment in the market tends to the point of particular equilibrium are known.

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THE ROLE OF ECONOMIC COOPERATION BETWEEN TWO RURAL COMMUNITIES

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ABSTRACT.

Historical civilizations have evidenced different routes to the collapse mainly due to political, warfare, cultural and environmental damages. This has animated modern researches to study and understand social, economic, and environmental challenges that modern societies must adopt in order to avoid history from repeat itself, and even worst, irreversibly. Many of these researches are focused on modelling through sets of ordinary differential equations (ODE's) representing the dynamic interaction between natural resources and population in an isolated society. In this work, we introduce the fact of cooperation between two similar societies, modelled as sets of ODE's of the type Brander and Taylor (1998), in the sense that economical exchange can exist between them. We couple two societies by introducing a simple receive-and-protect rule in which one society receive the other's help under the condition of protecting its own resources. We set that this cooperation may

be constant, when it does not change all over the time, or changes intermittently depending on the level of resources each society has at any time. When cooperation is constant, the resulting system is a 4-dimensional system of ODE's that evolves smoothly, but if cooperation is intermittent, the coupled 4-dimensional system becomes a Filippov system. In both cases, we found that under economic cooperation, societies can survive at least in the long run, different from what happens when both societies are treated in isolation for the same parameter values.

Keywords

Sustainability; Cooperation; Filippov system

Introduction

There is currently a lot of evidence that environment worldwide has been passed the ecosystemic boundaries mainly due to overexploitation of natural resource and overpopulation bringing as consequences: hungry and thirsty, migration, climate change, epidemics, and deforestation to name a few. To face these problems that concern us all, researches has been studying and understanding the dynamic processes of human-environment interactions of past societies worldwide that collapse either by political, social or environmental reasons in order to explain the route they followed and try to answer the question if modern societies are on a similar way and contribute to the decision making to avoid it.

Many of the available research dealing with populations and the way they used their natural resources are focused on mathematical modelling to qualify and quantify ancient civilizations that have followed the path to the collapse (J. Brander, 1998; Flores, 2015; Heckbert, 2013). Proposed models are mainly sets of ordinary differential equations related to the Lotka-Volterra model, where population is the predator and natural resources represent the prey like Brander and Taylor's model (J. Brander, 1998). From this model, many adaptations with specific purposes have been developed but, just a few deals with the movement of population and products trade (D. Angulo, 2015; S. Roman, 2018). In this work we introduce and study the economic cooperation between two rural communities modelled as Brander and Taylor's type communities consisting of two sets of ODE's, so that in absence of cooperation both communities independently evolve, but once economical exchange is introduced into the system, flows of input and output appear and the two planar systems becomes a 4-dimensional one. Incoming flows besides being used for subsistence also reflect the engagement towards the protection of the resource. Namely, each community receive the other's help under the condition of protecting an equal amount of its own resources. We study the long-run effect of cooperation on the coupled system when it occurs not only constantly (smooth) but also intermittently (Filippov, 1988) over time.

The model

The coupled Brander and Taylor's type models is

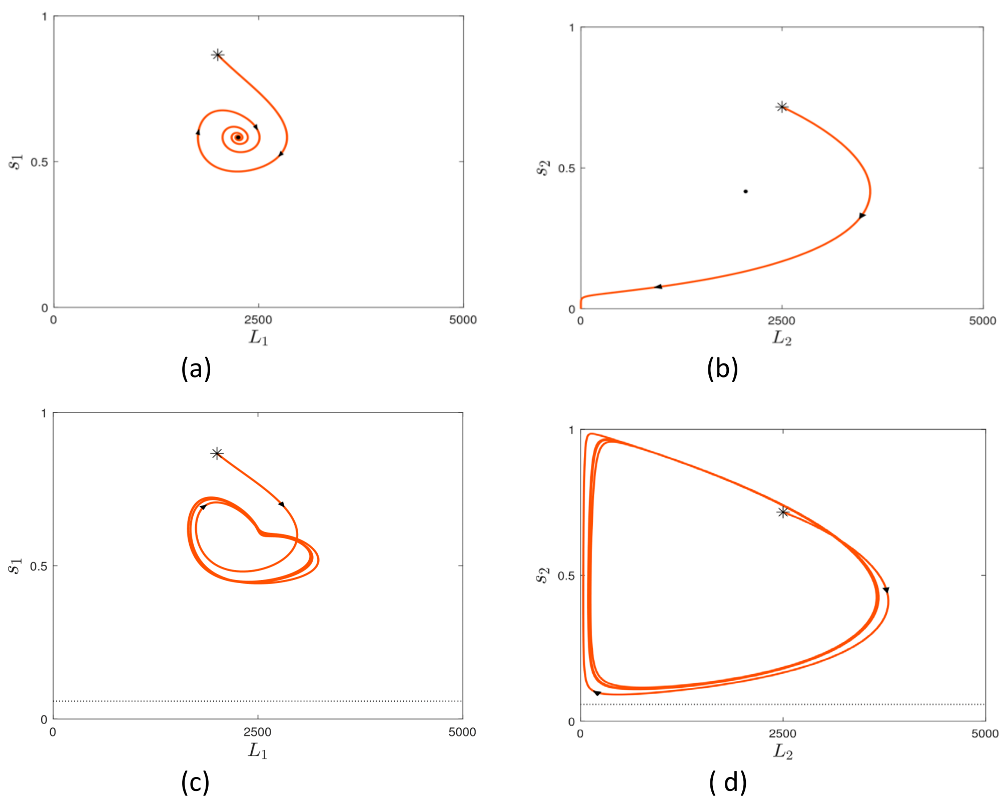
$$\begin{cases} \dot{L}_1 = \left(C_1\phi_1\alpha_1\beta_1S_1 + (1-C_2)\phi_2\alpha_2\beta_2S_2 - \sigma_1\right)L_1, \\ \dot{S}_1 = \rho_1\left(\dfrac{S_1}{T_1} - 1\right)\left(1 - \dfrac{S_1}{K_1}\right)S_1 - \alpha_1\beta_1L_1\left(S_1 - S_{2\to 1}\right), \\ \dot{L}_2 = \left(C_2\phi_2\alpha_2\beta_2S_2 + (1-C_1)\phi_1\alpha_1\beta_1S_1 - \sigma_2\right)L_2, \\ \dot{S}_2 = \rho_2\left(\dfrac{S_2}{T_2} - 1\right)\left(1 - \dfrac{S_2}{K_2}\right)S_2 - \alpha_2\beta_2L_2\left(S_2 - S_{1\to 2}\right). \end{cases} \tag{1}$$

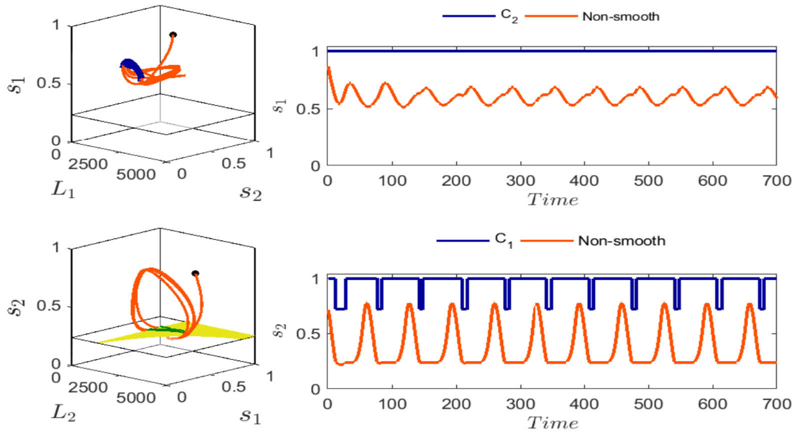
Where $C_1, C_2 \in [0,1]$ represent the portion of harvested resources taken for internal consumption, then, $(1 - C_1)$ and $(1 - C_2)$ are the percentages of outgoing resources from each community; $S_{1\to 2}$ and $S_{2\to 1}$ are the resources protected quantities defined as

$$S_{1\to 2}=\frac{(1-C_1)\,\phi_1\alpha_1\beta_1 S_1}{\phi_2\alpha_2\beta_2} \quad \text{and} \quad S_{2\to 1}=\frac{(1-C_2)\,\phi_2\alpha_2\beta_2 S_2}{\phi_1\alpha_1\beta_1}.$$

Results

Parameter values used for numerical computations are those reported in (J. Brander, 1998; D'Alessandro, 2007).





(e)

Figure 1: Outcomes for system (1) when considering different values of C_1 and C_2.

Conclusion

Figures 1(a) and 1(b) are numerical simulations of isolated communities, i.e. $C_1, C_2 = 1$. Under this condition, population of community 1 can live in harmony with environment without overharvesting their renewable resources (sustainable) but, community 2 exhaust its resources in the long run (unsustainable). For the same parameter values and initial conditions but considering the exchange of the 8% of the resources, namely, $C_1, C_2 = 0.92$, both communities falls into periodic solutions (invariant set). Despite this, neither community 1 nor community 2 exhaust completely their resources as shown in Figures 1(c) and 1(d). Finally, if cooperation is a mutual decision that should be taken depending on the level of resources each community has at any time, system (1) becomes a Filippov system with sliding region as plotted in Figure 1(e). In both cases, the continuous and discontinuous, the movement of resources between communities has a positive effect on the long run since exhaustion is avoided.

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A FIRST APPROACH TO A HYBRID ALGORITHM FOR MOBILE EMERGENCY RESOURCES ALLOCATION

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ABSTRACT

We present a hybrid algorithm based on Genetic Algorithms and Discrete Event Simulation that computes the algorithmic-optimal location of emergency resources. Parameters for the algorithm were obtained from computed historical statistics of the Bogotá Emergency Medical Services. Considerations taken into account are: (1) no more than a single resource is sent to an incident, (2) resources are selected according to incident

priorities (3) distance from resource base to incident location is also considered for resource assignment and (4) all resources must be used equally. For every simulation, a different set of random incidents is generated so it's possible to use the algorithm with an updated set of historical incidents. We found that the genetic algorithm converges so we can consider its solution as an optimal. With the algorithmic-optimal solution we found that arrival times are shorter than the historical ones. It's also possible to compute the amount of required resources to reduce even more the arrival times. Since every Discrete Event Simulation takes a considerable amount of time the whole algorithm takes a heavy amount of time for large simulation time-periods and for many individuals for generation in the genetic algorithm, so an optimization approach is the next step in our research. Also, less restricted considerations must be taken into account for future developments in this topic.

Keywords.

Genetic Algorithms; Discrete Event Simulation; Hybrid Modeling; Emergency Medical Services; arrival time; Optimization

Introduction

Emergencies care is a very important activity in urban centers because security and health of inhabitants depends to a large degree on it. One of the measured factors in the quality of emergency services is the speed in which all incidents are attended. Some international recommendations for maximum arrival time were proposed (Barrachina et al., 2014; Kim et al., 2017; Schluck, Wu, Whyte, & Abbott, 2018). Such recommendations are based on empirical knowledge. So, the goal of emergency services is to comply with proposed times and even improve on them. Emergency resources involve ambulances, fire trucks, patrols and others, so location of this mobile resources must be the best in order to guarantee arrival times (Benatar & Ashcroft, 2017; Fiedrich, Gehbauer, & Rickers, 2000; Hawe, Coates, Wilson, & Crouch, 2015; Luscombe & Kozan, 2016; Pradhananga, Mutlu, Pokharel, Holguín-Veras, & Seth, 2016).

Algorithm

To simulate the emergency caring dynamics using an informatic system becomes a useful tool to validate several scenarios in lesser time. We understand a scenario as a resource distribution. Different discrete event simulations (Beck, 2008) were run to check different scenarios. This methodology allows us to represent the behavior of assignment, transit and release of emergency mobile resources via definition of time-discrete evolution rules. Moreover, assignment complexity is delegated to the simulation in the evolution rules.

We precise an appropriate optimization tool as our purpose is to optimize arrival time by selecting the best possible scenario. As mentioned, arrival time problem can be seen as an optimization problem of emergency resources distribution. Therefore, we use genetic algorithms (Fogel et al., n.d.) because this technique considers the generation of new resource distributions from other simulated and evaluated distributions. The evaluation of the resource distributions is done with a fit function. Such function drives the convergence of the genetic algorithm. Criteria for the weighted fit function are:

1. Average arrival time computed from the simulation. This has a weight of 40%.
2. Match between resource type and incident priority. This has a weight of 20%.
3. Proportion of resource usage. This is, no resource is used more than others. This has a weight of 20%.

4. Number of incidents that didn't got an assigned resource. This has a weight of 20%.

This function maps large values to configurations with large values in each criterion in order to discard resource distributions that are not suitable. So, best fitted distributions are mixed in every iteration of the genetic algorithm. This procedure guarantees the algorithm convergence.

The algorithm can be described generaly like:

1. Get statistics that are used as simulation parameters.
2. Definition of generic parameters.
    a. Number of resources
    b. Start date of the discrete event simulations
    c. Final date of the discrete event simulations
    d. Simulation clock step size
    e. Number of individuals in each population (set of scenarios) for the genetic algorithm
    f. Number of iterations for the genetic algorithm
    g. Number of parents to mix in each new population
3. Random generation of incidents for the different discrete event simulations using historical statistics as a base. Each incident has its location, time, type and priority.
4. Random generation of the first resource distribution population.
5. Genetic algorithm starts.
6. Parallel discrete event simulations start.
7. Simulation clocks start.
8. At each simulation clock step:
    a. Incidents waiting for resource assignment are queued.

b. Execution of all arrival and release events for incidents that already have an assigned resource.

c. Resource assignment to queued incidents by priority and distance. Each incident gets a single resource.

d. All actions are logged within the simulation log.

9. Simulation clocks end.
10. Computation of fit values using simulation logs.
11. Selection of parents (the ones with best fit values) to mix them and create the new population of resources distribution.
12. Next genetic algorithm iteration starts.
13. By the end of the genetic algorithm, the distribution with the best fit value is called the algorithmic optimal.

Conclusions and comments

The proposed hybrid algorithm answers to its purpose correctly. The amount of discrete event simulations executed in every genetic algorithm iteration becomes a negative factor in the overall execution time. So, the algorithm has room for improvement.

On the other hand, the number of resources must be considered as a simulation variable. This involves an adjustment of the fit function to avoid that the number of resources exceeds limits. Such limites could be related to service financing.

Is of interest to simulate environments were more than one resource are assigned to a single incident. There are real situations where such things happen (Huang & Fan, 2011). This implies the introduction of high impact incidents within the simulations. To accomplish this, occurrence probabilities for such events must be computed from historical data.

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UNVEILING SOCIOECONOMIC DIFFERENCES IN COLOMBIA BY MEANS OF URBAN MOBILITY COMPLEX NETWORKS

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ABSTRACT

Social stratification lead to marked differences between people in several aspects of their lives, such as income, education, work, welfare and mobility. Here, we aim to analyze urban mobility by socioeconomic differences of travelers. In order to do so, we represent urban mobility by a complex network approach. We show that the topological properties of the networks allow to characterize mobility flows and to recognize differences in the dynamics of socioeconomic strata. We use data from origin destination surveys made for the two most populated cities in Colombia and we represent it in the form of a weighted and directed network. We found that urban mobility networks have structural differences if analyzed by socioeconomic strata of the population and unveil segregation patterns in the highest and lowest income strata.

Keywords.

Urban mobility; Socioeconomic segregation; Complex networks

Introduction

Understanding socioeconomic differences is of crucial importance to fight inequity, which is one of the main socio-political problems of Colombia. Under Laws 142 and 143 of 1994, there was designed a system that classifies housing into six socioeconomic strata according to the characteristics of housing and the utilities paying capacity of the household. Strata 1 to 3 have subsidized utility bills; stratum 4 pays the marginal cost of the utilities, and strata 5 and 6 pay more to subsidize the other strata. Although socioeconomic stratification was designed for housing, it has been widely used as a proxy of households income level and wealth status, being those in status 1 the poorest and those in status 6 the richest (Medina, Morales, Bernal, & Torero, 2007).

Also, understanding of urban mobility is crucial for urban planning, policy and decision making. A natural way for representing urban mobility is by mapping into graphs the different places or spatial zones of the city and the fluxes of people between them. This representation supports the analysis of complex networks (Newman, 2010), that has garnered the interest of researchers from several disciplines as it gives information about complex systems made of many interacting parts or elements. The fundamental insight from complex network analysis is that large-scale networks are characterized by properties of the system as a whole rather than by the individual properties of nodes and edges (Amaral & Ottino, 2004; Newman, 2010).

Here, we tackle the issue of the network topology and the relationship between socioeconomic composition of the population in a city and its relationship with urban mobility. We analyze the urban mobility of Bogota and Medellin metropolitan areas, in Colombia, using data from origin-destination surveys and segment the analysis by the socioeconomic strata of the travelers, in order to make comparisons between urban mobility of populations with different income levels.

Urban mobility complex networks

Network analysis provides the foundations for representing the interactions between spatial domains of a city in terms of the travel patterns of people (De Montis et al., 2007; De Montis, Caschili, & Chessa, 2013). The analysis of urban mobility using data from origin-destination surveys can be done by representing the spatial partition of the city in zones and the fluxes of people from an origin to a destination zone by a simple, directed and weighted network. The centroids of the origin-destination zones are mapped into the set of nodes *N*, and the fluxes into the set of weighted links *W*; each link going from node *i* to node *j* has weight w_{ij} and represents the amount of trips between origin zone *i* towards destination *j*. The resulting network can be represented as a weighted and directed graph *G(N,W)*. From the weighted network represented by the matrix *W* we obtain the adjacency matrix *A* with entries a_{ij} that take binary values (0/1) providing information about the existence or not of any trip from zone *i* to zone *j*.

In Figure 1 we present the map of the mobility hotspots for each socioeconomic status. The nodes are sized by its nodal degree. We show the upper interval in a Jenks natural breaks classification with two classes for each socioeconomic status. Similarly, in Figure 2, we present the map of urban mobility by strata in Medellin. In those maps, it is possible to identify the higher strata householders (namely 5 and 6) are located and move to limited parts of the city, while strata 2, 3 and 4 move around the city covering almost the whole area in both cities. Status 1 in Bogota is more constrained to the south part of the city, while in Medellin is distributed in five clusters: the center and some hillside of the valley.

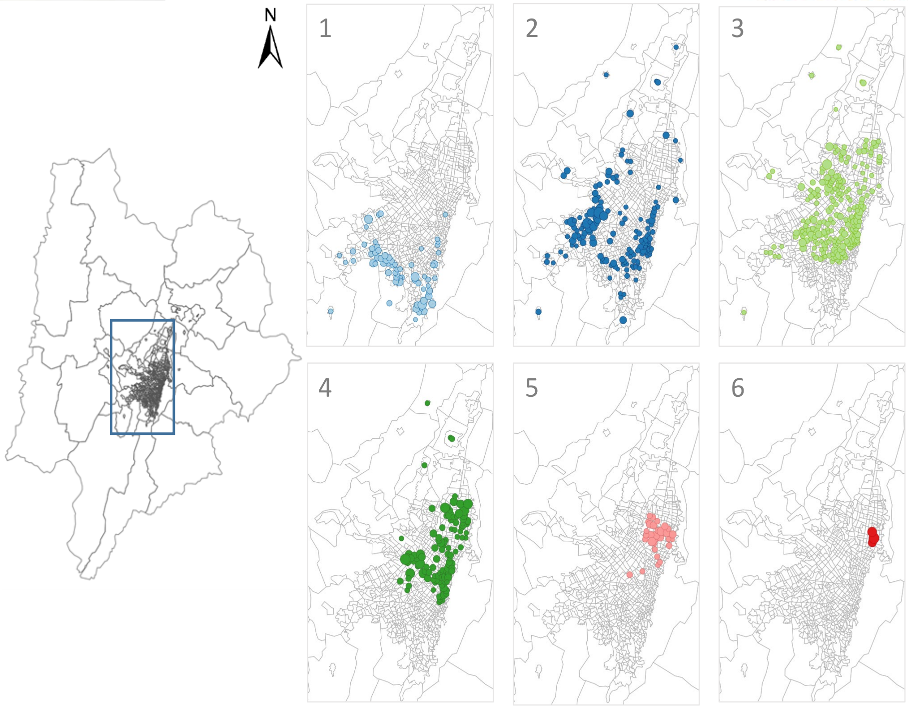

Figure 1 Map of the zones with higher nodal degree by socioeconomic strata in Bogota

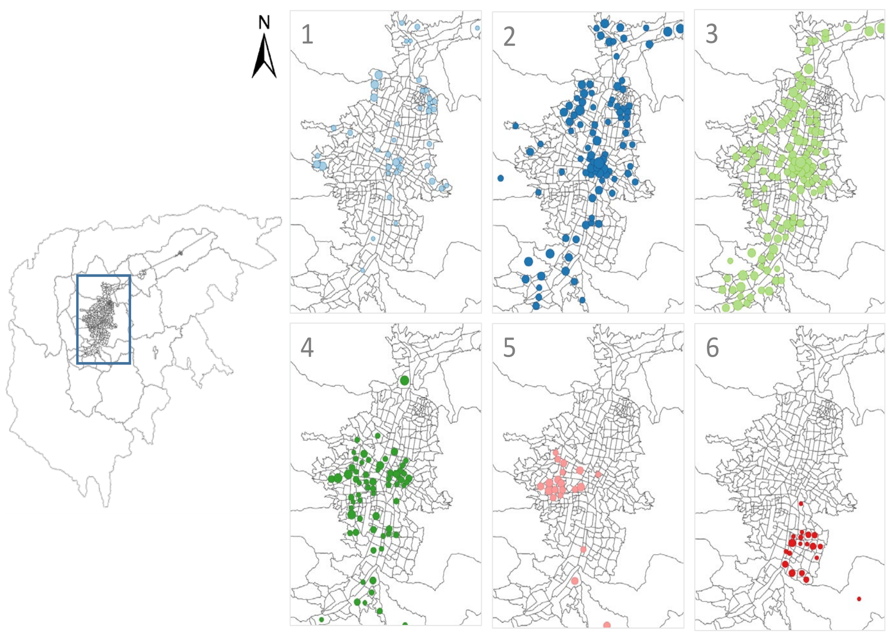

Figure 2. Map of the zones with higher nodal degree by socioeconomic strata in Medellin

The networks formed by the mobility of people belonging to strata 2 and 3 covers most of the city (more than 90% of the city in terms of number of zones visited), while the networks of people of the highest socioeconomic status only show that they visit 31.6% and 47.2% of the zones in Bogota and Medellin, respectively. With the number of nodes of each network, we can identify that people of high-income (strata 5 and 6) move selectively in few parts of the city and people of low to medium socioeconomic status move around the city.

Discussion

Spatial segregation is a common feature of metropolises and it can be related to ethnic, religion or socioeconomic groups. In our study, we analyzed the spatial segregation related to income by considering the urban mobility patterns of different socioeconomic strata.

We found that people from higher socioeconomic strata move in a very specific and constrained zones of the city. We interpret this result as a consequence of the ease for this group of people to locate according to their preferences and convenience, which in turn can improve their mobility patterns. The second group of people, which refers to medium and medium-low strata are located and move through most of the zones of the cities analyzed, and it is a consequence of the tradeoff between their paying capacity for a price-accessible housing and the location of their activities. Finally, the group composed by the lowest income households is constrained to move in limited zones of the city. We relate this result to the budget constraints of this people to buy or rent housing in well-connected zones and to the lack of possibilities to access most of the transportation means due to its cost and therefore the difficult to access distant zones to their homes in the city.

In a related work (Lotero et al 2016) we introduced a multiplex approach for each socioeconomic group, by including transportation modes as layers of the network. We found that transportation modes and socioeconomic status are mobility variables that are highly related. We found that extreme socioeconomic strata (highest and lowest) are less multimodal and more segregated in their mobility patterns, while mid-low strata (2 and 3) are less spatially segregated in terms of mobility and tend to use more transportation modes.

Although it is difficult to identify whether the segregation is a cause or an effect of socioeconomic differences, policy makers should consider these results in order to try to mitigate the negative consequences of socioeconomic segregation. These negative effects include a sense of insecurity (in low-income strata zones) and the distortion of land and housing markets (in high-income strata zones), among others. Our results give insights to urban planners to prioritize zones or groups of people in order to make urban mobility plans or interventions to incentive a multimodal mobility or to mitigate the spatial and socioeconomic segregation.

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A MULTIDIMENSIONAL ANALYSIS FOR THE MANAGEMENT OF RESEARCH PROJECTS IN BUSINESS FACULTIES

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According to Hekkert, et al (2011), the Science, Technology and Innovation Systems (SCTeI) function as macrostructures in which converge different actors promoting the generation and application of knowledge.

Science, Technology and Innovation Systems require the design of research strengthening strategies to be applied in response to the demands of the academic community, the productive sector, and society in general, being these strategies a guideline on the development of educational programs and research processes.

Business faculties follow international dynamics looking for the necessary improvement in order to be competitive, and that is why research projects have a relevant participation on the transformation of business education through the generation and increase of organizational capabilities related to maturity models (Backlund; et al, 2015).

At this respect, Backlund, et al (2015), analyze the literature about maturity models getting to two complementary basic definitions. At a first moment maturity models are organizational structures that reflect certain capabilities and define qualitative attributes, which are applied to classify competences into pre-defined areas (Kohlegger et al., 2009); later on, the authors consider that maturity models refer to the state where an organization could perfectly achieve its objectives.

The management of research projects in business faculties has the inherent complexity of the challenges of the Institutions of Higher Education in the context of internationalization (Guillotin, & Mangematin, 2015), requiring mechanisms that, framed on strategic management models (Kerzner, 2001; David, 2003; Resch, 2011; EFQM, 2012), tend to generate better interventions in a systemic scenario through relevant projects, which, in turn, should strengthen curricular development, and provide organizational capabilities (Backlund; et al, 2015). Consider that research projects, in general, have the basic elements of delay, feedback and accumulation within cause and effect dynamics, corresponding to a complex scenery (Forrester, 1961; Sterman; et al, 2015; Redondo; et al, 2017).

The above considerations imply a permanent analysis of project performance, and the adoption of the parameters of Colciencias (2017), the National Accreditation Council (CNA) (2013), and the guidelines of international accrediting bodies such as AACSB (2016), AMBA (2016), EQUIS (2016), IACBE, and ACBSP, as well as the analysis of the needs of the different stakeholders involved, this, in order to visualize better routes for improvement.

Any approach to the proposal of strategies to improve the results of research projects should start from an analysis of the particular context of each faculty, with the support of validated management models, in correspondence with the institutional strategic thinking and with the requirements of the academic community that is directly impacted (Bennis and O'Toole, 2005; Malaver, 2006; Besancenot, Ricardo and Vranceanu, 2009; Calderón, et al., 2010; AACSB, 2012; Calderón, et al., 2014; and, Sahoo, et al., 2016).

Having this in mind, in this paper there are shown two project management dimensions based on a literature review with the purpose of getting a theoretical approach to the variables that composed the dimensions.

The first dimension corresponds to the processes of the project life cycle, and the second one corresponds to the knowledge derived from the product life cycle.

Taking into account the paths from the Project Management Institute (PMBOK, 2017), the project life cycle has four phases, being these, conceptual, planning, execution, and termination.

When talking about research projects for business faculties, it is proposed a structure composed by eight phases, being these, (a) institutional call, (b) proposals, (c) analysis of the proposals, (d) communication of results, (e) execution of the projects, (f) follow-up, (g) completion of products, and (h) closing.

The product life cycle has five stages, development, introduction, growth, maturity, and retirement (PMBOK, 2017), being the products gotten from academic research classified as products of new knowledge generation, technical development and innovation, social appropriation of knowledge, and training of human resources.

In this way, the project life cycle corresponds to the administrative management and the product life cycle corresponds to the knowledge management.

According to the literature review, the project life cycle is impacted by seven variables which are organizational culture, as a mechanism that influences the acceptance or rejection of processes (Dueholm., et al, 2013); communication, as a media that connects the different stakeholders (Monteiro de Carvalho, 2013); team performance, as the way the different activities are done into the project focus on its success (Backlund; et al, 2015; Coetzer, 2016);

stakeholder management, as the analysis and establishment of proper relationships for project success (Iden & Bygstad, 2017); best practices, as the adoption and documentation of the best processes (Kahn; et al, 2006); management model, as the administrative path in order to get the best results (Abushama, 2016); and strategic thinking, as the strategic route to be followed into the project planning and execution processes (Shenhar; et al, 2001).

In the case of product life cycle, it is taken as a basic reference the proposal of Bharadwaj, and Tiwana (2005), in which there are considered seven variables related to knowledge management, knowledge creation, as the process of development of new knowledge; knowledge exploitation, as the process of utilizing preexisting organizational knowledge applying it in different contexts to the ones it was originally developed; knowledge digitalization, as the process of codification of the information; knowledge integration, as the coordinated application of individual-held specialist knowledge to collective activities; knowledge sharing, as the process of sharing specialized tacit and explicit knowledge; and knowledge appropriability, as a process that facilitates knowledge sharing and application.

A deep analysis of the interactions of the variables that composed the two dimensions make it possible to generate some reflections about new strategies in terms of decision making, organizational capacities, resources demand, and about the analysis of research project approval criteria, this, in order to formulate and approve projects that tend to be successful.

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