World Academy of Science, Engineering and Technology
International Journal of Educational and Pedagogical Sciences
Vol:10, No:12, 2016

Complexity in Managing Higher Education Institutions in Mexico: A System Dynamics Approach

José Carlos Rodríguez, Mario Gómez, Medardo Serna

***Abstract*—**This paper analyses managing higher education institutions in emerging economies. The paper investigates the case of postgraduate studies development at public universities. In so doing, it adopts the complex theory approach to evaluate how postgraduate studies have evolved in these countries. The investigation suggests that the postgraduate studies sector at public universities can be seen as a complex adaptive system (CAS). Therefore, the paper adopts system dynamics (SD) methods to develop this analysis. The case of postgraduate studies at Universidad Michoacana de San Nicolás de Hidalgo in Mexico is investigated in this paper.

***Keywords*—**Higher education institutions, complex adaptive systems, system dynamics, Mexico.

I. Introduction

NOWADAYS, there is great interest among scholars in analysing higher education institutions and universities from the perspective of the complex theory. Actually, this approach may allow including in the same analysis several actors, structures and interactions involved in developing postgraduate studies at higher education institutions. This paper makes use of the complex theory to explore the theoretical and empirical basis of the development of higher education institutions. This perspective suggests that CASs is an adequate framework to understand higher education institutions as self-organising, interdependent and co-evolving systems [1]-[3]. In this regard, higher education institutions should be understood as non-linear, as well as positive/ negative feedback evolving systems [1], [4]. From this perspective, this kind of organisations is far from equilibrium, and they organise in a self-organising manner towards unpredictable long-term outcomes [4].

In this paper, postgraduate studies at public higher education institutions in Mexico are analysed. Particularly, it discusses the main features characterising postgraduate studies at Universidad Michoacana de San Nicolás de Hidalgo (UMSNH) in the province of Michoacán, as an example of postgraduate studies development in this country. The actors and links established in this case allow developing a causal loop diagram (CLD) about postgraduate studies at UMSNH. This analysis suggests the possibility of likely restrictions to further develop postgraduate studies at public higher education institutions in Mexico. These restrictions, however, are illustrated in terms of some archetypes commonly used in SD analyses: Limits to Growth and Eroding Goals [5].

The paper concludes with some policy implications in relation to the possibility of continuing developing postgraduate studies at public higher education institutions (UMSNH). To successfully overcome the restrictions appearing at these institutions, policy recommendations should remove the limits to growth, rather than continue driving the reinforcing process of growth, and thus establishing a clear transition plan from current reality to specific goals.

The research questions conducting this research are: What are the main restrictions that might slow down or even block further developments of postgraduate studies at public higher education institutions? And what policies should overcome these restrictions in postgraduate studies development at public higher education institutions? The case of postgraduate studies at UMSNH in Mexico is analysed in this paper.

The remainder of this paper is organised as follows. Section II contains a literature review in relation to managing higher education institutions, and CASs and SD. Section III discusses a theoretical framework for managing higher education institutions. Section IV analyses the case of postgraduate studies at public universities in Mexico. Section V discusses a SD model of postgraduate studies at UMSNH in Mexico. Finally, Section VI presents some conclusions from this analysis.

II. Literature Review

A. Management of Higher Education Institutions

There is great interest to study higher education institutions from the perspective of the complex theory. Table I shows some literature in relation to the study of higher education institutions from several theoretical perspectives. An important feature in these analyses is that the systemic perspective is the most frequently method used to investigate the performance of higher education institutions. For example, some scholars consider that academic departments at universities can be seen as CASs [6], [7]. In fact, it is important to adopt in these analyses a dynamic, complex, and non-linear perspective in that it is important to recognise the relationship between knowledge and education, on the one

José Carlos Rodríguez is with the Economic and Business Research Institute (ININEE) – Universidad Michoacana de San Nicolás de Hidalgo (UMSNH), Mexico (corresponding author, phone: +52 (443) 316-5131, ext.: 200 and 203; e-mail: jcrodriguez@umich.mx).

Mario Gómez is with the ININEE – UMSNH (e-mail: mgomez@umich.mx).

Medardo Serna is with the UMSNH (e-mail: mserna@umich.mx).

hand, and sustainable development, on the other [8], [9].

From a similar perspective, SD methods can be used to analyse the performance of higher education institutions, exploiting the perspective of system archetypes to investigate likely declining trends in enrolment, research productivity, and resources for research [10].

TABLE I
SELECTED LITERATURE ON HIGHER EDUCATION INSTITUTIONS

Author	Type of model/variables	Contribution
[6]	Analysis from the perspective of complexity theory (CASs): • Departmental leadership • Leadership as a complex activity	Seeing academic departments as CASs
[8]	Case study (systems thinking): • Educational institutions	It develops an analysis from the perspective of dynamic, complex and non-linear systems in educational institutions, concluding that the degree of success of any intervention approach to quality improvement depends on the rigour of problem conceptualisation phase
[9]	Systems approach: • Sustainable development • Knowledge • Education	The systems approach as an adequate analytical perspective to analyse higher education institutions
[10]	SD methods: • Enrolment • Research productivity • Resources for research	Systemic perspective on managing higher education institutions
[11]	Case study: • Commitment to partnerships • Curriculum and learning • Quality and risk management • Geographic and economic settings • Change management	
[12]	Case study: • Competitive advantage in higher education institutions	The adaptation of three theoretical approaches from business strategy to the higher education sector

Other scholars investigate the performance of higher education institutions through using the case study approach [11], [12]. Particularly interesting is the case of investigating how competitive advantage can be developed at universities from the perspective of the business strategy approach.

B. Complex Adaptive Systems

The CAS approach allows exploring the theoretical and empirical basis of social phenomena in that it contributes to get insight on the nature of the relationships established between many actors in a system. Actually, the CAS approach is based on four dimensions [3]:

1) The number of elements that make up the system.
2) The attributes of the elements.
3) The number and type of interactions among the elements.
4) The degree of organisation inherit in the system.

In this regard, these features allow CASs to be characterised as self-organising, interdependent, and co-evolving systems [3]. Self-organising in CASs means that systems are formed by a large number of elements that make up a system [1]-[3]. Certainly, the elements that set up any system interact each other and none of them control the whole system. In addition, CASs are characterised to be interdependent meaning that decisions and actions of one agent may affect other agents' decisions and actions [1]-[3]. This feature also suggests that the behaviour of every individual depends on the behaviour of other individuals within the same system [1]. Finally, the CAS approach suggests that the evolution of one system is always to some extent dependent on the evolution of other systems or agents [1]. In this paper, it is argued that CASs can be studied by means of using SD methods. This possibility draws from the fact that SD models consider four components setting up a system and its structure [13]:

1) They are processes created through using stock-flow chains.
2) They are characterised by information feedbacks.
3) They are subject to several policy implications.
4) They contain many time delays.

However, the challenge when modelling SD models is to establish their boundaries in order to capture and reproduce the actual behaviour of systems. From this perspective, the aim of system thinking should be to accept and embrace boundaries as necessary for management and accountability [13], [14]. In this paper, this approach contributes to get insight on the features characterising higher education institutions and postgraduate studies at public universities in Mexico.

III. A Theoretical Framework for Managing Higher Education Institutions

The theoretical framework discussed in this section suggests that higher education institutions should be understood as CASs [1], [4]-[7], [15], and thus they can be studied from the perspective of the complexity theory [1]-[3], [7]. In this sense, higher education institutions should be understood as a set of relationships characterised by non-linearity, interdependence, and emergence [1]. In this sense, this analysis emerges from the limitations of two dominant worldviews [1]: the mechanistic worldview (metaphor of machine) and the economic worldview (metaphor of market). These perspectives correspond to two important perspectives in strategy that reflect these worldviews [4]: The strategic choice, and the strategic evolutionary process. The strategic choice perspective, inspired in Newtonian physics (metaphor of machine), assumes that organisations adapt to external conditions by rearranging to principles of logic, intentionality and rationality, while the strategic evolutionary process (metaphor of market), inspired in Darwinian evolution principle of adaptation through competitive selection, assumes that there is an evolutionary process of competitive selection in which organisations adapt to external changes [1], [4], [15]. Furthermore, the strategic choice perspective suggests that organisations adapt to environmental changes by restructuring themselves in an intentional and rational manner, while the strategy evolutionary process approach suggests that organisations adaptation might be blocked by institutional inertia and resource specificity [4]. Both approaches, however, establish the same assumption, namely that negative feedback processes allow driving successful systems toward predictable

equilibrium states of adaptation to the environment (stability, regularity and predictability) [4]. However, there is a third approach in strategy suggesting that organisations develop as non-linear, and positive and negative feedback evolving systems far from equilibrium in a self-organising manner toward unpredictable long-term outcomes [4]. Actually, this process implies an emergent order from new innovation and creativity that is truly new and it is not already in the past or the present and cannot be therefore being predicted [1], [4]. Table II summarises the main assumptions assumed in alternative strategy processes [4].

TABLE II
ASSUMPTIONS IN ALTERNATIVE STRATEGY PROCESSES [4]

Adaptation through choice	Adaptation through competitive selection	Alternative viewpoints (complex perspective)
Clear-cut cause-and-effect links (predictability)	Clear-cut cause-and-effect links (predictability)	Clear-cut cause-and-effect links, but they are circular leading to unexpected outcomes
Organisations intentionally seeks adaptive equilibrium	Organisations are selected according to criteria of equilibrium adaptation	Organisations are nonequilibrium systems with disorderly dynamics
Long-term outcomes are intentional and chosen	Long-term outcomes determined by environment and inertia of organisations	Long-term outcomes are partly emergent and partly intentional
Negative feedbacks drive systems	Negative feedbacks drive systems	Complex nonlinear systems with positive and negative feedbacks Spontaneous self-organisation and creative destruction

Yet, the complex perspective implies that there are two different types of feedback loops [16]: Reinforcing (positive) and balancing (negative) feedback loops. Reinforcing or positive feedback loops should be understood as a change that is reinforced by generating major changes which are self-reinforcing [17], while balancing or negative feedback loops should be understood as a force which is self-seeking or self-correcting [17]. Indeed, negative feedback loops may be focused on the stability of the system, whereas positive feedback loops may be focused on destabilise the system and make it move in an unpredictable direction [1]. However, the procedure characterising the complex perspective implies a process of learning for changing at organisations. Actually, learning and change are intertwined concepts in complex phenomena [1]. Indeed, there are three levels of learning [18]:

1) Learning for self-correction.
2) Learning for how to learn.
3) Learning as a corrective change.

Learning for self-correction and learning for how to learn can be seen as a first-order change, while learning as a corrective change in the systems of sets of alternatives or transformative change can be seen as a second-order change (seeing things differently) [19]. Therefore, learning might serve to keep a system in a condition of stability, or alternatively to keep a system in motion moving to a new state [1]. In relation to higher education institutions, transformative learning should be associated with deeper changes in terms of transforming educational systems [1]. In fact, such changes should be in relation to transforming and redesigning educational systems through transforming learning [18].

TABLE III
DIFFERENCES BETWEEN FIRST-ORDER AND SECOND-ORDER CHANGE AT EDUCATIONAL SYSTEMS [20]

First-order change	Second-order change
Improving/reforming educational systems	Transforming educational systems
Making adjustments in existing systems	Redesigning educational systems
Piecemeal change	Whole system/systemic change
Planning process	Design process
Designing for the future	Designing the future
Adaptive learning	Transforming learning

Table III shows the main differences between first-order changes and second-order changes at educational institutions. A second-order change means that learning for change transform educational systems through redesigning the whole system (designing to the future) [18]. Importantly, it is not only accommodation and transformation, but deeper changes that matters to transform educational systems [1].

In the case of higher education institutions, the learning process implies that all actors should act as learners in the system [1]. Indeed, this process may generate some kind of tensions between the actors participating in the process of learning. Actually, these tensions emerge from the fact that a holistic and systemic approach allows characterising systems by multiple variables and actors causally linked each of which might be associated with a distinct rate and direction of change [19].

IV. POSTGRADUATE STUDIES AT PUBLIC UNIVERSITIES IN MEXICO

A. An Overall Perspective

There are many factors that individual universities stress in relation to developing their activities [21]: Transferring knowledge, reflecting their own particular missions, the economic circumstances of particular localities or regions within which they are located, and the role researchers choose to play in relation to the process of knowledge and technology transfer. However, the roles and activities played by researchers at universities when generating, teaching, and transferring knowledge are the most important [22]-[24]:

1) Training of qualified personnel.
2) Advancement of scientific knowledge.
3) Entrepreneurial university.

Yet, these activities can be developed and appropriated to specific local economic development pathways, making one or other more important at different moments in time [22]-[24]:

1) Disseminating new knowledge and technologies.
2) Providing technical assistance in the process of the regional development strategy.
3) Making bridges between disconnected actors.
4) Problem-solving dimension through consulting and contract-research.

In the same way, various types of relations are important at different moments in time, namely informal contracts,

recruitment at first degree or postgraduate level, publication of research results, conferences, testing and standards development, recruitment at postdoctoral level, problem-solving/consulting by university staff, joint research and development of projects with industry, internships, exclusive licensing of university held patents, innovation-related expenditure spent on universities, and so forth [25]. However, the traditional paradigm at universities and higher education institutions (content-centred paradigm) implies that learning takes place as a result of transferring knowledge from teachers to students [26]. In fact, this paradigm is based on a perception of higher education institutions as closed systems [1]. On the other hand, the learning-centred paradigm can be described as a shift in the mission of universities from just providing instruction to producing learning and new knowledge [27].

In short, universities should implement market-oriented reforms if they are to become more responsive to social demands [1]. This means that universities must be seen as the capacity to respond, adapt and discover new activities in the context of a world that is always changing in an unpredictable way [1]. Learning is thus a way of interacting with the world [28].

B. Postgraduate Studies in Mexico

The case of postgraduate studies in Mexico is an example of insufficient development of higher education institutions. One of the most important challenges for higher education institutions in this country is to develop well qualified human resources [29]. In this regard, the Word Economic Forum reports that the Mexican education system is currently characterised by four main features [29] [30]:

1) Poor quality of its education system.
2) Poor quality of education in mathematics and sciences.
3) Low enrolment in post graduate programs.
4) Low training rate of engineers and scientists.

In the same way, the Ministry of Education in Mexico has recently pointed out that higher education institutions in this country are also characterised by four important features [29]:

1) Low coverage of higher education institutions with postgraduate programs.
2) Deep differences in terms of quality of postgraduate programs across higher education institutions.
3) Very weak links between higher education institutions and industry.
4) Serious restrictions to financing public higher education institutions and postgraduate programs.

All these features characterising the Mexican higher education system result hence in a limited capacity to train doctoral students and researchers, and thus opening up the need to acquire a critical mass of researchers in order to understand knowledge and technological developments for exploitation and commercialization [29]. Table IV shows data on graduated doctoral students and researchers per 10,000 of economically active population (EAP). In fact, some problems in the higher education system of this country continue to be big challenges to the next future. It is worth saying that these facts have obliged Mexico government to implement some important public policies to catch up with other countries. As an example of these policies is the Special Program for Science and Technology 2008-2012 (Programa Especial de Ciencia y Tecnología 2008-2012). The main objective of this program is to establish adequate mechanisms to support human resources training and development in order to support the improvement of the national postgraduate system through increasing the number of doctoral graduated students, as well as improving the percentage of doctoral graduated students in sciences and engineering [29]. In this way, this objective is at the basis of many programs implemented by the National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACYT), as well as many other provincial councils for science, technology and innovation with the same objective in mind, namely to increase the number of doctoral graduated students and the percentage of doctoral graduated students in sciences and engineering.

TABLE IV
GRADUATE DOCTORAL STUDENTS AND RESEARCHERS (2008) [30]

Country	Doctoral graduates per 10,000 of EAP (%)	Researchers per 10,000 of EAP (%)
Brazil	1.2	1.3
Canada	2.6	8.2
Mexico	0.6	0.8
South Korea	4.3	9.7
Spain	4.1	5.7

C. The Case of Postgraduate Studies at UMSNH

Postgraduate studies in the province of Michoacán is a case of successful development of a postgraduate educational system [31]. Postgraduate studies at UMSNH have dramatically improved in terms of the number of master and doctoral programs offered by this university, as well as the number of postgraduate programs included at the National Program for High Quality Postgraduate Programs (Programa Nacional de Posgrados de Calidad, PNPC) of CONACYT. Nevertheless, some factors could weaken these trends in the next future. These trends will be analysed in the next section of this paper. However, UMSNH is the most important higher education institution offering postgraduate studies in Michoacán [31]. It is worth saying that there are also other important higher education institutions in this province, such as Universidad Nacional Autónoma de México (UNAM-Campus Morelia), El Colegio de Michoacán, Instituto Tecnológico de Morelia and Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM-Campus Morelia), among others. In short, there are 32 higher education institutions and research centres offering 296 postgraduate programs in this province. Indeed, more than 21.3% of these programs are recognised of excellence in the PNPC of CONACYT. Table V shows data on postgraduate programs at UMSNH. However, the case of postgraduate studies at UMSNH could be of great interest for several reasons:

1) UMSNH is the biggest higher education institution in Michoacán, offering 21.6% of postgraduate programs in this province.

2) This university offers 58 master and doctoral postgraduate programs of which 51 programs are in the PNPC.
3) UMSNH turns to be the most important higher education institution in this province offering doctoral programs.
4) Most of the postgraduate programs in this university are research-oriented programs.
5) The rate of growth of postgraduate programs at UMSNH (number of programs and enrolment) has been above the national average in the last years.

These characteristics make the case of UMSNH to be aware of the possibility of weakening these trends in developing postgraduate programs at this university. Importantly, it is important to keep in mind that in Mexico the quality and recognition of postgraduate studies as high quality programs (PNPC) allow them to get access to funding from CONACYT and other public agencies.

TABLE V
POSTGRADUATE PROGRAMS AT UMSNH (2016)

Type of Program	Number of Programs	PNPC Programs
Postgraduate specialization	10	1
Master programs	37	31
Doctoral programs	21	20

V. AN SD MODEL OF POSTGRADUATE STUDIES IN MEXICO

A. A CLD of Postgraduate Studies at UMSNH

Postgraduate programs at UMSNH must face the same challenges than all public universities and higher education institutions in Mexico, mainly to increase the number of master and doctoral graduate students, as well as to improve the percentage of master and doctoral graduate students in sciences and engineering [29]. To achieve this task, many actors participate when offering postgraduate studies at this university, mainly the President of UMSNH, the General Office for Postgraduate Studies, directors of postgraduate programs, faculty, CONACYT, students, and the private sector (firms).

Table VI presents the actors in postgraduate programs at UMSNH and their primary objectives. The primary objectives followed by each actor demonstrate how complex higher education programs could be in terms of the number of elements that make up this system, the attributes of these elements, the number and type of interactions, and the degree of other organisation inherit in this system [3].

The actors and links established allow developing a CLD on higher education programs at UMSNH. In this regard, a core idea in SD is that system archetypes are fundamental to describe many problems in systems thinking terms [13]. In fact, system archetypes can assist model conceptualisation by virtue of their properties to transfer thinking form one domain to another, and thus to communicate modelling insights by collapsing a model down to its basic loops [13]. However, generic archetypes in SD can help with creating dynamic hypotheses, as well as communicating systemic insights [13].

TABLE VI
ACTORS IN HIGHER EDUCATION INSTITUTIONS: PRIMARY OBJECTIVES AND VARIABLES

Actor	Primary objectives	Involved variables (CLD)
President of the Higher Education Institution (UMSNH)	▪ Postgraduate programs inclusion into PNPC ▪ Get funding for developing research projects ▪ Get funding for postgraduate students	▪ Postgraduate Programs Funding ▪ Programs/Researchers Evaluation * ▪ Research Results ▪ CONACYT R&D Funding
Head of the General Office for Postgraduate Studies	▪ Postgraduate programs inclusion into PNPC ▪ Get funding for postgraduate students	▪ Postgraduate Programs Funding ▪ Master's and Doctoral Postgraduates ▪ Programs/Researchers Evaluation * ▪ Research Results ▪ CONACYT R&D Funding
Directors and Directors of Postgraduate Programs	▪ New students enrolment in postgraduate programs ▪ Successful graduation of postgraduate students ▪ Postgraduate programs inclusion into PNPC	▪ Postgraduate Enrolment * ▪ Master's and Doctoral Postgraduates ▪ Programs/Researchers Evaluation * ▪ Research Results
Faculty	▪ Publishing in prestigious journals ▪ Get funding for developing research projects ▪ Postgraduate programs inclusion into PNPC	▪ Postgraduate Enrolment * ▪ Master's and Doctoral Postgraduates ▪ Programs/Researchers Evaluation * ▪ Research Results ▪ CONACYT R&D Funding
National Council for Science and Technology	▪ Furnishing funds for postgraduate students ▪ Successful graduation of postgraduate students	▪ Postgraduate Enrolment * ▪ Master's and Doctoral Postgraduates ▪ Postgraduate Programs Funding ▪ Programs/Researchers Evaluation * ▪ Research Results
Students	▪ Get funding for enrolment in postgraduate programs ▪ Successful graduation of postgraduate students	▪ Postgraduate Enrolment * ▪ Postgraduate Programs Funding ▪ Master's and Doctoral Postgraduates
Private Sector	▪ Knowledge/technology transfer ▪ Hiring postgraduate students	▪ Master's and Doctoral Postgraduates ▪ Appropiability/Opportunity Evaluation * ▪ Patenting ▪ Research Results

*Main sources of tension among actors.

The CLD in Fig. 1 shows the complexity of a higher education institution and the complexity of successful developing postgraduate programs (PNPC). As suggested, the case of postgraduate studies at UMSNH in Mexico is analysed in this paper. The CLD in this section is characterised by five reinforcing (positive) feedback loops and four balancing (negative) feedback loops. The loop R1 corresponds to the typical role played by universities and higher education institutions, namely training of qualified personnel and advancement of scientific knowledge [22]-[24]. This loop implies a positive relationship between Postgraduate Enrolment, Master and Doctoral Postgraduates, and Postgraduate Programs Funding. This loop is also characterised by a time delay between Postgraduate Enrolment and Master and Doctoral Postgraduates corresponding to the average time it takes to earn a postgraduate degree (2.5 years

in master programs and 4.5 years in doctoral programs).

The loops R2/B1 establish a positive/negative relationship between Postgraduate Enrolment, Master and Doctoral Postgraduates, and Programs/Researchers Evaluation by CONACYT. These loops are characterised by two time delays: a time delay between Postgraduate Enrolment and Master and Doctoral Postgraduates, and a time delay between Master and Doctoral Postgraduates and Programs/Researchers Evaluation by CONACYT (3.5 years average time in the case of postgraduate programs). It is worth saying that postgraduate programs are evaluated for being into the PNPC, a program administrated by CONACYT. However, the loop B1 turns positive as R2 due to a learning and adaptation process followed by postgraduate programs within the higher education system [1] [4]. In fact, this process corresponds to first and second levels of learning, namely learning for self-correction and learning for how to learn [18].

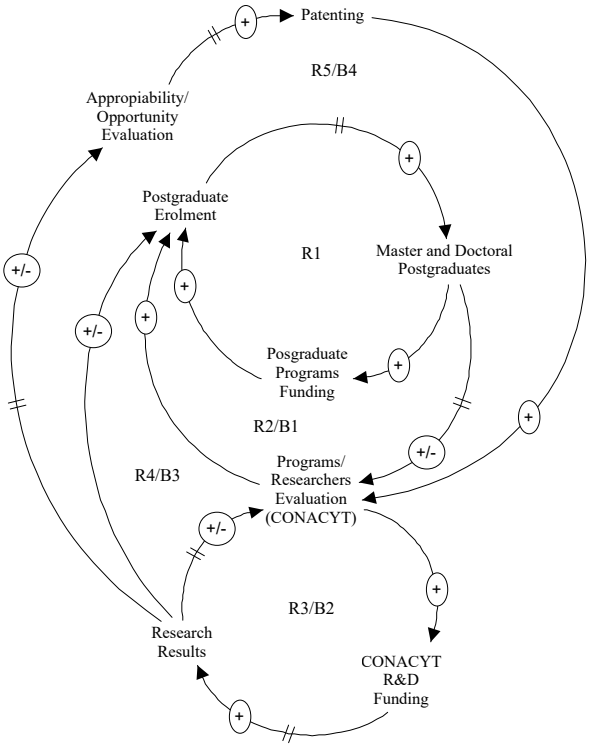

Fig. 1 A CLD of higher education institutions: The case of UMSNH

The loops R3/B2 show a relationship between Research Results, Programs/Researchers Evaluation by CONACYT, and CONACYT R&D Funding. These loops are also characterised by two time delays: A time delay between Research Results and Programs/Researchers Evaluation by CONACYT, and a time delay between CONACYT R&D Funding and Research Results (average time of 2 years) [32]. As in the case of the loops R2/B1, it is worth saying that researchers are evaluated every four years to remain as members of the National System of Researchers (Sistema Nacional de Investigadores, SNI). In the same way, the loop B2 turns positive as R3 due to the fact that researchers follow a process of learning and adaptation to remain into SNI (first and second levels of learning) [18]. Importantly, taking together the loops R1 and B2 (short-term), on the one hand, and the loops R2 and B2 (short-term), on the other, they show the behaviour that could be found in the Limits to Growth archetype.

The dynamic theory in this archetype suggests that continuing efforts will produce diminishing returns as one approaches the limits or a reinforcing process of accelerating growth will encounter a balancing process as the limit of the system is approached [5]. Particularly, in these cases, the loop B2, namely (poor) Research Results, (less) CONACYT R&D Funding, and (poor) Programs/Researchers Evaluation by CONACYT, could be slowing down or even blocking the efforts for further future growth. Moreover, the loops B1 and B2 (short-term) taken together demonstrate the behaviour that could be found in the Eroding Goals archetype. When there is a gap between a goal and a condition, the goal is lowered to close the gap deteriorating performance [5]. Also in this case, dynamic theory demonstrates that a gap between a goal and an actual condition can be resolved in two ways [5]: (i) by taking corrective action to achieve the goal, or (ii) by lowering the goal. Once again, in this case, (poor) Programs/Researchers Evaluation by CONACYT might be slowing down not only (poor) Research Results and (less) CONACYT R&D Funding, but also (less) Postgraduate Enrolment and thus (less) Master and Doctoral Postgraduates. Furthermore, the time delays between CONACYT R&D Funding and Research Results, and between Research Results and Programs/Researchers Evaluation by CONACYT, on the one hand, and Master and Doctoral Postgraduates and Programs/Researchers Evaluation by CONACYT could be worsening this condition and stressing the cyclical state that could be found in these loops. It is thus important to mention that in the case of postgraduate studies at UMSNH, the archetypes Limits to Growth and Eroding Goals demonstrate likely conditions for impeding future further growth of postgraduate programs. However, in order to push down the pressures implied by these archetypes, policy implications should be corresponding to the first and second levels of learning, namely learning for self-correction and learning for how to learn [18]. We will return to this issue in the next section.

The loops R4/B3 also demonstrate the importance of learning and adaptation of higher education institutions. Effectively, these loops show a relationship between Postgraduate Enrolment, Master and Doctoral Postgraduates, Programs/Researchers Evaluation by CONACYT, CONACYT R&D Funding, and Research Results. These loops show the importance of choosing prestigious programs when new students enrol in postgraduate programs (measured by the quality of research projects and research results achieved by researchers, availability of funding for students, and evaluation of postgraduate programs by CONACYT). However, these loops are characterised by three time delays: a time delay between Postgraduate Enrolment and Master´s and Doctoral Postgraduates (2.5 years in master's programs and 5 years in doctoral programs), a time delay between Master and Doctoral Postgraduates and Programs/Researches Evaluation

by CONACYT (3.5 years average time in the case of postgraduate programs), and a time delay between CONACYT R&D Funding and Research Results (average time of 2 years) [31]. Importantly, these loops show an overall perspective in terms of the attractiveness of postgraduate programs drawn for being well evaluated.

Finally, the loops R5/B4 aim to include firms in the analysis. The objective of firms is to access knowledge and technology transfer from higher education institutions and universities. These loops show a relationship between Research Results, Appropriability/Opportunity Evaluation, Patenting, Programs/Researchers Evaluation by CONACYT, and CONACYT R&D Funding. It is important to mention two important features in these loops. First, they demonstrate the every time more importance of supporting technology transfer mechanisms by CONACYT. Second, even if every time more actors are aware of the importance of technology transfer for universities and higher education institutions to industry, there are not still adequate mechanisms to support this practice. Actually, it is suggested in this paper that successful technology transfer practices should correspond to the third level of learning, namely seeing things differently, or learning as a corrective change in the system of sets of alternative or transformative change (second-order change) [18]. Importantly, this practice is not yet so extensive at higher education institutions and universities in Mexico. Moreover, a change in the mission paradigm at public universities in Mexico shall be a big challenge in order to become an entrepreneurial university. The mission of universities in this country should not be only training of qualified personnel and advancement of scientific knowledge, but the mission of entrepreneurial university. In this sense, for example, universities must be more involved in developing successful practices to transfer new knowledge and technology to firms, while companies must be involved in financing R&D research projects at universities. Clearly, this procedure may contribute to cut down the time delays for opportunity/appropriability evaluation and patenting. In fact, this procedure may contribute to advance learning for self-correction and how to learn to learning as a corrective change in the systems of sets of alternatives or transformative change (second-order change or seeing things differently) [18].

The structure of the system (actors and links) shows likely tensions that could be emerging from the behaviour (decisions) followed by each actor in the system [33]. From the perspective of the SD methods, for example, this is evident in the case of the relationships established between universities and industry [33].

The next section discusses the dynamics of the system in terms of short-term (B1–B4) and long-term (R2–R5) transformations and evolution. The main argument is that long-term transformations do not guarantee the advancement from the first and second levels of learning (learning for self-correction and learning for how to learn) to the third level of learning (learning as a corrective change in the systems of sets of alternatives or transformative change or second-order change) [18]. As stated before, transformative learning should be actually associated with deeper changes in terms of transforming educational systems [1].

B. Short-Term and Long-Term Trends in Postgraduate Studies at UMSNH

The CLD in this section allows establishing the conditions for analysing likely short-term and long-term trends in postgraduate studies at UMSNH. Short-term trends are characterised by several balancing feedback loops, while long-term trends are characterised by several reinforcing feedback loops (Table VII).

As already suggested in previous sections, in order to advance postgraduate programs, higher education institutions must transit from learning for self-correction and learning for how to learn (first-order change) to learning as a corrective or transformative change (second-order change). This means that the restrictions imposed by Limits to Growth and Eroding Goals should be overcome through applying adequate policies to reduce the tension emerging among actors in the system. On the one hand, correcting actions in Limits to Growth should be focused on removing the limit rather than continuing to drive the reinforcing process of growth, identifying potential balancing processes before they begin to affect growth, and identifying the links between the growth processes and limiting factors to determine ways to manage the balance between these two trends [5]. On the other hand, correcting actions in Eroding Goals may include anchoring goals to an external frame of reference, determining whether the drift in performance is the result of conflicts between stated goals, and establishing a clear transition plan from current reality to the goal [5].

TABLE VII
SHORT-TERM AND LONG-TERM TRENDS IN HIGHER EDUCATION IN MEXICO: THE CASE OF UMSNH

Term	Programs/Researchers Evaluation (CONACYT)		Postgraduate Enrolment
	Programs Evaluation	Researchers Evaluation	
Short-term	B1	B2	B3
Long-term	R2	R3	R4

C. Upcoming Challenges

UMSNH has been one of the most successful higher education institutions in developing postgraduate studies in Mexico. The accelerated rate for creating new master and doctoral programs of high quality at this institution may impose serious restrictions to continue growing postgraduate studies. In addition, postgraduate studies already recognised as PNPC impose additional restrictions to growing postgraduate studies. On the one hand, it is important to continue designing and opening new postgraduate programs according to social demands. On the other, the big challenge is to maintain and advance ready-made postgraduate programs in the PNPC.

VI. CONCLUSIONS

This paper contributed to get insight on postgraduate studies development at higher education institutions in Mexico. The analysis was developed through applying SD methods. The

theoretical framework in this research derived from the complex theory and the CASs approach. Results in this research suggested the possibility of finding some kind of restrictions to further develop postgraduate studies at UMSNH. These restrictions derived from tensions found between actors participating in the system. Indeed, this scheme opened up the possibility of implementing some alternative policies to overcome these restrictions. Certainly, these policies should be design in terms of short-term and long-term planning and implications.

Finally, further research on postgraduate studies at higher education institutions should include developing a simulation model to evaluate alternative policy scenarios. However, this kind of simulation models could be developed through applying SD methods.

ACKNOWLEDGMENTS

We are very grateful to Dr. Ireri Suazo for data released by the General Office for Postgraduate Programs – UMSNH. Professor Mario Gómez shows gratitude to Professor Aitor Ciaterra for hosting him as a Visiting Researcher at Universidad del País Vasco in Spain. Financial support from the National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACYT) in Mexico is gratefully acknowledged.

REFERENCES

[1] F. C. Bento, *Organizational Complexity: Leadership and Change in Research-Intensive Academic Departments*, Thesis Dissertation, Faculty of Social Sciences and Technology Management, Norwegian University of Science and Technology, 2013.

[2] I. P. McCarthy, "Technology management: A complex adaptive system approach", *International Journal of Technology Management*, Vol. 25, No. 8, pp. 728–745, 2003.

[3] I. P. McCarthy, C. Tsinopoulos, P. Allen, and C. Rose-Anderssen, "New product development as a complex adaptive system of decisions", *Journal of Product Innovation Management*, Vol. 23, No. 5, pp. 437–456, 2006.

[4] R. D. Stacey, "The science of complexity: An alternative perspective for strategic change processes", *Strategic Management Journal*, Vol. 16, No. 6, pp. 477-495, 1995.

[5] W. Braun, *The System Archetypes The Systems Modeling Workbook*, 2002.

[6] F. C. Bento, "The contribution of complexity theory to the study of departmental leadership in processes of organisational change in higher education", *International Journal of Complexity in Leadership and Management*, Vol. 1, No. 3, pp. 275-288, 2011.

[7] F. C. Bento, "A discussion about power relations and the concept of distributed leadership in higher education institutions", *The Open Education Journal*, Vol. 4, pp. 17-23, 2011.

[8] B. Oyo, and D. Williams "Re-conceptualisation of higher education quality management problems using feedback systems thinking", *International Journal of Management in Education*, Vol. 3, No. 3/4, pp. 220-233, 2009.

[9] N. Pandey, and V. Vedak, "Structural transformation of education for sustainable development", *International Journal of Environment and Sustainable Development*, Vol. 9, No. 1/2/3, pp. 3-15, 2010.

[10] P. L: Galbraith, "System dynamics and university management", *System Dynamics Review*, Vol. 14, No. 1, pp. 69-84, 1998.

[11] D. C. Chou, "Building a successful partnership in higher education institutions", *International Journal of Information Systems and Change Management*, Vol. 6, No. 1, pp. 84-97, 2012.

[12] E. W. Mainardes, J. M. Ferreira, and G. Tontini, "Creating a competitive advantage in higher education institutions: Proposal and test of a conceptual model", *International Journal of Management in Education*, Vol. 5, No. 2/3, pp. 145-168, 2011.

[13] E. Wolstenholme, "Using generic system archetypes to support thinking and modelling", *System Dynamics Review*, Vol. 20, No. 4, pp. 341-356, 2004.

[14] P. Senge, *La Quinta Disciplina: el Arte y la Práctica de la Organización Abierta al Aprendizaje*, Garnica, Buenos Aires/México/Santiago/Montevideo, 2008.

[15] R. D. Stacey, "Learning as an activity of interdependent people", *The Learning Organization*, Vol. 10, No. 6, pp. 325-331, 2003.

[16] J. W. Forrester, "Polices, decisions, and information sources for modelling", in J. D. W. Morecroft, & J. D. Sterman (Eds.) *Modeling for Learning Organizations*. Productivity Press, 1994.

[17] J. D. Sterman, *Business Dynamics*. McGraw-Hill/Irwin, 2000.

[18] G. Bateson, *Steps to An Ecology Mind. Chicago/London*, The University of Chicago Press, 1972.

[19] I. P. McCarthy, T.B. Lawrence, B. Wixted, & B. Gordon, "A multidimensional conceptualization of environmental velocity", *Academy of Management Review*, Vol. 35, No. 4, pp. 604-626, 2010.

[20] S. Sterling, "Higher education, sustainability, and the role of systemic learning", in P. Corcoran, & A. Wals (Eds.) *Higher Education and the Challenges of Sustainability: Problematic, Promise and Practice*, Kluwer, Dordrecht, 2004.

[21] R. K. Lester, "Universities, innovation, and the competitiveness of local economies: A summary report from the local innovation systems", Working Paper IPC-05-010, Industrial Performance Center, MIT, 2005.

[22] L. M. Branscomb, F. Kodama, & R. Florida, *Industrialization Knowledge*, The MIT Press, Boston, 1999.

[23] H. Etzkowitz, "The second academic revolution: The role of the research university in economic development", in S. E. Cozzens et al. (Eds.), *The Research System in Transition*, Dordrecht: Kluwer Academic Publisher, 1990.

[24] H. Etzkowitz, A. Webster, & P Healey, *Capitalizing Knowledge: New Intersections of Industry and Academia*, State University of New York Press, Albany, 1998.

[25] A. Hughes, "University-Industry Linkages and UK Scientific and Innovation Policy", Working Paper, Centre for Business Research, University of Cambridge, 2006.

[26] C. Nygaard, & C. Holtham, "The Need for Learning-Centred Higher Education". in C. Nygaard, & C. Holtham (Eds), *Understanding Learning-Centred Higher Education,* Frederiksberg: Copenhagen Business School Press, pp. 11-29, 2008.

[27] R. B. Barr, & J. Tagg, "From teaching to learning: A new paradigm for undergraduate education", *Change*, Vol. 27, No. 6, pp. 12-25, 1995.

[28] J. Biggs, *Teaching for Quality Learning at Universities*, Buckingham: Open University Press, 2003.

[29] J. M. Cabrera, M. Torres, M. Salinas, & L. M. Villalobos, "Diagnóstico de la formación de recursos humanos de alto nivel en México", in M. Serna, J. M. Cabrera, R. M. Pérez, & M. Salinas (Eds.) *Diagnóstico del Posgrado en México: Ocho Casos de Estudio*, Consejo Mexicano de Estudios de Posgrado, A. C., México City, 2013.

[30] WEF, The Global Competitiveness Report 2011-2012, World Economic Forum, 2012.

[31] M. Serna, & R. M. Pérez, "Diagnóstico del Posgrado en el Estado de Michoacán", in M. Serna, J. M. Cabrera, R. M. Pérez, & M. Salinas (Eds.) *Diagnóstico del Posgrado en México: Ocho Casos de Estudio*, Consejo Mexicano de Estudios de Posgrado, A. C., México City, 2013.

[32] J. C. Rodríguez, & M. Gómez, "Anchor tenants, technology transfer and regional innovation systems in emerging economies: a system dynamics approach", *International Journal of Transitions and Innovation Systems*, Vol. 2, No. 1, pp. 14-37, 2012.

[33] J. C. Rodríguez. *University-Industry Technology Transfer in Canada: An Analysis of Stakeholders' Performance Using System Dynamics.* Thesis Dissertation, École des Sciences de la Gestion, Université du Québec à Montréal (UQAM), 2010.