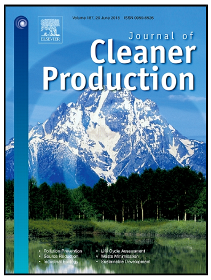

Applying Backcasting and System Dynamics Towards Sustainable Development: The Housing Planning Case for Low-Income Citizens in Brazil

Jorge Musse, Aline Sacchi Homrich, Renato de Mello, Marly M. Carvalho

PII:	S0959-6526(18)31255-1
DOI:	10.1016/j.jclepro.2018.04.219
Reference:	JCLP 12800
To appear in:	*Journal of Cleaner Production*
Received Date:	29 June 2017
Revised Date:	17 April 2018
Accepted Date:	24 April 2018

Please cite this article as: Jorge Musse, Aline Sacchi Homrich, Renato de Mello, Marly M. Carvalho, Applying Backcasting and System Dynamics Towards Sustainable Development: The Housing Planning Case for Low-Income Citizens in Brazil, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.04.219

Applying Backcasting and System Dynamics Towards Sustainable Development: The Housing Planning Case for Low-Income Citizens in Brazil

Jorge Musse[a], Aline Sacchi Homrich[b]*, Renato de Mello[a], and Marly M. Carvalho[b]

[a] *Industrial Technology Department - Santa Catarina State University (UDESC), Santa Catarina, Brazil*
[b] *Production Engineering Department - Polytechnic School University of São Paulo, São Paulo, Brazil*

*Corresponding author, E-mail: alinesacchihomrich@gmail.com. Address: Av. Profº Almeida Prado,128, Travessa 2, Bloco G 2, 2nd floor, Cidade Universitária Butantã - 05508900 - São Paulo, SP Brasil

Short biographical notes on all contributors:

Jorge de Oliveira Musse is a Professor at the State University of Santa Catarina (UDESC). He holds a PhD in Knowledge Engineering Management from the Federal University of Santa Catarina, a Masters in Mathematics from the Pontifical Catholic University of Rio de Janeiro and graduation in Mathematics from the University of Joinville. He collaborates as Extension Director of the Distance Education Center of UDESC. He can be reached at musse@udesc.br.

Aline Sacchi Homrich is a Doctoral Researcher in Production Engineering, at the University of São Paulo (USP). She holds a BSc in Mechanical Production Engineering and has an MSc in Lean Project/Service Management from the Mechanical Engineering Department of the Federal University of Santa Catarina. She has several years of experience in infrastructure projects. Currently, she collaborates as a doctoral researcher in the Industrial Engineering Department at the Polytechnic School of the University of São Paulo (USP), in Quality and Product Engineering (QEP) and in the Project Management Lab (LGP) at USP. Her main research themes are Sustainable Business Models in Product Service Systems, Circular Economy, Industrial Sustainability and Ecosystems and System Dynamics for Sustainability.
Corresponding author

Renato de Mello is a Professor at the State University of Santa Catarina (UDESC) in the Industrial Technology Department. He is the leader of a research group on fuzzy logic and simulation projects. He holds BSc in Civil Engineering and PhD in Environmental Engineering Sciences from the University of São Paulo, and MSc in Production Engineering from the Federal University of Santa Catarina, where he also carried out a Post-Doctoral Program. He has published a book and several articles in the area and can be reached at renato.mello@udesc.br.

Marly M. Carvalho is a Full Professor at the University of São Paulo (USP) in the Production Engineering Department of the Polytechnic School in Brazil. She is the coordinator of the Project Management Lab (http://www.pro.poli.usp.br/lgp) and Quality and Product Engineering (QEP) CNPq research group. She holds a BSc in Production Engineering from the University of São Paulo, and MSc and PhD degrees in the same area from the Federal University of Santa Catarina, and the Post-Doctoral Program at the Polytechnic of Milan. Marly has published 12 books and a number of articles in relevant journals and she can be contacted at marlymc@usp.br.

Acknowledgements:

The authors gratefully acknowledge the financial support of the Brazilian research funding agencies CNPq (National Council for Scientific and Technological Development), CAPES (Federal Agency for the Support and Improvement of Higher Education) and FAPESP (São Paulo Research Foundation).

Applying Backcasting and System Dynamics Towards Sustainable Development: The Housing Planning Case for Low-Income Citizens in Brazil

Abstract *This study presents a combined method of backcasting and system dynamics. It is designed to support complex decision-making that impacts sustainable development and involves multiple stakeholders. The study investigates the city housing planning problem for low-income citizens, specifically families with a monthly income that totals between one and three Brazilian minimum wages (from ca. 275 to 830 dollars). The case-based research encompasses modelling, simulation and stakeholder participation in the housing planning sector of the city of Florianopolis in Brazil. The simulation period was set between 2012 and 2030, using a backcasting approach. Three "desired future situations" were combined with three possible "future scenarios": optimistic, intermediate and pessimistic. The number of houses to be built in the given period were proposed based on the manifest variables and their interrelationships according to the expertise and tacit knowledge of the stakeholders. The results showed which variables were the most relevant influencers to reach a sustainable housing system for Florianópolis in 2030, considering the "desired future situations". The joint-approach modelling, between governmental institutions, researchers and those representing the community in a free, friendly front-end platform, enabled decision-makers to control and update the alternative scenarios and variables, under the conditions and time desired. The case represents a partnership between community, academia and government and fosters the application of new technologies to old social issues.*

Keywords: *Backcasting for sustainability; system dynamics; modelling and simulation; decision support systems.*

Highlights

- A multi-method approach was applied: a literature review and a four-step framework application in an illustrative case study.
- Main backcasting clusters and strategic orientations were identified with different backgrounds and geographic regions.
- Backcasting (BC) and system dynamics (SD) is further explained and explored in a low-income housing system in Brazil.
- The participatory backcasting approach and quantitative SD method represents a unique and useful experience of joint collaboration between government, resident associations, politicians and university researchers.

1 Introduction

In order to meet the need for sustainable development, in recent years, academics, government and experts from different sectors have been paying significant attention to the main strategic areas such as: urban and traffic planning (Soria-Lara and Banister, 2017; Robert, 2017), transport and emissions issues (Robèrt, 2017; Timms et al., 2014), energy and heating generation (Pereverza et al., 2017; Zivkovic et al., 2016), water issues (van Vliet and Kok, 2013; Loehman, 2014), agricultural production (Kanter et al., 2016; Gebhard et al., 2015), food waste (Ryan-Fogarty et al., 2017) and the environment (Sandstrom et al., 2016; Haslauer et al., 2016). In particular, one of the seventeen sustainable development goals (United Nations, 2015), Goal 11 (sustainable cities and communities) motivates the research in this paper.

Backcasting is a methodology that lends itself well to address such complex systems, and keeps track of the most essential elements of visions. According to Dreborg (1996), to be characterized as a backcasting study, the chosen scenarios must reflect the "wanted solutions" for a specific social problem. The approach starts by generating the desirable future idea, and then looks backwards to the present, to draw a path between the two (Robinson, 1990; Quist and Vergragt, 2006). Being mostly normative (Robinson, 1990) there are distinctive backcasting methods, applying both qualitative and quantitative methods. According to Dreborg (1996), this approach is preferable to the usual forecasting in the following situations: when the problem is complex affecting some sectors and society levels; when the change in activities is mandatory; when marginal changes inside the system are not enough, and when dominant trends are part of the problem.

The backcasting approach emerged in the 1970s and was applied in many different fields (Vergragt and Quist, 2011), e.g. in agriculture, heating, transports and water. In the 1980s, however, researchers began to take a more focused approachto backcasting as a way to design "desirable future visions" (Dreborg, 1996; Holmberg and Robert, 2000; Holmberg, 1998; Robinson, 1988; Robinson, 2003; Phdungsilp, 2011).These visions were to "collect and consider together the views of decision-makers, experts, and the general public on the future of the region" (Neuvonen and Ache, 2017), in order to build a stakeholders' network committed to the desired future.

System dynamics is a theoretical and practical method, most known from the late 1950s and 60s, of simulating future scenariosthat compliments the backcasting approach.

Complex and uncertain systems can be modelled to show their behaviours over the long term by using loops of feedback interactions. Mapping complex systems structures (Meadows et al., 2006; Forrester, 1971) enables the main drivers of decisions to be seen in the broader context by understanding them as part of a common and joint process. This then allows managers to foresee the consequences of decisions before making them and acting on them.

In addition, the 2030 agenda for sustainable development is worth noting. In this, world leaders adopted the New Urban Agenda for sustainable urban development, "rethinking the way we build, manage, and live in cities through drawing together cooperation with committed partners, relevant stakeholders, and urban actors at all levels of government as well as the civil society and private sector" (United Nations, 2016). Taking these words into account, the stakeholder perspectives are, therefore, critical for any studies.

As the United Nations (2016) points out, one of the common urban challenges is "a shortage of adequate housing and declining infrastructure". This paper, therefore, aims to contribute to potential solutions by answering two research questions (RQS) looking at a specific environment in Brazil. (RQ1) How can integrating multiple stakeholders in the housing planning problem draw a sustainable future vision for building houses for low-income families? (RQ2) Would applying backcasting and system dynamics, jointly, help to provide a solution to the housing issue, for the long-term future and taking into account uncertain complex systems?

Aligned to these questions, it must be mentioned that a well-regarded group of researchers proposed a participatory approach, called second order backcasting (Carlsson-Kanyama et al., 2008; Eames and Egmose, 2011; Eames et al., 2013; Robinson et al., 2011; Svenfelt et al., 2011; Wangel, 2011b), to include not only experts but also other stakeholders and citizens. Beyond the sustainability and social responsibility concepts (Ascher, 2007; Searcy, 2012; Elkington, 1997; Wangel, 2011a), participatory backcasting emphasize the process of social learning and the involvement of all actors in the process (Green and Vergragt, 2002). The research of this paper, therefore, also includes such an approach. Therefore, to address and answer the proposed questions (RQS), an illustrative case is reported using the city of Florianopolis in Brazil. A combined method of second order backcasting and system dynamics modelling was performed, through computer-aided simulation, to consider the issue of housing planning for low-income families and to support decisions aligned with urban sustainable development goals.

This research paper is structured in five parts. This first section gave the contextualization, aims and research questions. The second section discusses the concepts of backcasting and system dynamics in the most well-cited scientific publications. The third section describes the methodological approach used to develop the case study, followed by the fourth section which provides an illustrative case. The fifth section presents the discussion. The conclusions are given in the sixth section.

2 Literature Review

2.1 Sustainability oriented decision-making

Predominant planning and strategy approaches in complex systems traditionally deal with the state of systems in linear terms and do not always recognize the nature of the sustainable development process (Kajikawa, 2008). However, it can be argued that the most appropriate strategy for sustainable development is the creation of knowledge, provoked by the effective participation of stakeholders, managers and planners in these evolving processes (Broman and Robert, 2017).

Backcasting is considered a suitable approach as a planning tool for the service of an idea, situated in the future, which is intended to become a concrete fact (Quist and Tukker, 2013). A vision of the future expresses desires and dreams, and indicates needs or problems currently being faced, of a group, a community, a region or country. Backcasting allows such visions to be built step by step, in a participatory way, guided by the principles of sustainable development. It shows how present-day activities can be developed or altered in order to reach the desired outcomes in the future. However, to be effective, the approach must be systematically operationalized and guided because of the complexity of the issues involved (Neuvonen and Ache, 2017).

System dynamics, on the other hand, is a method, that uses modelling and simulation through identifying fundamental variables and their interrelations to create certain outcomes, according to the system characteristics (Akkermans and Dellaert, 2005). Therefore, decision-making with a sustainability-oriented approach may benefit from system dynamics to accelerate the process of knowledge creation.

Combining the knowledge of stakeholders from the relevant community, experts, researchers and governmental representatives allows the identification of ideas to help solve collective problems. This, in turn, influences social learning and the sum of the information learned needs to be shared among the decision-makers (Neuvonen and Ache, 2017; Dyer and Dyer, 2017). Therefore, governmental decision-makers need to be part of the process.

2.2 The backcasting approach

The predominant approaches to planning in strategic complex systems traditionally deal with governments that do not always recognize the nature of the sustainable development process (Dyer and Dyer, 2017). The creation of knowledge is, therefore, the most appropriate strategy for sustainable development (Mulder, 2014).

In this respect, backcasting is a tool that shows how future desired situations may become concrete facts. This future, however, must be built systematically, in a participatory way, guided by principles that ensure that different knowledge holders are guided to a common sustainable purpose (Broman and Robert, 2017).

According to Robinson (1990), the biggest distinguishing feature of backcasting is a concern, not with what futures can happen but how desirable futures can be achieved. It might be, therefore, explicitly normative, involving working backwards from a desirable future to the present. However, it can also be run as combinations of backcasting from normatively designed scenarios within robust boundary conditions, e.g. validated boundary conditions for any normatively developed scenario claimed to be sustainable (Broman and Robèrt,2017; Ny et al., 2006). The principles of decision are, then, not normative, whereas the plan to comply with them are. Börjeson et al. (2006) also state that normative scenarios are meant to answer "how a certain target can be reached" by preserving or transforming the current situation. To determine the viability of a particular future and what political measures would be required to reach that point, a scientific quantitative approach becomes mandatory (Hojer et al., 2008)in order to evaluate and improve scenarios and their feasibility and coherence to the defined target (Börjeson et al., 2006). The broadening of the concept of backcasting, so that alternative scenarios are contemplated, transforms the normative approach into a double challenge: to develop alternative scenarios and to know the relationships between variables that can provide optimum (economic, social and technical), sub-optimal, and progressive paths and those to be avoided (Hennicke, 2004; Dreborg, 2004). In recent history, a number of cases have been successfully performed. Appendix A presents a list of publications regarding these cases and also some suggested applications and scientific studies in many strategic sectors and countries.

The first author to use the term “backcasting” was Robinson (1982, 1988, 1990, 2003) in publications related to energy, concentrating on reviews of technical and economic potential. Until the 1990s, these types of studies had an academic approach (Robèrt, 2000); however, tools to perform sustainable development (e.g. adding boundary conditions for social and ecological sustainability)came after.. In this respect, three complementary backcasting methods may be highlighted, even though there are explicit overlaps among them.

The first method is described by Robinson in 2003. In this approach, social and economic criteria are set externally to the analysis.which concentrates on a social footprint and is more oriented to goals, policy, design and systems. The second method is the “Framework for Strategic Sustainable Development (FSSD)” (Broman et al., 2000; Broman and Robert, 2017), also known as The Natural Step (TNS). This departs from a natural-scientific angle and, instead, outlines basic and unifies principles designed as boundary-conditions for any sustainable scenario. It then pursues the social-processto reach its full development. The third approach is Sustainable Technology Development. This focuses on achieving sustainable futures by means of sustainable technologies (Phdungsilp, 2011).

Although named after distinctive influences and research projects, these approaches overlap in their aims: the reduction of consumption and emissions, the protection of biodiversity and ecosystems, the efficient use of resources, the social engagement of the community, and the necessary use of technological solutions in the long term. The realism of sustainability scenarios in the studies are intensely discussed, but generally the analysis is confined to technical feasibility, while social and economic feasibility is set aside. Currently, the multi-systemic concept of backcasting and sustainability mentioned by Kajikawa (2008) covers the environment, human well-being, equality, human development and the economy, and is primarily explained as a social goal or long-term objective.

Although the first generation of backcasting imposes regulatory conditions previously defined, the second generation allows the vision of the future to emerge as a product of the analysis and commitment process of society. This is the product of a social learning process, inherently open and unpredictable (Robinson, 2003). The stakeholder perspectives are, therefore, critical for these studies, which propose a participatory approach for backcasting, known as second order backcasting (Carlsson-Kanyama et al., 2008). The stakeholders should include experts government figures and citizens. The use of a set of different scenarios is a way to deal with uncertainty (Quist and Vergragt, 2006).

Hojer et al. (2008) state, however, that backcasting is forecasting dependent, considering that, without the various types of forecasts showing the problems that will arise if current trends continue in the future, it would be difficult to identify the changes needed to meet goals. Bagheri and Hjorth (2007) suggest that, in traditional modelling, a person or a group of specialists build the model and explains the results only to policy-makers. However, in order to integrate the learning process, it is necessary that all relevant stakeholders, as well as experts in analyses, are involved in the model-building process. Regarding this aspect, backcasting models should be able to target specific social problems and talk to non-experts to an unusual level (Robinson, 2003).

2.3 The system dynamics approach

As complexity and uncertainty are features of all social or environmental systems, sustainable development has to be treated within a systemic framework able to deal with these characteristics. So it is necessary to map the dynamic of the feedback structures (Bagheri and Hjorth, 2007). System dynamics applies mainly to the study of systems that are likely to change over time and that have feedback loops, processes in which an action performed by a component of the system will influence the whole system interaction affecting this component again (Maani and Cavana, 2000). The system dynamics method consists of mapping structures of complex systems, examining the interrelations of its elements and drivers (Forrester and Forrester, 1969, 1971), regarding more specifically the interactions of the feedback loops Some modelling and simulation programs are usually applied in this method (in this case, STELLA II®), as well as a long-term observation and historical data identification. The aim is to implement and evaluate effective cause-consequence relations in order to act on them. The quantitative aspect is usually one key-point to solve the specific looping issues.

Herein merges the approach of scenarios and modelling, as the "process" of building a model is always useful, because it generates new knowledge about the system, its components and the interactions between them. Thus, the modelling process, as a first step, can be even more important than the result (Bagheri and Hjorth, 2007). The modelling of complex systems is a fundamental instrument considered to perform system dynamics. Since sustainability strategies emphasize the social learning process and the involvement of all actors in the process, modelling must consider the stakeholders' participation under expert supervision. This first step is intensely researched in publications such as Ny et al. (2006), Holmberg and Robèrt (2000), Broman et al. (2000), Robèrt et al. (2002) and Broman and Robèrt (2017). The social dimension and the close involvement of the actors in scenario studies makes it easier for social innovations to emerge, even in areas where solutions are considered strictly technical. Some sustainability goals end up being more fruitfully pursued through social innovations than through technical or physical changes (Wangel, 2011a).

System dynamics allows the understanding of changes in system behaviours over time. In real life, behaviour problems are analysed in a linear fashion. First there is an action and, after some time, the result of this action, and the analyses correspond to the moment of conclusion (Forrester, 1958). System planning over longer periods of time generates the need to anticipate scenarios, where aspects may not be able to be controlled. These include (i) the system: a set of elements that interact continuously over time to form a unified whole; (ii) the dynamic: referring to variables that are constantly changing over time; (iii) structures of the system: relations and connections between the elements of the system; (iv) system behaviour: the way these elements vary over time.

Another fundamental component of system dynamics is simulation. This allows the manager to foresee consequences of a decision and to rearrange actions before acting. This, then, means working with a new way of thinking, with new tools and new parameters (intangibility and uncertainty). The origin of this modelling process is in a problem or a necessity felt by the community, such as references to place, local resources or the lack of them, or even culture and beliefs. This shared construction concept substitutes interrelations for integration. It substitutes global for differential, distinguishing essential from accessory.

In addition to its obvious advantages in terms of time and trial-and-error processes, system dynamics contributes considerably to social learning, as previously mentioned, especially among the members of groups not used to the language of specialists – their use of formulas or technical jargon. System dynamics makes the acceleration of knowledge creation possible through its inherent characteristic of simulation.

2.4. Backcasting and system dynamics – decision-making to sustainability

The proposed method combines the backcasting approach with systems dynamics to create knowledge in complex systems for decision-making. This, according to Bagheri and Hjorth (2007), involves social learning processes that result in adaptive responses to validated boundary conditions of sustainability as well as uncertainties about the best ways to comply with such boundary conditions.

The backcasting approach identified by the authors to arrange this combination properly was the "funnel metaphor and the ABCD-procedure of the FSSD" (Broman and Robèrt, 2017). Detailed steps performed to use backcasting with system dynamics are shown in Appendix B. The core contribution of this combinationis the proposal of scenarios via the backcasting approach and the proposal of quantitative decisions via the system dynamics method, that is, the modelling and simulation of the main variables.

This process is based on a set of tools usually applied in group dynamics. In addition to having formal knowledge experts to clarify issues regarding the subject or problem, group dynamics presentations stimulate the participants and stakeholders to express themselves and expose their tacit knowledge. According to Forrester (1958), the wealth of information that is inside each mind can be accessed through group discussion.. Changes caused by discussion then enrich the group learning process, providing greater and clearer explanations to expand the knowledge required for decision-making.

System dynamics combined with backcasting weresuitable methods for this study They enabled theory to be combined with reality. They allowed the, simulation of actions to be taken over the long term and took into account the complexities and uncertainties of the housing system sector of a municipality. Although the systemic view of complex problems has already been studied and published previously by authors such as Ny et al. (2006), Gaziulusoy et al. (2013) and Broman and Robèrt (2017), there have only been two published cases using the system dynamic method with real simulation examples for sustainable futures backcasting: the transport sector (Schade and Schade, 2005) and the urban water system application (Bagheri and Hjorth, 2007). This research application in the low-income housing system in Brazil is another piece of information to emphasize the importance and the relevance of such contributions.

3 Research Methods

This study explores the intersection between backcasting and system dynamics through a combination of the literature review and simulation. This follows an increasing trend of applying multi-methodological research in operations management (Singhal and Singhal, 2012a; Singhal and Singhal, 2012b) in order to mitigate the weaknesses of any one method. The systematic literature review is used for the framework proposal for this research, and, then, an illustrative case study is employed to investigate the challenges of the framework application.

3.1. Systematic literature review and conceptual framework

The systematic literature review was performed using transparent and replicable procedures (Miguel, 2007; Littell et al., 2008), in three steps, as suggested by Tranfield et al. (2003): data collection, data analysis and synthesis. Bibliometric and content analysis were also performed, as suggested by Carvalho et al. (2013).

The survey of published articles was conducted on the main academic databases until January 2018, using the ISI Web of Science platform, including only indexed journals with a calculated impact factor in the JCR (Journal Citation Report). The systematic literature review was performed in two rounds (Table 1), with no restrictions regarding academic subjects, journals or publication dates (please note that the symbol (*) includes any variation of the word).

Table 1: Selection Criteria: Systematic Literature Review Search Strings

Rounds	*Search Strings*	*Results*
1 - from Web of Science Core Collection	**TOPIC:** (backcasting) *AND* **TOPIC:** (sustainability or "sustainable development" or "triple bottom line" or social or environment*) **Refined by: DOCUMENT TYPES:** (ARTICLE OR REVIEW) **Timespan:** All years. **Indexes:** SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH.	143
2 - from Web of Science Core Collection	**TOPIC:** (backcasting) *AND* **TOPIC:** (sustainability or "sustainable development" or "triple bottom line" or social or environment*) *AND* **TOPIC:** ("system dynamic*") **Refined by: DOCUMENT TYPES:** (ARTICLE) **Timespan:** All years. **Indexes:** SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH.	2

The selection criteria resulted in 143 articles in the sample; from these, only two referred to the term "system dynamics". With the article sample chosen, the descriptive statistic offers an overview of the publications regarding aspects such as yearly distribution of the number of publications (Figure 1), most relevant journals (Figure 2) and most cited papers (Figure 3).

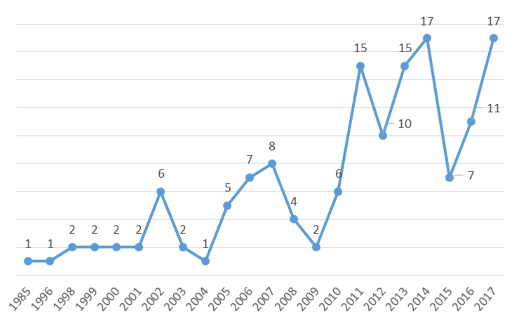

Figure 1: Number of Publications per Year

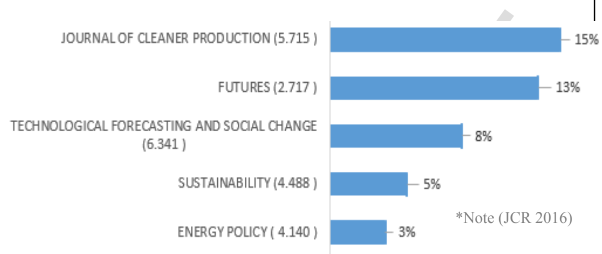

Figure 2: Main Journals of the Article Sample (at Least 5 Articles Published)

From the total sample, the largest numbers of publications belong to the *Journal of Cleaner Production*, *Futures*, *Technological Forecasting and Social Change*, *Sustainability and Energy Policy*, totalling 45% of the articles. The most cited articles are presented in Figure 3. This group represents 57% (1,859 citations) of the total amount of citations.

Figure 3 identifies the relevance level of papers through yearly citations between 1996 and 2017. However, the first paper of the selected sample was published in 1985. There is an evident contribution from the authors Robèrt et al. (2002), Dreborg (1996), Gleick (1998), Robinson (2003), Quist and Vergragt (2006) and Holmberg and Robèrt (2000). These authors maintain their relevance. Ny et al. (2006) seem to be gaining more relevance recently, regarding their focus theme: sustainability constraints to making life-cycle management strategic. On the other hand, Hertwich (2005), who also deals with sustainable consumption and life-cycle approaches, seems to be decreasing in relevance. From this group, only citations from Bagheri and Hjorth (2007) are related to system dynamics.

From the recent most relevant articles presented in Figure 3, identified by the average citation graph (line – scale to the right), a comparison of their total citations was added (columns – scale to the left).

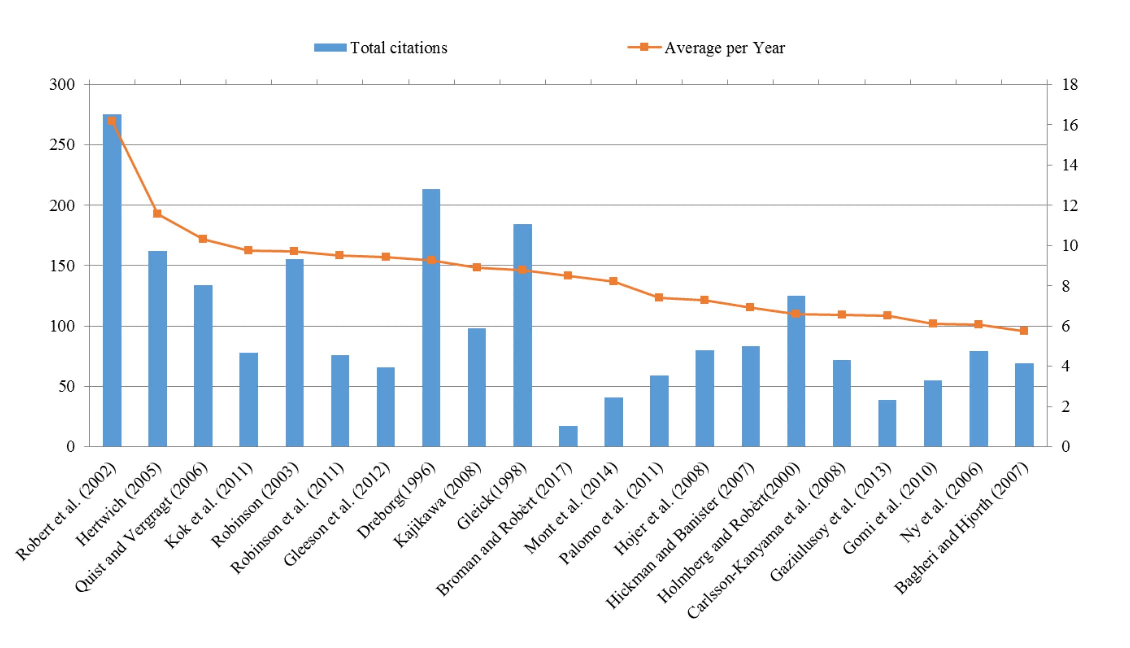

Figure 3: Most Relevant Articles in the Sample by Number of Average Citations per Year and Total Citations

Most of these papers were referred to in Section 2, as they are tightly connected to the main theme of this paper: the participatory backcasting approach leading to the development of more sustainable futures, using case study examples and applied to highly complex social issues. One article, in particular, must be highlighted: the paper from Broman and Robèrt (2017), despite being extremely recent, has an impressive average citation per year (see Figure 3). It consists of a reflection and further evolution of a 25-year learning process between scientists and practitioners on the Framework for Strategic Sustainable Development (FSSD).

In the next step, the network analysis uses the bibliometric software Sitkis (Schildt, 2002), with support of UCINET and NetDraw (Borgatti et al., 2002), to show the main keywords used by this article sample and their interrelation; for example, it shows the keywords systematically together, which provides an encompassing overview of the literature on backcasting and sustainability (Figure 4).

Most of the keywords are connected to strategic social issues, such as: cities, transport, energy, policy, innovation, technology, future and transition. Another aspect is the connection with the methods used to perform the backcasting approach evidenced by the words: framework, stakeholder participation, scenario, forecasting, systems and methodology.

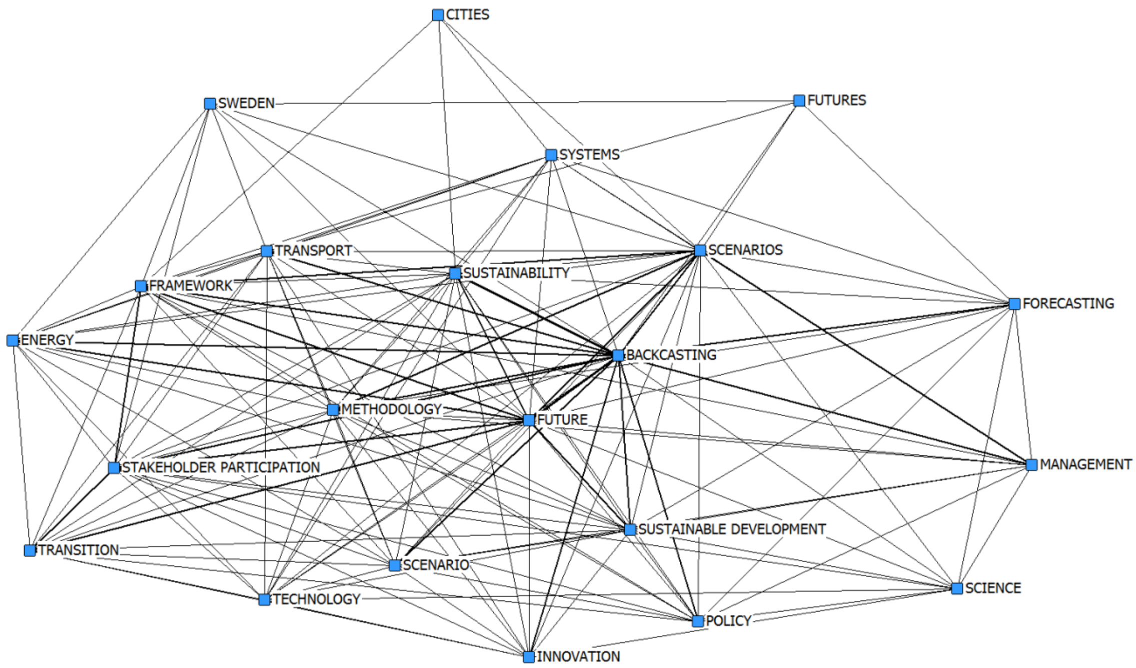

Figure 4: Backcasting and Sustainability Sample Keywords Network

** Note: The size of the lines represents the intensity of the relationships between the keywords, in terms of the number of times the keywords are used in the same article.*

The systematic literature review sheds light on the distinctive approaches. Based on this theoretical background discussed in Section 2, the proposed framework combines backcasting with system dynamics (see Appendix B). The literature stressed backcasting as a suitable approach to the definition of public policies in the social area. The FSSD and the so-called ABCD-procedure was then applied with the aim to build pathways using dynamic programming, while ensuring stakeholders participation to reach a shared vision, the variables definition, and prioritization. The four-step framework combines the strengths of the two approaches, simulating actions to be taken over the long term planning, through second generation backcasting, which allows stronger stakeholders engagement and commitment to make possible a common vision of the future to emerge.

. Although there are some overlaps in approaches, a *four-step* conceptual framework integrating literature streams was developed: step 1: stakeholders' strategic orientation to the problem; step 2: building up scenarios for sustainable futures; step 3: backcasting: creating sustainable alternatives; step 4: action plan monitoring. Appendix B summarizes the *four-step* framework and the alignments with the core studies in which each step was grounded. The articles with system dynamics applications, modelling and simulations were particularly important in combining backcasting and system dynamics for sustainability application, as suggested by Robinson (1982, 1990), Bagheri and Hjorth, (2007) and Schade and Schade (2005).

3.2. Illustrative case study

As suggested by Voss et al. (2002), the starting point was the conceptual framework developed to operationalize the key variables and to structure the research protocol (see Appendix B). Then, an illustrative case was conducted, mixing qualitative and quantitative data.

The case selection criteria were the need of house demands modelling, related to low-income communities in the city housing system, considering slum formation mitigation, access to the key stakeholders and data availability. The case was performed using the municipality of Florianópolis, an island in Brazil of 436,5 km ^{2}. It has one of the highest human development indices (HDI) in the country, 0.875 according to the UNDP (2000), but suffers from the effects of disordered urban growth. The housing planning sector of this municipality fitted the case selection criteria.

As suggested by Breukers et al. (2014), “in contrast to systems research where the researcher defines system boundaries, the dialogue allowed system boundaries to be defined along the process in a bottom-up manner”. The triangulation of the backcasting approach and system dynamics, using both historic and participatory methods, was applied. The boundaries of the model contained the aspects of family income, geography, housing construction systems, population dynamics, demand dynamics and costs. The designed system also considered the aspects of economic dynamics, housing policies, control policies and house obsolescence problems. Due to governance issues, the system boundaries did not include some aspects of the whole system, such as, for instance, solving the low-income problem through better education or other measures. Instead, the system focused on sustainability problems arising in the housing planning of the municipality, in order to discuss economic issues and their effectiveness in the creation of ecologically sustainable environments. The research also focused on the segment of population composed of families with a monthly income up to three Brazilian minimum wages (R$ 2,860.00 – US$ 830, in 2018), without financial autonomy, dependent on public housing programmes and subject to irregular housing on wasteland. The period for the project execution ran from 2010 to 2030. As suggested by Eames and McDowall

(2010), the research employed a participatory expert stakeholder-led methodology, building on a set of transition scenarios. System dynamics modelling used Stella® software. For the simulation, future normative scenarios of *optimistic*, *intermediate* and *pessimistic* perspectives in annual intervals over a 30-year period were applied.

Several sources of evidence were applied and multiple stakeholders were included. The ABCD-procedure supported the execution of backcasting for co-creation. This procedure encompassed the step A (participants learn about the challenge and opportunities), step B (participants analyze the current situation), step C (participants identify possible solutions), and step D (participants prioritize among the possible solutions) (Broman and Robèrt, 2017).

The participants of the case study were informed of this methodology in advance of the social process,by the *Valora* group, which was composed of four lecturers/scientists from the State University of Santa Catarina (UDESC), an expert from the Brazilian Institute of Geography and Statistics (IBGE) and an expert from the Brazilian Institute of Environmental and Natural Resources (IBAMA). This group was in charge of organizing the stakeholders' participation in every step of the framework. It counted with the partnership of the "Social Observatory of Florianópolis - SOF" (to which our senior researcher was the president at the time of the study). SOF is one of the main influencers in the area of low-income housing policies and exists to monitor public management and social demands, also serving as a link between community interests and public power, having no political partisan character, representative of business interests or social classes (http://florianopolis.osbrasil.org.br/).

While Valora group was concentrated on the four-step framework implementation, including SD modelling, the Social Observatory of Florianópolis was the institutional environment where the stakeholders' panels took place, mainly by consulting their expectations regarding the public policies of the housing sector. Then, future scenarios were drawn based on these panels and used as input to scenarios modelling and feedback. In addition, six other participants from governmental and non-governmental organizations (NGOs), representing the policy-makers' and the communities' representatives also took part of the activities' committee.

4 Results

Appendix B details the four-step framework and the main references for each step. This framework has been carried out as an iterative learning process with the stakeholders presented in Section 3.2.

4.1. Step 1: Stakeholders' strategic orientation to the problem

This step was led by the Valora group with the "Social Observatory of Florianópolis" as explained in Section 3.2.

To accomplish this first step, the project leader alerted and levelled the knowledge of participants to the principles of sustainability, major social and technological trends, possible or future events, impacts on culture and in society structure, among others. Power-point presentations and brainstorming sessions were used to encourage each participant to contribute their expert knowledge. The dynamics of previous cases were explained by government participants. After this first series of workshops, discussions lasted for at least three months.

The boundaries of the model presented in Section 3 were defined in a participatory way by these stakeholders, through in-depth discussions carried out in two groups and consolidated in a final forum. The project leader subdivided the participants into two working groups according to the personal abilities of the team; at least one expert was allocated in each group.

The first group, called Group A, took responsibility for studying and knowing the economic and technological characteristics that affect the main housing planning system, based on the principles of sustainable development. The second group, called Group B, was responsible for the studies related to the political, social, cultural and environmental characteristics related to the studied programme, also based on the principles of sustainable development. To accomplish their goals, each group used distinctive methodologies, researches and tools to share acquired data. Brainstorming, consensus building, Delphi, illustrations diagrams and learning in practice (a series of visits to specific areas) were performed. After one month of intense preparation, the two groups regrouped and shared the learning obtained through systematic power-point presentations to all the participants and also to interested parties of the city hall.

In addition to these participatory stakeholder dynamics, a significant survey on data related to the model was performed. The data gathered by the experts are summarized in Appendix D (I and II). The majority of Florianópolis families with an income of up to three minimum wages live in "*areas of social interest*" (Miranda, 2008). These are defined as being partially, or totally, deprived of public services whether owing to the absence or the great difficulty of access to areas, such as day-care centres, health posts, public safety, buses and schools. Moreover, most of these areas are unsuitable for housing because they are subject to flooding, liable to landslides and present poor infrastructure.

Habitar Brasil Program (BID-HBB) indicate that there are more than 13,000 dwellings and more than 51,000 inhabitants living in areas of social interest in Florianópolis (Alvez, 2008) as shown in Appendix C. Moreover, the number of social interest areas increased from 40 to 64, in the period from 1987 to 2007 (Miranda, 2008). However, it should be noted that the poorest population in the city is predominantly concentrated in the central areas, closer to jobs and services (see Table 2). Taking into account the municipality of Florianópolis, by sharing the number of inhabitants, 342,315, by the number of resident families, 108,456 (Appendix D-II), we obtain the figure 3,15626, which is the average number of inhabitants per family.

The housing demand for these families is close to 80% (21.169/26.966) (see Table 2). These families are presumed to be living at that moment in unsuitable, unsustainable and high-risk areas. According to an IBGE (2010) survey on housing shortages in Florianópolis, 5,530 households were built in slums or similar.

Table 2: Population Projection, Number of Households, Households' Number, Households with Monthly Incomes of up to 3 MW, Households of Families with Monthly Income of up to 3 MW, Own Housing, Social Housing, Subnormal Housing and Demand for Housing for these Families in the Municipality of Florianópolis (2010–2030)

Year	**2010**	**2030**
Florianópolis population and population projection	455,143	654,726
Number of Families (Population / Avg. family components = 3,15626)	144,203	207,437
number of Households (95,741% of families Nº)	138,061	198,602
Families with up to 3 MW monthly income (18,7% of families nº)	26,966	38,791
Families households up to 3MW monthly income (14% of households n°)	19,328	27,804
Own housing of families of up to 3 MW of monthly income (10% of families' households with until 3MW of monthly income nº)	1,932	2,780
Social housing of families of up to 3 MW of monthly income (20% of families' households with until 3MW of monthly income nº)	3,865	5,560
Subnormal housing of families of up to 3 MW of monthly income (70% of families' households with until 3MW of monthly income nº)	13,531	19,464
Household demand from families with monthly income of up to 3 MW (families with monthly income of up to 3 MW – own households of families with monthly income of up to 3 MW – social housing of families with monthly income of up to 3 MW)	21,169	30,451

Source: IBGE (2001).

Based on the discussion of the data and on information about the resident population in the municipality of Florianópolis (Appendix D-I and II) shared with the stakeholder participants, it was decided to limit the analysis to families with a monthly income of up to three minimum wages. That is, for the purpose of modelling the housing system, this selection criterion was chosen because, in this sample, most families were found not to have decent housing.

The real situation of the housing deficit for the families in Florianópolis was the result of this first method step. The high demand for housing related to families with monthly incomes of up to three minimum wages was evidenced in the necessity of the housing planning sector..

4.2 Step 2: Backcasting – building up scenarios for sustainable futures

The next meetings occurred twice a month over four months and the whole group discussed solutions to reduce the high housing demands for the selected families. Data on the behaviour of the national and world economy and its projection for the next 20 years were also taken into consideration to build three desired progressive future scenarios: *pessimistic*, *intermediate* and *optimistic*. The definition of these scenarios regarded the situation prevailing in the housing policy. They focused, therefore, on establishing which macro-variables (social-environmental-economic) would influence these scenarios and how these relationships would happen.

The stakeholders' perceptions were sought though participatory backcasting and scenario building. In these meetings, the core variables were discussed, based on the decision regarding boundaries made in step 1, resulting in the development of three archetypal guiding visions, *pessimistic, intermediate* and *optimistic.*

In the *pessimistic* scenario, the world economy is stable; the national public policy of housing financing has no concerns related to the high index of housing deficit for low-income families; and there is an omission of the inspection bodies for the irregular occupation of unsuitable areas for housing. In the *intermediate* scenario, the world economy is slightly increasing, with small fluctuations; the national housing financing public policy is concerned with the high housing deficit ratio for low-income families; and there is a non-strict control policy regarding irregular housing construction and occupation of unsuitable areas. Finally, in the *optimistic* scenario, the world and national economy is in full growth; the national housing financing public policy aims at a significant reduction of the housing deficit for low-income families; there is an increasing control policy regarding the irregular housing construction and occupation of unsuitable areas. (see Appendix D-III)

The result from the explicit formulation of knowledge led to the definition of sustainable desirable futures for the housing problem (step 2). The potential knowledge dissemination and the learning process achieved by the participants led to another brainstorming meeting held with the assistance of experts. The aim was to identify new emergent variables and dependency relationships among them. The definition of these variables and their interrelations were fundamental for the next (third) step: the process of the creation and simulation of the system modelling, according to system dynamics (SD).

During the last meeting of step 2, before the elaboration of a detailed model for simulation among the participants of the *Valora* group, there were many suggestions of variables to be taken into consideration. Some were discarded after discussion and analysis, but those approved by the group went through a new round of discussion and in-depth analysis, in order to establish their possible interrelationships. The more reliable the variables choice and their interrelationships, the better the system simulation and, consequently, the better the data availability to the city managers.

4.2.1 Specific data – step 2: The case of the Florianópolis housing system

All members of the group agreed that the "desired future 1" to be a situation slightly better than the current demand (78.5%), so this scenario (*pessimistic*) was decided to have a housing demand of 70% in 2030. There was also consensus on the definition of the *intermediate* "desired future 2" (housing demand of 45% in 2030) and the "desired future 3"– *optimistic* (housing demand of 20% in 2030). After the presentation and discussion, it was agreed to work with the following main variables: economy, housing policy, control policy and rate of housing obsolescence. The cost per housing taken into consideration was approximately U$ 6,900.00 (the Basic Unit Cost – CUB for popular houses in Santa Catarina in the Social Interest Program (PIS) in July 2010 was U$ 203.50 multiplied by the minimum housing area, which is 34 m^2). Another consideration was the average monthly cost per inspector contracted by the municipality government, to control unsuitable areas for housing, estimated at U$ 1,900.00 (salary per month).

Regarding the rate of housing obsolescence, it was considered that there might be a reduction through the collapse or demolition of existing houses during the next 20 years. Another key factor also considered was that, owing to the enormous deficit in family housing, the application of emergency financial resources might become necessary.

4.3 Step 3: Backcasting and SD – creating sustainable alternatives through looping simulation

At this stage, the participants, led by the project leader, organized the modelling proposals formatted in the previous stage. This would express the consensus and guide the action programme to the solution. In this case, nine sectors were considered to structure the modelling and a simulation solution with their respective 48 variables and interrelationships. With the efforts of the group's experts and after many rounds of model tests, in-depth analyses and simulation tests, the housing planning system for families with a monthly income of up to three minimum wages was approved. The decision came about naturally, since the process of constructing the plan to solve the housing demand of these families was developed from the beginning on a shared basis, creating and disseminating knowledge, transforming the activities of the group members into a social learning process.

4.3.1 Specific data – step 3: The case of the Florianópolis housing system

To structure the modelling for simulation, based on system dynamics principles, the solution for the housing system was designed into nine sectors (see Table 3).

Table 3: Sectors for System Dynamics Modelling

1. *OwnHousing Construction Sector*	housing built by private initiative and acquired by families define the variable Own-Housing, base for the Own-Housing Construction Sector;
2. *Social-Housing Construction Sector*	housing built through government initiative and donated to families define the Social-Housing Variable, the basis for the Social-Housing Construction Sector; The public financing policy of housing is another variable that interact within these two sectors, and is related to the behaviour of the national and world economy, the demand for housing, housing obsolescence and emergency housing construction;
3. *Subnormal-Housing Construction Sector*	provides the number of families living in sub-standard housing. The Subnormal Variable indicates the number of dwellings built in areas not allowed by the government This variable is directly related to the areas of social interest inspection policy and to the housing demand;
4. *Population-Dynamic Sector*	provides the number of families with monthly income of up to three minimum wages, related variables: population rate of these families, the population of Florianópolis and the number of families with incomes of up to three minimum wages;
5. *Demand Dynamic Sector*	defines the housing need for these families during the period, determined by the difference between the population and the amount of Own-Housing and Social-Housing;
6. *Housing Cost Dynamic and Control Cost Dynamic Sector*	calculates the value that should be invested in the housing construction as well as determines the cost to be applied to control the areas subject to subnormal housing construction. This variables sector is related to the cost of popular housing, the inspectors' salaries (technicians of the city hall), the amount of housing built and the areas of social interest inspection policy;
7. *Family Demand Dynamic Relationship Sector*	is the result between the demand of housesshared bythe number of families, monitors the behaviour of the relationship variation;
8. *Subnormal-Housing and Demand Dynamic Relationship Sector*	describes the relationship between the number of subnormal houses and the corresponding value of housing demand;
9. *Subnormal-Housing and Families Dynamic Relationship Sector*	is responsible for the relationship between the number of subnormal houses and the number of families with a monthly income of up to three minimum wages

Source: *Valora* Group Workshop

These last three sectors provide a quick view, through tables or graphs, of the variation between the demand for housing, the number of families studied and the amount of houses in areas of social interest.

Since the system dynamics method was performed with software STELLA II®, as a tool, three mechanisms could be used to input data and perform the variables analysis: *(a) Data Control Panel*, (Figure 5) containing the options *(b)* and *(c)* as follows. This is the *front-end interface* in which the cityhall housing planning managers input the data and deal with the variables, according to the future vision desired; *(b) Input List Device,* responsible for the input of the variables: own housing and social housing; *(c) Graphical Input Device*, responsible for the definition of the representative graphs for: Economic Behaviour (GNP); Florianopolis population; Population Rate with income of up to 3MW; Own-Housing Financing Policy; Own-Housing Obsolescence Rate; Social-Housing Behaviour, Social-Housing Financing Policy; Social-Housing Obsolescence Rate; Area Control Behaviour; Own-Housing Emergency Factor; Limit Own-Housing Construction; Social-Housing Emergency Factorand Limit Social-Housing Construction.

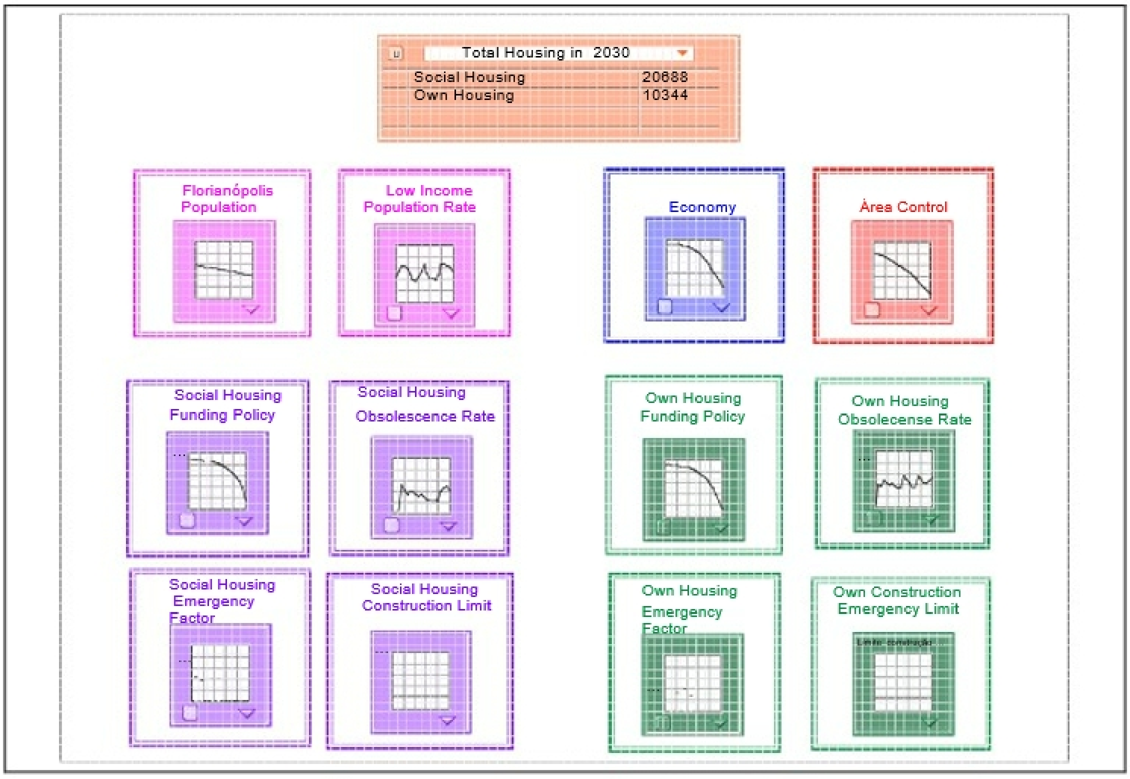

Figure 5: *Front-End Interface* – Data Control Panel

Source: Author with STELLA II® Software

Owing to limitations of space, only the SD modelling of three sectors are being presented, because they represent the core contribution of this illustrative case in the housing system of Florianópolis, namely: *Own-Housing Construction Sector* (Figure 6) and *Social-Housing Construction Sector* (Figure 7) and *Housing Cost Dynamic – Control Cost DynamicSector* (Figure 8).

The *Own-Housing Construction Sector* (Figure 6) and *Social-Housing Construction Sector* are responsible for the housing quantification (Figure 7).

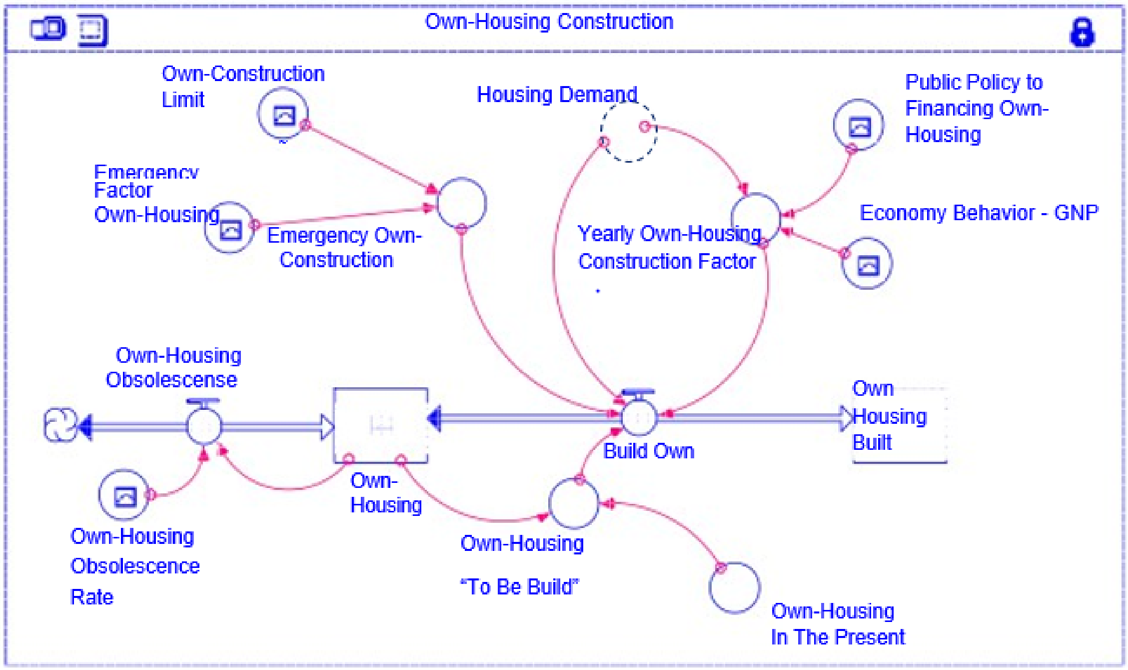

Figure 6: *(Housing System) Own-Housing Constructions*
Source: Author with Software STELLA II

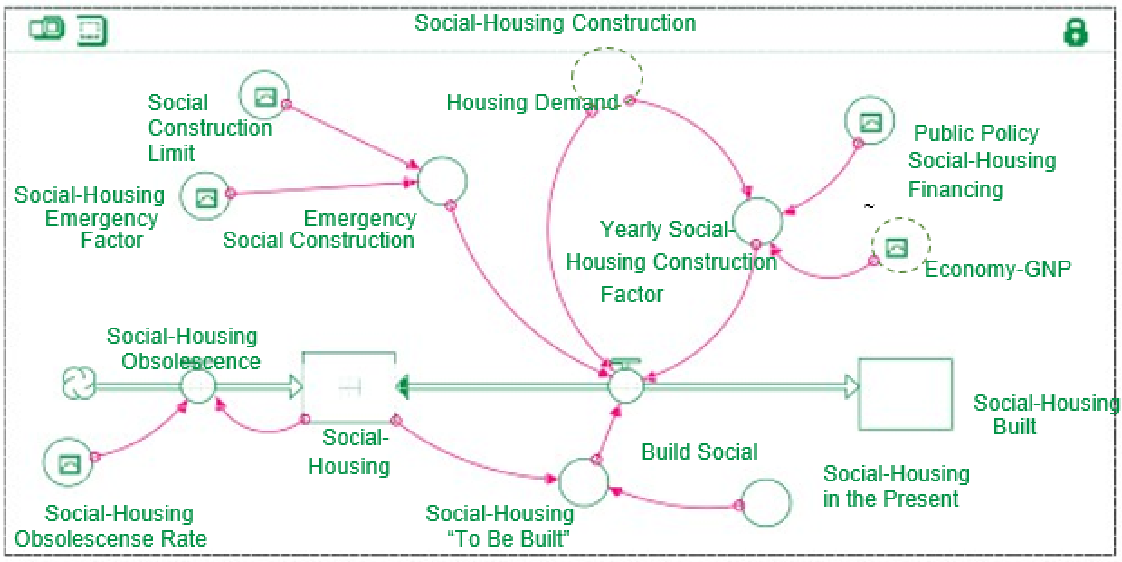

Figure 7: *(Housing System) Social-Housing Constructions*
Source: Author with Software STELLA II

The *Housing Cost Dynamic – Control Cost Dynamic Sector* (Figure 8) shows how to calculate the value that should be invested in housing construction and also determines the costs to be applied to control the areas subject to subnormal housing construction.

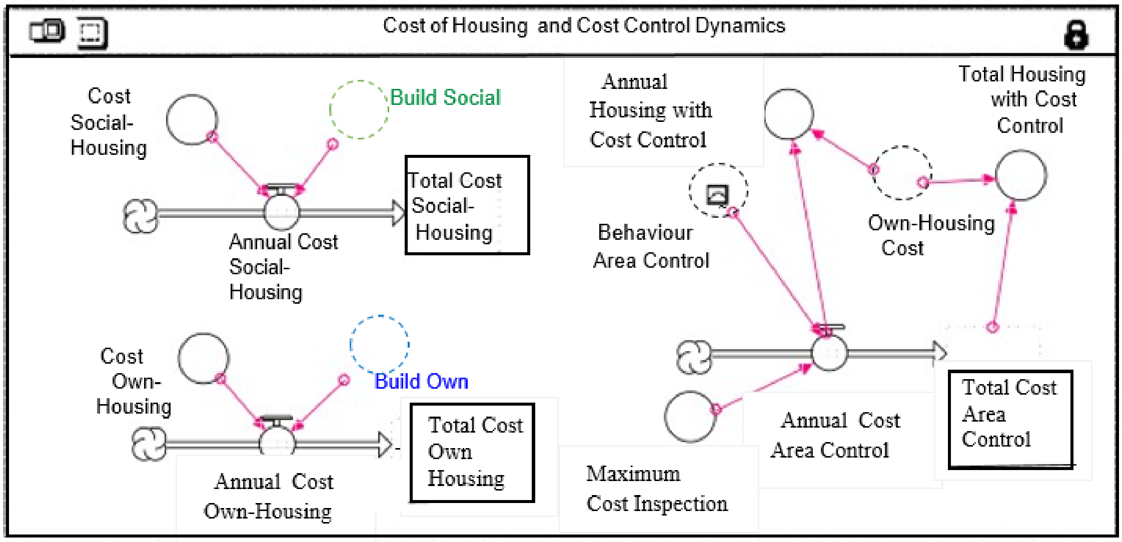

Figure 8 (Housing System) Dynamics: Cost of Housing and Cost Control
Source: Author with Software STELLA II®

Each variable had a coupled rate so that the model calibration requires parallel solutions based on forecasting, because the system looks for *intermediate* scenarios and paths that do not yet exist. The alternative found was to make forecasting models for short periods, so that it was possible to verify conditions of stability and to obtain plausible scenarios. Inputs from stakeholders were established in panels where representatives from the policy-makers and from the communities sent their views on how variables and aspects of future scenarios could behave. Face-to-face, online meetings and group message contacts were held, structuring the panels of the representatives.

The modelling simulation overview of variables (Appendix D-III) shows the scenario defined as *optimistic*. For each scenario the three hypotheses defined for future own housing demand was considered, namely: desired future 1 – 70% own-housing demand; desired future 2 – 45% own housing demand; and desired future 3 – 20% own housing demand.

For each new data entry, it was necessary to analyse the modelling simulation results, observing not only the behaviour of the input variable but the joint behaviour of the variables, social housing, own housing and subnormal housing. For the housing sector managers, the goal was to propose appropriate interventions or measures over time to achieve their objectives. For this, they experimented with the variables "emergency build own" and "emergency build social", restarting the simulations and observing the modelling behaviour. The cost per housing was also taken into account; likewise, the average monthly cost per fiscal to control areas unsuitable for housing.

4.4 Step 4: Action plan implantation and monitoring

The desirable and sustainable future visions were obtained by sharing knowledge between those involved in the process and through defining variables and their interrelationships to establish system behaviour (by modelling and simulation). The group's explicit knowledge generated solutions and a dynamic overview for the highly complex housing sector problem.

This fourth stage consisted specifically in the implementation of the planned solution and the monitoring of all actions taken. Its implementation was carried out in parts, following a schedule of actions and follow-ups with the responsible city managers. The experiences obtained with the oriented construction of the modelling served as learning for the next stages. The monitoring of the proposed closing-loop-feedbacks procedure allowed adjustments to the process over time, regarding access to new technologies, to break trends and new procedural approaches that allowed knowledge consolidation.

The return to the previous stages, after the first applications of the plan, was mandatory over a period of time. This was to rethink the need of inputting other variables and their interrelationships, to foster more alignment in simulations, directing the sector to new applied knowledge. The results were presented in panels with specific stakeholders at the Social Observatory of Florianópolis, which then held discussions about the availability of future budgets, new demands and environmental conditions, so that they could analyze and incorporate into their political platforms.. At the end of this stage, the city managers involved in the process presented a plan (best path construction) to reduce the housing demand of Florianópolis for families with incomes of up to three minimum wages with the respective tables, steps, schedules, costs and further information needed to detail the project implementation.

5 Discussion

To address the challenges of "a shortage of adequate housing" pointed out by the United Nations (2016), the proposed framework extracted from second order backcasting (Carlsson-Kanyama et al., 2008; Eames and Egmose, 2011; Eames et al., 2013; Robinson et al., 2011; Svenfelt et al., 2011; Wangel, 2011b) the importance of social learning and the knowledge of a path to a vision of the future, of both experts and non-experts. In this paper, how the development of a vision of a sustainable housing system for Florianopolis in 2030 has been showed by using backcasting and system dynamics, with the gathered efforts from the research community, politicians, NGOs, popular audience reports and the city planning sector. This shared vision was communicated towards structured future scenarios and alternatives, careful designed with system dynamics simulation, in which the core variables were modelled for the long-term future, gathering data from multiples sources.

A combined approach of backcasting and system dynamics allowed a participatory stakeholder dialogue and an in-depth data survey related to the key variables. The research contributed to a better understanding of housing planning for low-income citizens in the studied case. While the backcasting helped to define a shared vision of the problem and the key variables, the functions' modelling with strong data-driven support served as feedback looping and refinement, through a triangulation process. The backcasting statement for the shared vision was detailed and explored in the modelling process, analysing alternative scenarios.

The four-step framework combining backcasting and system dynamics for sustainability was developed, grounded in previous literature as shown in Appendix B. The framework application was designed for guiding public sector managers, organizational leaders and citizens in building a pathway towards sustainability in the search for knowledge creation in the city housing planning process involving multiple stakeholders. In the first step, to avoid a focus solely on technical possibilities, and with the aim of bridging multiple stakeholders' perspectives towards future-oriented action, the dialogue between experts and non-experts was established. The boundaries for the problem were defined in a participatory way and key variables analysed, supported by data surveyed and socialized through specialists supported by appropriate methods and tools. Then, in the second step, the group was invited to draw future scenarios and to start looking for specific ways to solve the problem, defining desirable and sustainable future visions and identifying critical manifested variables to be modelled. The third step was the organization of the formatted proposals, in order to express the consensus, to develop a causal relationship among the variables and structure this into modelling and simulation solutions to allow directed actions to the problems identified.

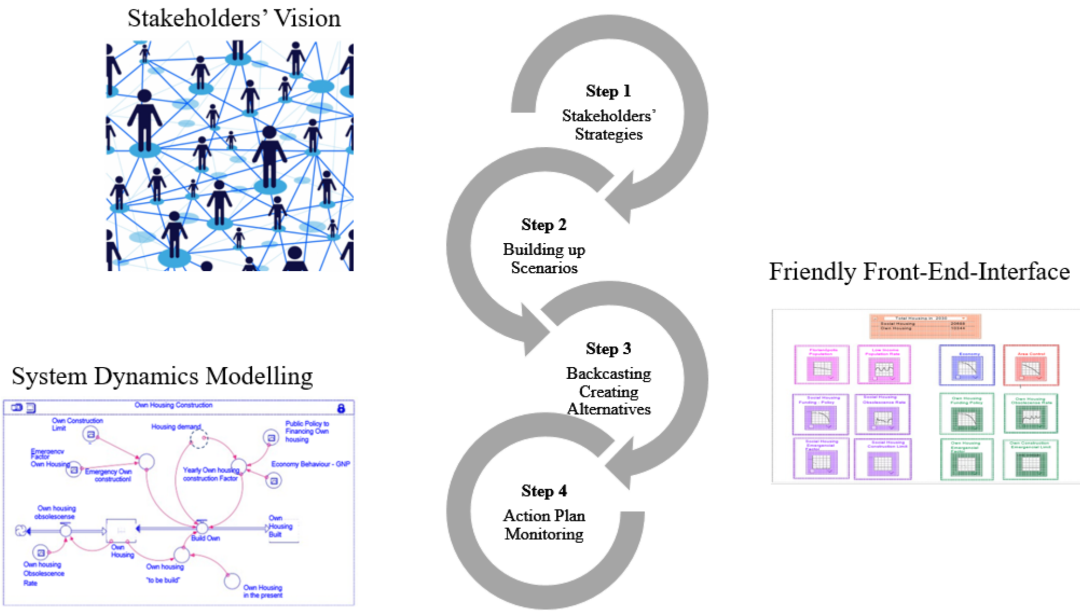

Figure 9: Four-step Framework Overview

The system's modelling and simulation was designed by using the computer-aided tool (STELLA II®software) to simulate the whole system behaviour through certain boundary conditions; that is, by changing variables and the scenarios. Finally, the fourth step was designed for a long-term project follow-up, to stimulate continuous dialogue and interaction with the public (Neuvonen and Ache, 2017), decision-makers and experts, for re-interpreting the framework by identifying new opportunities and constraints (Quist et al., 2011). For this, the model was designed with a friendly front-end interface to make further discussion easier and to allow non-expert stakeholders to collaborate in the acceleration of the knowledge creation process, and the simulation application itself. The main idea of the research was to help in the avoidance of possible failures in the actions taken by government, by anticipating systems' reactions though simulation tests.

The expected result was the use of explicit knowledge to provide better conditions for decision-making. So, after modelling the system and simulating scenarios to identify the better options, the monitoring of looping becomes fundamental for the housing sector. Each stage of execution brings new data and information to consolidate what was previously known and to generate new knowledge. The simulations generate a complex set of results which supports planners and managers of local housing, since stakeholders can set new information yearly to update the visual scenario results. Moreover, the discussions on the model boundaries and new variables can be added in a shared vision.

The Social Observatory of Florianópolis that helped in the stakeholders' panel for the scenarios building also participated of a structured feedback about the four-step framework. The results of the system dynamics modelling were presented and discussed at the Observatory with the stakeholders in the area so that they could analyse and incorporate insights into their political platforms. (http://florianopolis.osbrasil.org.br/)

Regarding actual achievements compared with the theoretical expectations, it is widely known that social learning requires time, effort and a great sense of common wealth. In this case, the complexity of the community in focus, the variables and the stakeholders involved were high, though helped by the participation of highly capable and influent people. On the one hand, the method application and the updatable variables definition was a complex process, but that eventually offered a useful tool for decision-makers to manage with, otherwise uncertain, diffuse or blurry information. On the other hand, managing interests requires more than hard skills to cope with the pressure of social problems in a developing country's environment.

6. Conclusions

This paper contributes to the literature by answering the research questions (RQS) looking at a specific environment in Brazil. (RQ1) How can integrating multiple stakeholders in the housing planning problem draw a sustainable future vision for building houses for low-income families? (RQ2) Would applying backcasting and system dynamics, jointly, help to provide a solution to the housing issue, for the long-term future and taking into account uncertain complex systems?

First, the main goal accomplished by this research was the bringing together of the popular participation, governmental associations and academic research on building sustainable scenarios, fostering a bridge between government actions and relevant stakeholders. The monitoring of the scenarios' implementation gave a possibility of feedback to the community. Second, a four-step framework based on the literature review was proposed, combining backcasting and system dynamics in order to face the challenges of the shortage of adequate housing. Looking at the process through the four-step framework, multiple stakeholders helped to identify the core variables for the planning problem for low-income citizens, the alternatives and the future desired vision in loops of learning and knowledge creation. In each step, participants were involved in the knowledge creation, dissemination, appropriation for a better understanding of their own positions and the shared vision, which were decisive for the social learning process.

A combined approach allowed for the mitigation of weaknesses of both methods, backcasting and SD, merging a participatory stakeholder dialogue and an in-depth data-driven modelling that contributes to a better understanding of the housing planning for low-income citizens in the studied case.

There are implications for practice because the framework applications show a pathway for modelling, bridging multiples stakeholders, in a free and friendly front-end platform, which enables decision-makers to control and update the alternative scenarios and variables, under the conditions and timeframes desired. The illustrative case presented represents a partnership between community, academia and government to foster the application of new technologies to old social challenges for providing houses to low-income families, through a structured upgradeable dynamic thinking.

The main feedback from stakeholders relates to the user-friendly screens for the data adjustment of the nine-modelled sectors. For the managers from the social housing sector, in particular, it is possible to identify the potential of the method. The main deliverables, besides the upcoming knowledge, are the friendly support platform, free for use by the community over time, as an initial tool that is available to interested parties, with public data to be updated for urban planning. Future perspectives to this research partnership are the continuous monitoring of the platform and its assessment, evolving and adding perceived relevant variables, once the main stakeholders' structure has been already mapped, helping in system boundaries exploration and tradeoffs.

For future research, the four-step framework could be applied to other sustainable goals and problems, such as the urban mobility sector; water supply and sewage; the preservation of risk areas; hospital, road and rail infrastructures as well as port systems. All these, regardless of their complexity, affect the environment and therefore require social learning and social responsibility. For each, an appropriate model must be designed, to equate the economic, political, social, cultural, technological and environmental characteristics from each community.

Another stream of future research is technical, combining other approaches, methods and tools presented in this research to support the projection and evaluation of environmental sustainability and territorial management, involving multicriteria, which integrate dynamic programming models with fuzzy logic scenario evaluation models. Moreover, these models can be combined in a Geographic Information Systems (GIS) environment, in order to allow the construction of sustainability maps, maps of environmental values and maps of homogeneous zones, which are also necessary for economic and ecological zoning.

References

Akkermans, H. & Dellaert, N. 2005. The rediscovery of industrial dynamics: the contribution of system dynamics to supply chain management in a dynamic and fragmented world. System Dynamics Review 21(3): 173-186.

Ascher, W. 2007. Policy sciences contributions to analysis to promote sustainability. Sustainability Science 2(2): 141-149.

Bagheri, A. & Hjorth, P. 2007. Planning for sustainable development: a paradigm shift towards a process-based approach. Sustainable Development 15(2): 83-96.

Borgatti, S. P., Everett, M. G. & Freeman, L. C. 2002. Ucinet for Windows: Software for social network analysis.

Börjeson, L., Höjer, M., Dreborg, K. H., Ekvall, T. & Finnveden, G. 2006. Scenario types and techniques: towards a user's guide. Futures 38, 723-739.

Breukers, S., Hisschemoller, M., Cuppen, E. & Suurs, R. 2014. Analysing the past and exploring the future of sustainable biomass. Participatory stakeholder dialogue and technological innovation systems research. Technol. Forecast. Soc. Change 81, 227-235. doi:10.1016/j.techfore.2013.02.004

Broman, G. I. & Robert, K. H. 2017. A framework for strategic sustainable development. Journal of Cleaner Production 140 17-31.

Broman, G., Holmberg, J. & Robert, K.H. 2000. Simplicity without reduction: Thinking upstream towards the sustainable society. Interfaces (Providence). 30, 13-25. doi:10.1287/inte.30.3.13.11662

Carlsson-Kanyama, A., Dreborg, K. H., Moll, H. C. & Padovan, D. 2008. Participative backcasting: A tool for involving stakeholders in local sustainability planning. Futures 40(1): 34-46.

Carvalho, M. M., Fleury, A. & Lopes, A. P. 2013. An overview of the literature on technology roadmapping (TRM): Contributions and trends. Technological Forecasting and Social Change 80(7): 1418-1437.

Dreborg, K. H. 1996. Essence of backcasting. Futures 28(9): 813-828.

Dreborg, K. H. 2004. Scenarios and Structural Uncertainty. Explorations in the field of sustainable transport.

Dyer, G. & Dyer, M. 2017. Strategic leadership for sustainability by higher education: the American College & University Presidents' Climate Commitment. Journal of Cleaner Production 140 111-116.

Eames, M. & Egmose, J. 2011. Community foresight for urban sustainability: Insights from the Citizens Science for Sustainability (SuScit) project. Technological Forecasting and Social Change 78(5): 769-784.

Eames, M., Dixon, T., May, T. & Hunt, M. 2013. City futures: exploring urban retrofit and sustainable transitions. Building Research and Information 41(5): 504-516.

Eames, M. & Egmose, J. 2011. Community foresight for urban sustainability: Insights from the Citizens Science for Sustainability (SuScit) project. Technol. Forecast. Soc. Change 78, 769-784. doi:10.1016/j.techfore.2010.09.002

Eames, M. & McDowall, W. 2010. Sustainability, foresight and contested futures: exploring visions and pathways in the transition to a hydrogen economy. Technol. Anal. Strateg. Manag. 22, 671-692. doi:10.1080/09537325.2010.497255

Elkington, J. 1997. Cannibals with forks. The triple bottom line of 21st century.

Forrester, J. W. 1971. World dynamics, Wright-Allen Press Cambridge, MA.

Forrester, J.W. 1958. Industrial dynamics-a major breakthrough for decision makers. Harv. Bus. Rev. 36, 37.

Forrester, J.W., 1969. Urban dynamics. MIT Press Cambridge.

Gaziulusoy, A.I., Boyle, C. & McDowall, R., 2013 System innovation for sustainability: a systemic double-flow scenario method for companies. J. Clean. Prod. 45, 104-116. doi:DOI 10.1016/j.jclepro.2012.05.013

Gebhard, E., Hagemann, N., Hensler, L., Schweizer, S. & Wember, C. 2015. Agriculture and Food 2050: Visions to Promote Transformation Driven by Science and Society. Journal of Agricultural & Environmental Ethics 28(3): 497-516.

Gleick, P. H. 1998. Water in crisis: Paths to sustainable water use. Ecological Applications 8(3): 571-579.

Green, K. & Vergragt, P. 2002. Towards sustainable households: a methodology for developing sustainable technological and social innovations. Futures 34(5): 381-400.

Haslauer, E., Biberacher, M. & Blaschke, T. 2016. A spatially explicit backcasting approach for sustainable land-use planning. Journal of Environmental Planning and Management 59(5): 866-890.

Hennicke, P. 2004. Scenarios for a robust policy mix: the final report of the German study commission on sustainable energy supply. Energy Policy 32(15): 1673-1678.

Hertwich, E. G. 2005. Life cycle approaches to sustainable consumption: a critical review. Environmental Science and Technology 39(13): 4673-84.

Hojer, M., Ahlroth, S., Dreborg, K.H., Ekvall, T., Finnveden, G., Hjelm, O., Hochschorner, E., Nilsson, M. & Palm, V. 2008. Scenarios in selected tools for environmental systems analysis. Journal of . Cleaner Production 16, 1958–1970. doi:10.1016/j.jclepro.2008.01.008

Holmberg, J. & Robert, K. H. 2000. Backcasting - a framework for strategic planning. International Journal of Sustainable Development and World Ecology 7(4): 291-308.

Holmberg, J. 1998. Backcasting: a natural step in operationalising sustainable development. Greener management international 30-52.

Holmberg, J. & Robert, K.H. 2000. Backcasting – a framework for strategic planning. International Journal of Sustainable Development and World Ecology. 7, 291-308. doi:Doi 10.1080/13504500009470049

Kajikawa, Y. 2008. Research core and framework of sustainability science. Sustainability Science 3(2): 215-239.

Kanter, D. R., Schwoob, M. H., Baethgen, W. E., Bervejillo, J. E., Carriquiry, M., Dobermann, A., Ferraro, B., Lanfranco, B., Mondelli, M., Penengo, C., Saldias, R., Silva, M. E. & de Lima, J. M. S. 2016. Translating the Sustainable Development Goals into action: A participatory backcasting approach for developing national agricultural transformation pathways. Global Food Security-Agriculture Policy Economics and Environment 10 71-79.

Kok, K., van Vliet, M., Barlund, I., Dubel, A. & Sendzimir, J. 2011. Combining participative backcasting and exploratory scenario development: Experiences from the SCENES project. Technol. Forecast. Soc. Change 78, 835-851. doi:DOI 10.1016/j.techfore.2011.01.004

Littell, J. H., Corcoran, J. & Pillai, V. 2008. Systematic reviews and meta-analysis, Oxford University Press.

Loehman, E. 2014. Social Investment for Sustainability of Groundwater: A Revealed Preference Approach. Sustainability 6(9): 5598-5638.

Maani, K. & Cavana, R. Y. 2000. Systems thinking and modelling - understanding Change and Complexity, Prentice Hall.

Meadows, D. H., Randers, J. & Meadows, D. L. 2012. Limits to growth: the 30-year update. Routeledge.

Miguel, P. A. C. 2007. Case study in production engineering structuring and recommendations for its conduction. Production 17(1): 216-229.

Mulder, K. 2014. Strategic competencies, critically important for Sustainable Development. Journal of Cleaner Production 78 243-248.

Neuvonen, A. & Ache, P. 2017. Metropolitan vision making – using backcasting as a strategic learning process to shape metropolitan futures. Futures 86 73-83.

Ny, H., MacDonald, J. P., Broman, G., Yamamoto, R. & Robert, K. H. 2006. Sustainability constraints as system boundaries – An approach to making life-cycle management strategic. Journal of Industrial Ecology 10(1-2): 61-77.

Pereverza, K., Pasichnyi, O., Lazarevic, D. & Kordas, O. 2017. Strategic planning for sustainable heating in cities: A morphological method for scenario development and selection. Applied Energy 186 115-125.

Phdungsilp, A. 2011. Futures studies' backcasting method used for strategic sustainable city planning. Futures 43(7): 707-714.

Quist, J. & Tukker, A. 2013. Knowledge collaboration and learning for sustainable innovation and consumption: introduction to the ERSCP portion of this special volume. Journal of Cleaner Production 48 167-175.

Quist, J. & Vergragt, P. 2006. Past and future of backcasting: the shift to stakeholder participation and a proposal for a methodological framework. Futures 38(9): 1027-1045.

Quist, J., Thissen, W., Vergragt, P.J. 2011. The impact and spin-off of participatory backcasting: From vision to niche. Technological Forecasting and Social Change 78, 883-897. doi:DOI 10.1016/j.techfore.2011.01.011

Quist, J., Tukker, A. 2013. Knowledge collaboration and learning for sustainable innovation and: introduction to the ERSCP portion of this special volume. Journal of Cleaner Production. 48, 167-175. doi:DOI 10.1016/j.jclepro.2013.03.051

Quist, J., Vergragt, P., 2006. Past and future of backcasting: the shift to stakeholder participation and a proposal for a methodological framework. Futures 38, 1027-1045.

Robert, K. H., Schmidt-Bleek, B., de Larderel, J. A., Basile, G., Jansen, J. L., Kuehr, R., Thomas, P. P., Suzuki, M., Hawken, P. & Wackernagel, M. 2002. Strategic sustainable development – selection, design and synergies of applied tools. Journal of Cleaner Production 10(3): 197-214.

Robèrt, K. H. 2000. Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development, and to each other? Journal of Cleaner Production. 8, 243-254.

Robert, K.H., Schmidt-Bleek, B., de Larderel, J.A., Basile, G., Jansen, J.L., Kuehr, R., Thomas, P.P., Suzuki, M., Hawken, P. & Wackernagel, M. 2002. Strategic sustainable development – selection, design and synergies of applied tools. Journal of Cleaner Production. 10, 197-214. doi:10.1016/s0959-6526(01)00061-0

Robert, M. 2017. Engaging private actors in transport planning to achieve future emission targets – upscaling the Climate and Economic Research in Organisations (CERO) process to regional perspectives. Journal of Cleaner Production 140 324-332.

Robinson, J.B. 2003. Future subjunctive: backcasting as social learning. Futures 35(8): 839-856.

Robinson, J. B. 1988. Unlearning and Backcasting – Rethinking Some of the Questions We Ask About the Future. Technological Forecasting and Social Change 33(4): 325-338.

Robinson, J. B. 1990. Futures under glass: a recipe for people who hate to predict. Futures 22(8): 820-842.

Robinson, J., Burch, S., Talwar, S., O'Shea, M. & Walsh, M. 2011. Envisioning sustainability: recent progress in the use of participatory backcasting approaches for sustainability research. Technological Forecasting and Social Change 78(5): 756-768.

Robinson, J.B. 1982. Energy Backcasting – a Proposed Method of Policy Analysis. Energy Policy 10, 337-344. doi:Doi 10.1016/0301-4215(82)90048-9

Ryan-Fogarty, Y., Becker, G., Moles, R. & O'Regan, B. 2017. Backcasting to identify food waste prevention and mitigation opportunities for infant feeding in maternity services. Waste Management 61 405-414.

Sandstrom, C., Carlsson-Kanyama, A., Lindahl, K. B., Sonnek, K. M., Mossing, A., Nordin, A., Nordstrom, E. M. & Raty, R. 2016. Understanding consistencies and gaps between desired forest futures: An analysis of visions from stakeholder groups in Sweden. Ambio (45) Suppl 2 100-8.

Schade, B. & Schade, W. 2005. Evaluating economic feasibility and technical progress of environmentally sustainable transport scenarios by a backcasting approach with ESCOT. Transport Reviews. 25, 647-668. doi:10.1080/01441640500361033

Schildt, H. 2002. Sitkis: Software for Bibliometric Data Management and Analysis. Helsinki Institute of Strategy and International Business 6.

Searcy, C. 2012. Corporate Sustainability Performance Measurement Systems: A Review and Research Agenda. Journal of Business Ethics 107(3): 239-253.

Singhal, K. & Singhal, J. 2012a. Imperatives of the science of operations and supply-chain management. Journal of Operations Management 30(3): 237-244.

Singhal, K. & Singhal, J. 2012b. Opportunities for developing the science of operations and supply-chain management. Journal of Operations Management 30(3): 245-252.

Soria-Lara, J. A. & Banister, D. 2017. Participatory visioning in transport backcasting studies: Methodological lessons from Andalusia (Spain). Journal of Transport Geography 58 113-126.

Svenfelt, A., Engstrom, R. & Svane, O. 2011. Decreasing energy use in buildings by 50% by 2050 – A backcasting study using stakeholder groups. Technological Forecasting and Social Change 78(5): 785-796.

Timms, P., Tight, M. & Watling, D. 2014. Imagineering mobility: constructing utopias for future urban transport. Environment and Planning. A 46, 78-93. doi:10.1068/a45669

Tranfield, D., Denyer, D. & Smart, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management 14(3): 207-222.

UNDP, 2000. United Nations Development Programme.

United Nations, 2015. Transforming our world: The 2030 agenda for sustainable development. New York United Nations, Department of Economic and Social Affairs.

van Vliet, M. & Kok, K. 2013. Combining backcasting and exploratory scenarios to develop robust water strategies in face of uncertain futures. Mitigation And Adaptation Strategies for Global Change 20, 43–74. doi:10.1007/s11027-013-9479-6

Vergragt, P. J. & Quist, J. 2011. Backcasting for sustainability: Introduction to the special issue. Technological Forecasting and Social Change 78(5): 747-755.

Voss, C., Tsikriktsis, N. & Frohlich, M. 2002. Case research in operations management International Journal of Operations & Production Management. 22, 195-219.

Wangel, J. 2011a. Change by whom? Four ways of adding actors and governance in backcasting studies. Futures 43(8): 880-889.

Wangel, J. 2011b. Exploring social structures and agency in backcasting studies for sustainable development. Technological Forecasting and Social Change 78(5): 872-882.

Zivkovic, M., Pereverza, K., Pasichnyi, O., Madzarevic, A., Ivezic, D. & Kordas, O. 2016. Exploring scenarios for more sustainable heating: The case of Nis, Serbia. Energy 115 1758-1770.

APPENDIX A

Sector	Country	References	#
Agriculture	Germany	Gebhard et al (2015)	2
	Uruguai	Kanter et al (2016)	
Cities/Landscape	Australia	Boschettiet al (2015); Dortmans (2005)	17
	Austria	Haslauer (2015); Haslauer (2012)	
	Canada	Moffatt (2014)	
	Finland	Neuvonen and Ache (2017)	
	Netherlands	Dassen et al. (2013); Kourtit and Nijkamp (2013); Van Berkel and Verburg (2012)	
	Sweden	Hojer et al. (2011); Phdungsilp (2011); Svane and Weingaertner (2006); Weddfelt et al. (2016)	
	UK	Bailey et al (2012);Dixonet al (2014); Eames et al. (2013); Eames and Egmose (2011)	
Climate	Canada	Robinson et al. (2011)	5
	EU	Keune et al. (2012)	
	South Africa	van der Voorn et al (2012)	
	Sweden	Carlsson-Kanyama et al. (2013)	
	Switerland	Gret-Regamey and Brunner (2011)	
Companies	New Zealand	Gaziulusoy et al. (2013)	2
	Sweden	Broman et al. (2000)	
Consumption	Canada	Newton et al. (2002)	10
	Finland	Mont et al. (2014); Neuvonen et al. (2014)	
	Ireland	Davies and Doyle (2015); Doyle and Davies (2013)	
	Japan	Furukawa and Ishida (2013)	
	Norway	Hertwich (2005)	
	Sweden	Missimer et al. (2010); Quist and Tukker (2013); Bratt et al. (2011)	
Ecosystem	Spain	Palacios-Agundez et al. (2013)	1
Education	Netherlands	Mulder (2014); Quist et al. (2006)	5
	Spain	Sanchez-Marono et al. (2015)	
	US	Dyer and Dyer (2017); Iwaniec et al. (2014)	
Emissions	Japan	Gomi et al. (2010)	5
	Sweden	Robert (2017)	
	UK	Anderson et al. (2008); Hickman and Banister (2007); Robertson (2016)	
Employment	Hungary	Kiraly et al. (2013); Koves et al. (2013)	2
Energy / Energy futures/ Biomass	Germany	Hennicke (2004)	9
	Sweden	Dreborg (1996); Robert et al. (2007); Svenfelt et al. (2011); Ahlroth and Hojer (2007)	
	UK	Anderson (2001); Upham et al. (2014)	
	Austria	Wachter et al. (2012)	
	Australia	Giurco et al. (2011)	
	Netherlands	Breukers et al. (2014)	
Environment	Australia	Cook et al. (2014); Gordon (2015)	28
	Canada	Cinq-Mars and Wiken (2002); Le et al. (2001); MacDonald (2005); Neumann et al. (2005); Noori et al. (1999); Robinson (2003)	
	China	Gong and Chen (2012)	
	EU	Brunner et al. (2016)	
	Italy	Sisto et al. (2016)	
	Netherlands	Heijungs et al. (2014); Jansen (2003); Mulder (2007); van Kouwen et al. (2009)	
	Scotland	Manning et al. (2006)	
	Sweden	Broman and Robert (2017);Holmberg and Robert (2000); Robert et al. (2002); Sandstrom et al (2016); Carlsson-Kanyama et al. (2008); Hojer et al. (2008); Holmberg et al. (1999);	
	UK	Caritte et al. (2015); Cotton (2013)	
	US	Kajikawa (2008); van der Leeuw et al. (2011); Worthington et al. (2014)	
Polimer Chains	Netherlands	Partidario and Vergragt (2002)	1
Food	Ireland	Davies (2014); Ryan-Fogarty et al. (2017)	4
	Netherlands	Quist and Vergragt (2006)	
	Sweden	Wallgren and Hojer (2009)	
Heating	Serbia	Zivkovic et al. (2016)	2
	Ukraine, Serbia	Pereverza et al. (2017)	
Hydrogen	UK	Eames and McDowall (2010); McDowall and Eames (2007)	2
Land use	Austria	Haslauer et al. (2016)	6
	France	Houet et al. (2010)	
	Netherlands	Quist et al. (2011); van der Graaf et al. (1997)	
	Portugal	Ferreira et al. (2016)	

APPENDIX A (Continuation)

Sector	Country	References	#
Land use	US Sweden	Ethier et al. (2014); Maclaurin and Leyk (2016) Milestad et al. (2014)	2
Products	Sweden	Byggeth et al. (2007); Ny et al. (2006)	2
Shale gas	Canada	Yap (2016)	1
Technology	Japan New Zealand	Morioka et al. (2006) Gaziulusoy et al. (2008)	2
Transports	France Germany Spain Sweden UK US Korea	Caid et al. (2002); Lopez-Ruiz and Crozet (2010) Schade and Schade (2005); Zimmermann et al. (2012) Palomo et al. (2011); Soria-Lara and Banister (2017) Akerman and Hojer (2006); Banister and Hickman (2013); Hojer (1998); Robert (2005); Robert (2017); Roth and Kaberger (2002); Wangel (2011); Wangel et al. (2013) Potter (2007); Taeihagh et al. (2009); Timms et al. (2014) Barrella and Amekudzi (2011); Vergragt and Brown (2007) Zhou et al. (2014)	20
Water	Canada Iran Netherlands Ukraine US	Gleeson et al. (2012) Bagheri and Hjorth (2007) Frijns et al. (2013); Kok et al. (2011); van Vliet and Kok (2015) Zhovtonog et al. (2011) Gleick (1998); Tusak Loehman (2014)	8

Note 1: Many of these publications are successful case applications, some are suggested field applications and some scientific research not yet applied, but all of them mention the backcasting approach as a core theme.
Note 2: The categorization into sectors is based on the "Web of Science" classification and the authors' understanding. For specific details, it is suggested that the original publications be checked. This summary table is just a glimpse of what has been done previously regarding strategic deployment of scientific backcasting studies.

APPENDIX B

Four-Step Framework for the Deployment of Backcasting with System Dynamics to Sustainable Futures in the Low-Income Housing System of Florianópolis

Step #	***Description***	***References***
Step 1: Stakeholders' strategic orientation to the problem	• Analysing the problem, within a programme or project context. • Stakeholders are the actors playing roles and have responsibility for the solution implementation: local leaders group, government representatives, community representatives, invited experts (non-formal and formal knowledge representatives). • Use of tools, such as interviews, workshops, brainstorming, practical learning, and comparative analysis. • *Main goal: to share the information about the problem, providing knowledge on the subject to the participants, as well as promoting and stimulating the process of sharing tacit knowledge, aiming at the creation of new ideas by the invited experts' experiences and discussion.*	Robinson (2003); Wangel (2011); Carlsoon-Kanyama et al. (2008); Quist and Vergragt (2006)
Step 2: Building up scenarios for sustainable future	• Participants are combined into several discussion groups, each one led by specialists whose knowledge on the situation is expressed through a number of selected workshops toolkits. • The toolkit applied (brainstorming, creativity encouragement by illustrations, learning in practice, comparative analysis and eventually Delphi for consensus confirmation) depends on the problem or interest and can be translated into documents, tables or lists of ideas. The key condition is that it must faithfully express all the participants' points of view as long as they are coherent to the "matured first-step ideas". • Definition of the scenarios – to support the learning process, it is important that the scenario analysis process is highly integrative and reveals the higher level consequences, along with the trade-offs associated with the choices (Robèrt, 2003; Quist et al., 2011; Mont et al., 2014). • *Main goal: to work on the future desired visions challenge, by creating and structuring solutions to the presented problem. Note: the creation of desirable scenarios does not exempt the solution proposals conceived by the interested parties from risk, (step 3 is fundamental to solve this issue).*	Broman and Robèrt (2017); Mont et al. (2014); Quist et al. (2011); Börjeson et al. (2006); Robèrt (2003); Holmberg and Robèrt (2000); Broman et al. (2000); Robèrt et al. (2002)
Step 3: Backcasting: creating sustainable alternatives	• Participants must position themselves in the future and know how to look back in search of tangible variables, ideas, technological leaps and tendencies, as well as realize technological, cultural, behavioural and organizational changes that may occur and that may be particularly necessary to achieve the desired future state. • Requisite: the group must perform the analysis by modelling and simulation, using appropriated computer-aided tools (in this case STELLA II®). However, to be part of the learning process, it is necessary that policy makers, main stakeholders, as well as specialists keep involved in the whole process of building the model (Bagheri and Hjorth, 2007). • *Main goal: anticipate the a posteriori monitoring by building, through System Dynamics (SD), a model for quantitative "real world" simulation to prevent realizing mistaken decisions only after having travelled half the path in the wrong direction. Backcasting, even if well engineered, has not yet been tested, making it useful for simulation with numbers on a model rather than within a real system. Knowing the variables of the problem and their interrelations, and following the orientation of the SD method, STELLA II® software as a computer-aided tool was used to find the optimized paths, with a friendly interactive programming interface.*	Bagheri and Hjorth, (2007); Schade and Schade (2005); Hojer et al. (2008); Ny et al. (2006); Gaziulusoy et al. (2013); Mani and Cavana (2000); Forrester (1969, 1971)
Step 4: Action plan monitoring	• Once the plan is prepared, he should also be feasible. It is, therefore, designed and architected by the users (those interested and involved) with the respective tables that include steps, schedules, costs and resources; in short, everything that a project entails. • The execution is monitored a posteriori, in which the strategic planning control, monitoring key events and using flexibility and adaptability, must be performed. The data raised generate information to allow knowledge consolidation in interactive steps. In each step of the plan implementation, the results must be analysed with new technologies and knowledge trends updates in a participatory and transparent manner. • *Main goal: constant reviewing of determined sustainability principles and success criteria indicators.*	Broman and Robèrt (2017); Neuvonen and Ache, (2017); Bagheri and Hjorth, (2007); Ny et al. (2006); Gaziulusoy et al. (2013); Mani and Cavana (2000); Forrester (1969, 1971)

APPENDIX C

Number of dwellings and estimated population of the communities that are in the areas of social interest of Florianópolis, by region of the municipality

Group	Community	Dwellings Nº	Estimated Population
Continental Region	Arranha-Céu	121	472
	MacLaren	116	452
	Nova Jerusalém	225	878
	Vila Aparecida I	310	1209
	Vila Aparecida II	241	940
	Ponta do Leal	66	257
	CCI	45	176
	Jardim Ilha Continente	182	710
	Morro da Caixa I	533	2079
	Morro da Caixa II	213	831
	Chico Mendes	561	2188
	Novo Horizonte	233	909
	N. Sra. da Glória	128	499
	Monte Cristo	193	753
	Nova Esperança	58	226
	Morro do Flamengo	121	472
	N. Sra. do Rosário	126	491
	PC3	38	148
	Sta. Terezinha I	222	866
	Sta. Terezinha II	143	558
	Subtotal	**3.875**	**15.113**

Group	Community	Dwellings Nº	Estimated Population
Central Region (Morro da Cruz)	Morro do Horácio	621	2.422
	Morro do 25	428	1.669
	Morro do Céu	66	257
	Mont Serrat	722	2.816
	Serrinha I	393	1.533
	Serrinha II	90	351
	Mocotó	341	1.330
	Santa Rosa	45	176
	Caieira V. Operária I,II e III	726	2.831
	Morro do Tico-Tico	146	569
	Queimada	186	725
	Vila Santa Vitória	329	1.283
	Penitenciária	290	1.131
	Mariquinha	163	636
	Angelo Laporta	17	66
	José Boiteux	199	776
	Laudelina Cruz Lemos	35	137
	Santa Clara/Monsenhor	45	176
	Subtotal	**4.842**	**18.884**

Group	Community	Dwellings Nº	Estimated Population
North Region	Balão	107	417
	Sol Nascente	560	2.184
	Morro do Janga	229	893
	Morro do Quilombo	161	628
	Vila Cachoeira	207	807
	Angra (Adão) dos Reis	32	125
	Morro do Mosquito	51	199
	São Bernardo (R.Papaquara)	35	137
	Vila Arvoredo (Siri)	158	616
	Cartódromo	84	328
	Canasvieiras	10	39
	Vila União	175	683
	Subtotal	**1809**	**7055**

Group	Community	Dwellings Nº	Estimated Population
South Region	Rio Tavares I (Seta)	111	433
	Rio Tavares II	139	542
	Carvoeira (Boa Vista)	83	324
	Costeira I	56	218
	Costeira II	92	359
	Costeira III	53	207
	Costeira IV	154	601
	Costeira V	69	269
	Pantanal	102	398
	Areias do Campeche	144	562
	Panaia	31	121
	Tapera I	1423	5550
	Tapera II	242	944
	Rio das Pacas	6	23
	Subtotal	**2705**	**10550**
	Total	**13231**	**51601**

Source: SMHSA (2008)

APPENDIX D

I – Families living in private households classified by total monthly income

Family nominal monthly income	Families Nº	%
Up tp 1/4 minimum wages*	18	0.017
More than 1/4 to 1/2 minimum wages*	154	0.14
More than 1/2 to 3/4 minimum wages*	311	0.29
More than 3/4 to 1 minimum wages*	2,643	2.44
More than 1 to 1 1/4 minimum wages*	485	0.45
More than 1 1/4 to 1 1/2 minimum wages*	1,306	1.2
More than 1 1/2 to 2 minimum wages*	4,941	4.56
More than 2 to 3 minimum wages*	7,794	7.19
More than 3 to 5 minimum wages*	16,222	14.96
More than 5 to 10 minimum wages*	27,194	25.07
More than 10 to 15 minimum wages*	12,784	11.79
More than 15 to 20 minimum wages*	9,008	8.31
More than 20 minimum wages*	22,967	21.18
No income	2,631	2.43
Total	**108,456**	**100**

Source: Demographic Census (IBGE, 2001)
*Note: 1 minimum wage is approximately U$295

II – Households living in private households by number of household components in Florianópolis

Number in Family	Family Number	Percentage
1 person	13,340	12.30%
2 persons	26,626	24.55%
3 persons	27,121	25.00%
4 persons	23,952	22.08%
5 persons	11,454	10.56%
6 or more persons	5,963	5.51%
Total	108,456	100%

Source: IBGE (2000)

III – Defined variables and respective scenarios for simulation

Variable	Description - Optimistic Scenario	Description - Intermidiate Scenario	Description - Pessimistic Scenario
Economy	Decreasing from the future to the present	Slightly decreasing from the future to the present, with small changes	Stable and in crisis
Public financing policy for social housing construction	Decreasing from the future to the present	Slightly decreasing from the future to the present, with small changes	No concern for the high housing deficit index
Public financing policy for own housing construction	Decreasing from the future to the present	Slightly decreasing from the future to the present, with small changes	No concern for the high housing deficit index
Area control	Decreasing from the future to the present	Decreasing from the future to the present	Practically nonexistent
Projection of population	Decreasing from the future to the present	Decreasing from the future to the present	Decreasing from the future to the present
Population rate	Stable	Stable	Stable
Social housing obsolescence	Slightly decreasing from the future to the present	Slightly decreasing from the future to the present, with small changes	Slightly decreasing from the future to the present
Own housing obsolescence	Slightly decreasing from the future to the present	Slightly decreasing from the future to the present, with small changes	Slightly decreasing from the future to the present

Source: Data based on workshops-results with *Valora* group