Designing tools for Systemic Design: Identifying structural Leverage points

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Abstract

Systemic design is a relatively new methodological framework that emerged from the need to articulate systems thinking and design thinking to consider the potential effects that designs can have on a system. Although there have been great advancements towards this articulation there are still opportunities for improvement in relation to incorporating System Dynamics tools in a more rigorous manner, especially with regards to interventions that address systems structure: stocks and flows and feedback loop dominance. We present some tools that we designed for helping systemic designers identify Meadow´s systemic leverage points in their design process. These tools serve as guided thinking tools that illustrate possible starting points for the ideation process. For now, we tested these tools in an educational setting applying them to a class application case.

Key words: Systemic design, Leverage points, Education

I. Introduction

Systemic design emerged from the need to articulate systems thinking and design thinking to consider the potential effects that designs can have on a system. In recent years, there has been a methodological development of systemic design, which can be considered a first step toward coordinating both types of thinking (design and systems). However, these new methods do not necessarily leverage on the full potential of systems thinking. It is evident that System Dynamics tools such as stakeholder mapping, Causal Loop Diagrams, or Systemic leverage points are sometimes used in ways that are not necessarily consistent with the purpose for which they were created, or their use as tools to support decision-making is limited and their full potential is lost. Some systemic designers do not consider the dynamic nature of the problems they address or do not take advantage of the potential that simulation models can offer. This calls for developing a methodological framework for systemic design based on the articulation of Design thinking and System dynamics, to close the gap that currently exists in the design of solutions to problems in complex social systems. We are working on a new methodological framework that will propose new tools and some redefinitions. The tools presented here were developed in the context of an ongoing research project of the Department of Design at the Universidad de los Andes (Bogota, Colombia) and were prototyped in an undergraduate Industrial Engineering class. In Section II we present the conceptual background for Systemic design, the motivation for designing these tools and a preliminary proposal for developing a systemic design methodology. We also present the System Dynamics course in which the tools were piloted. In Section III we present the methods we used for designing guided thinking tools for identifying systemic leverage points and describe the tools and how they should be used. In Section IV we present the main results of a pilot test of these tools in a System Dynamics course. Section V discusses the main findings from an educational perspective and the potential of these tools to strengthen Systemic Design and finally we conclude in Section VI.

II. Background

Systemic design

According to Jones (2021), Systemic design adapts multi-level research modes and methodologies to guide design practice in defining and embracing complex systems. By integrating systems thinking and its methods, systemic design draws on design competencies (form and process reasoning, social and generative research methods, and drawing and visualization practices) to describe, map, propose, and reconfigure complex services and systems. Visualizing problems to see and synthesize the challenges designers face provides a greater chance of addressing them appropriately (Alben, 2008). In this context, systemic design is understood as a way of "zooming out" into the design process to challenge the status quo and reveal the context in which designers' ideas and observations are framed (Clark & Smith, 2010; Jenkins, 2010; Lockwood, 2010).

Current literature on Systemic design highlights the need to articulate Design thinking with Systems thinking and proposes specific premises for how this can be achieved. Case studies can be found in real-life contexts in which Design thinking and Systems thinking are used as a methodological axis (Barbero & Pallaro, 2017; Battistoni et al., 2019; Blomkamp, 2022; Giraldo Nohra et al., 2020; Zang et al., 2023), and there are also several tools and toolkits that articulate both ways of thinking and addressing complex problematic situations or "wicked problems" (CoLab, 2016; Design Council, 2021; Drew, C. Robinson, C. Winhall, 2020; Van Ael et al., 2021). These referents evidence a use of systems thinking tools mainly through the identification and visualization of the social system from the mapping of actors, the understanding of the dynamics of the system from Causal Loop Diagrams and sometimes the identification of leverage points (Meadows, 1999) as points of the system to intervene in the design process. Although the use of these systems thinking tools is a step towards the articulation of both methodologies, it is not sufficient and the potential that Systems Dynamics tools can have is largely lost in terms of uncovering systems structure (stocks and flows) and simulation over time. None of the systemic design application cases we encountered included the identification of stocks and flows as part of the process of understanding the system's structure, and therefore did not use computational simulation models to consider the system's behavior over time. Since there is no explicit identification of the structure of stocks and flows, the process of identifying possible interventions overlooks the potential that designs could have on the system's material structure.

To this end, the ongoing research project aims to redefine the current concept of Systemic design by combining methodologies, heuristics, and tools from both design and engineering (especially System Dynamics). The project proposes that Systemic design be carried out in two phases: 1) Characterization of the complex situation and 2) Design of systemic interventions. The first phase consists of two stages: I) the identification of the characteristics of the complex situation, which consists in specifying the problem to be solved, defining reference modes, mapping actors, and making explicit system´s design assumptions; II) followed by a systemic characterization of said complex situation, where different types of models are built (Causal Loop Diagrams, Stocks and flows models) in order to gain systemic insights. The second phase also consists of two stages: III) delimiting systemic intervention points, through the identification of leverage points, key indicators and design requirements; and IV) design of systemic interventions thorough an iterative and creative process supported by scenario simulation and validation processes. In each of these stages, elements of design thinking and system dynamics are used in combination to produce an enhanced methodology (Table 1).

Table 1. Proposed stages for Systemic Design

Phase	Stage	Methodologies, heuristics, tools
1. Characterization of the problem situation	I. Identification of the complex problem.	Definition of the problem as a complex engineering problem (Koen, 2003), definition of behavior over time graphs (Sterman, 2000e), identification and mapping of actors and the roles they play (Olaya & Gomez-Quintero, 2016; Van Ael et al., 2021), identification of different aspects of the problem context (Jones & Van Ael, 2022), and making explicit the system's design assumptions (Ulrich, 1987, 2005).
	II. Systemic characterization of complex situations.	Develop Causal Loop Diagrams, Stocks and flows models (Sterman, 2000a, 2000c), and Systemic insights such as dynamic hypothesis that incorporates user perspective elements, such as user values (Boztepe, 2007; Kheirandish et al., 2020).
2. Design of systemic interventions	III. Delimitation of systemic intervention points.	Identify points that are systemically strategic for intervention (Meadows, 1999). Define success indicators, characterize design requirements, and define needs, benefits, and opportunities of stakeholders.
	IV. Design of systemic interventions	Design interventions aligned with the systemic leverage points; It is primarily a stage of creativity and consolidation of proposals (Ideo.org, 2015). Evaluate the potential effects that interventions may have on systemic indicators. Develop a communication strategy for the proposal.

While the research project aims to cover the entire process, from the conceptualization of the complex situation as a system to the design of interventions, in this article we focus on the stage of delimiting systemic intervention points. In this stage, the systemic leverage points are identified (Meadows, 1999), success indicators are defined, requirements and design assignment are established, and the needs, benefits, and opportunities of the stakeholders are defined.

System Dynamics course

The designed tools have been tested in different academic spaces; the tools for identifying leverage points were tested in a System Dynamics course that is taught to fifth-semester students in the Industrial Engineering undergraduate program. The course assesses three competencies: 1) construction and evaluation of stock and flow models, 2) systemic conceptualization based on feedback loops, and 3) systemic policy design. In competency 3 students develop structural analysis skills, emphasizing how bathtub dynamics determine the behavior of an accumulation (Sterman, 2000c, 2000b; Sweeney & Sterman, 2000), as well as how feedback loops produce the behavior of flows in an accumulation (Sterman, 2000d). Additionally, students develop skills for identifying dominant feedback loops using experimental simulation (Ford, 1999; Richardson, 1986). These two skills allow students to develop a dynamic hypothesis for the behavior of a variable of interest (Sterman, 2000e). Based on this dynamic hypothesis, students must design systemic policies to improve system performance by identifying systemic leverage points (Meadows, 1999). It is at this point that the guided thinking tools were tested.

Throughout competency 3 we use a theoretical case that illustrates the dynamics of car theft in a city. The case includes a general description and a stock and flows model with explicit balancing and reinforcing feedback loops that can be simulated in Vensim (Annex 1). In different previous sessions students develop a dynamic hypothesis of the problem that considers bathtub dynamics of the variable of interest “Circulating vehicles” and its inflow “Total of new vehicles that start circulating”, and outflows “Vehicles go out of circulation” and “Annual theft”, and also study dynamics of additional stocks of “Impact of operations against criminal gangs” and “Theft attractiveness”. Students use simulation to identify loop dominance. These sessions help students build a dynamic hypothesis and are challenged to design interventions that ensure that the number of Circulating vehicles does not decrease at any time; This is a theoretical purpose stated by the police.

As a starting point for designing interventions, students are asked to identify systemic leverage points. For academic purposes, Donella Meadows´ leverage points are divided into two large groups: structural leverage points and transcendental leverage points. The first group refers to those leverage points that directly affect the stocks and flows structure (leverage points 10 and 9) and the feedback processes of the system (leverage points 8, 7, and 6); while those in the second group are not directly related to the structure but rather to the decision-making and meta-design processes (leverage points 5 and 4) and paradigms that permeate the system as a whole (leverage points 3, 2, and 1). Leverage points 12 and 11 are not addressed due to their low effectiveness in changing system behavior and also because the policy design possibilities do not usually invite for creativity. In this paper we focus on the first group of structural leverage points. As a heuristic, and for academic purposes, the System Dynamics teaching staff has defined that structural leverage points can be impacted in different ways (Table 2).

Table 2. Possibilities of operationalizing leverage points

Leverage point (Meadows, 1999)	**Operationalization of leverage points**
10. The structure of material stocks and flows	- Add or eliminate flows. - Create new material delays that imply new outflows. - Create new stocks.
9. The length of delays, relative to the rate of system change	- Change the time of an existing delay.
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against	- Strengthen a dominant loop that produces desirable effects. - Reduce the strength of a dominant loop that produces undesirable effects. - Strengthen a non-dominant loop that could produce desirable effects.
7. The gain around driving positive feedback loops	- Strengthen a dominant loop that produces desirable effects. - Reduce the strength of a dominant loop that produces undesirable effects. - Strengthen a non-dominant loop that could produce desirable effects.
6. The structure of information flows	- Add new information links that create new balancing or reinforcing feedback loops.

After identifying structural leverage points in the car theft case, students are asked to design interventions and test their effectiveness using the simulator. These are only experimental exercises for students to put into practice scenario testing simulation models.

III. **Design of guided thinking tools**

In the search for tools that would allow the articulation of systemic thinking and design thinking (CoLab, 2016; Design Council, 2021; Drew, C. Robinson, C. Winhall, 2020; Van Ael et al., 2021) we discovered that although there were some useful tools for visualizing complexity, most of them did not use the whole potential of stocks and flows models and simulation. Since there is no use of stock and flow models, systemic designers miss the opportunity to consider possibilities for intervention in the system's structure. Additionally, the lack of simulation makes it nearly impossible to understand how feedback loops are producing behavior. For these two reasons, the application and use of Meadows' leverage points falls short, as these models, while visualizing the complexity of the system, are not necessarily useful for connecting the system with the behavior they produce.

We understand Meadows´ leverage points as a heuristic for encompassing complexity and identifying where to begin designing, since often in Design thinking, one does not know how to begin and the systemic value is lost. Leverage points are a starting point for thinking and, in that sense, they help narrow down the possibilities for the intervention design process. The research project proposes that the starting point of the ideation process be based on identifying points where it makes systemic sense to do so, taking into account the long-term effects it can have, as well as the changes it can produce in the system's feedback loops and the dynamics of accumulations. Our proposal is that the design process have solid systemic support to prevent the creation of additional problems in the future.

Although some systems design toolkits mention Meadow's leverage points (Jones & Van Ael, 2022), we believe their use encourages the creation of lists that are not necessarily aligned with the system's structure and are not sufficiently guided to leverage its full potential. For this reason, we decided to create our own leverage point identification tools that guide thinking towards possible systemically supported intervention points. The purpose of the tools we present here is to identify systemic leverage points and to promote creativity in thinking about possible interventions that consider the structure of the system. We want designers to consider structural interventions that do not necessarily directly affect the variable of interest and to explore the possibilities offered by a systemic conceptualization of the problem.

Once this need was identified, the research team—made up of a research assistant studying industrial engineering and design, a master's student in industrial engineering, and the principal investigator—set about the task of developing these tools. The design of the tools took a couple of sessions of approximately three hours. Following this, the tools were tested with a teaching assistant from the Systems Dynamics course, and the corresponding adjustments were made. The tools were then tested again in the System Dynamics course using the case of car theft in a city. These tools are intended to be used in phase 2 of the systemic design process that consists of designing systemic interventions, especially in stage III where the delimiting of systemic interventions takes place; This means that the use of these tools require prior identification of the complex problem and a systemic characterization of the complex situation, hence require that a stocks and flows simulation model is available.

Tool 1: Leverage points for stocks and flows structure

This tool aims to help designers identify potential impacts of leverage points 10) The Stocks and flows structure (Figure 1) and 9) The magnitude of delays (Figure 2). As mentioned previously, a stocks and flows simulation model and some previous systemic insights (or dynamic hypothesis, particularly in terms of bathtub dynamics and feedback loop dominance) are required for using these tools.

This tool is completed by following these steps:

1. Identify all the stocks in the model and write their names above the accumulation drawing.
2. Identify the inflows associated with each stock and write their names in the corresponding space.
3. Identify the outflows associated with each stock and write their names in the corresponding space.
4. Draw the current behavior over time of each stock in the space within the accumulation drawing marked "Current".
5. Draw the desired behavior over time of each stock in the space within the accumulation drawing marked "Desired".
6. Add inflows or outflows to each stock that would allow it to have the desired behavior. For each new flow you add, mark the corresponding box with a check mark.

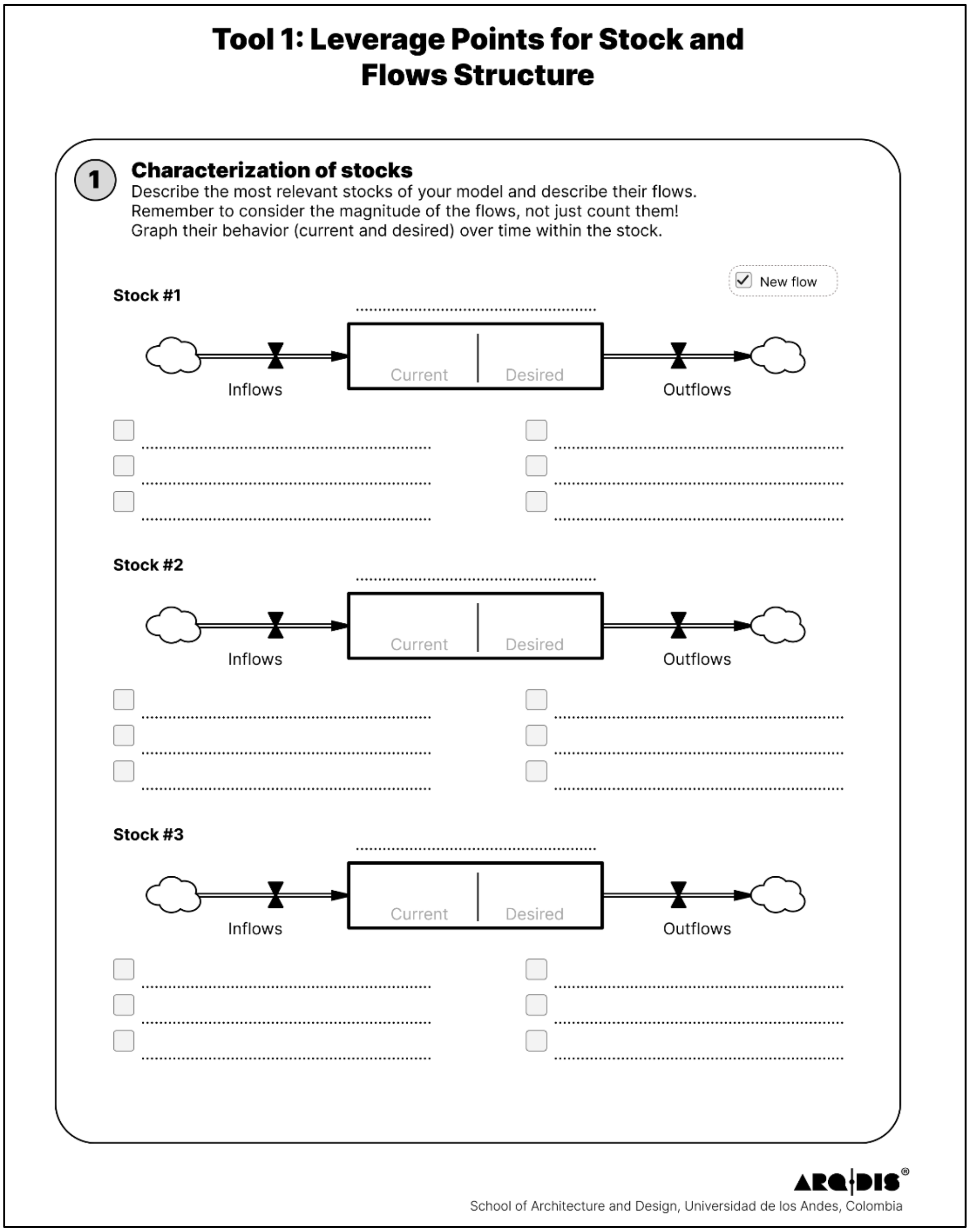

Figure 1. Template for identifying structural leverage point 10.

The second part of the tool is completed by following these steps:

1. Identify all delays in the model. Identify the variable associated with the delay time and the name of the process being delayed.
2. Mark the current value of the delay magnitude with an "X."
3. Define the delay time unit.
4. Mark the desired value of the delay magnitude with a "•."
5. Define operationally how this change in delay time could be achieved. Does the decision-maker have power over this time?
6. Answer what is the expected impact on the difference between flows associated with the stock?

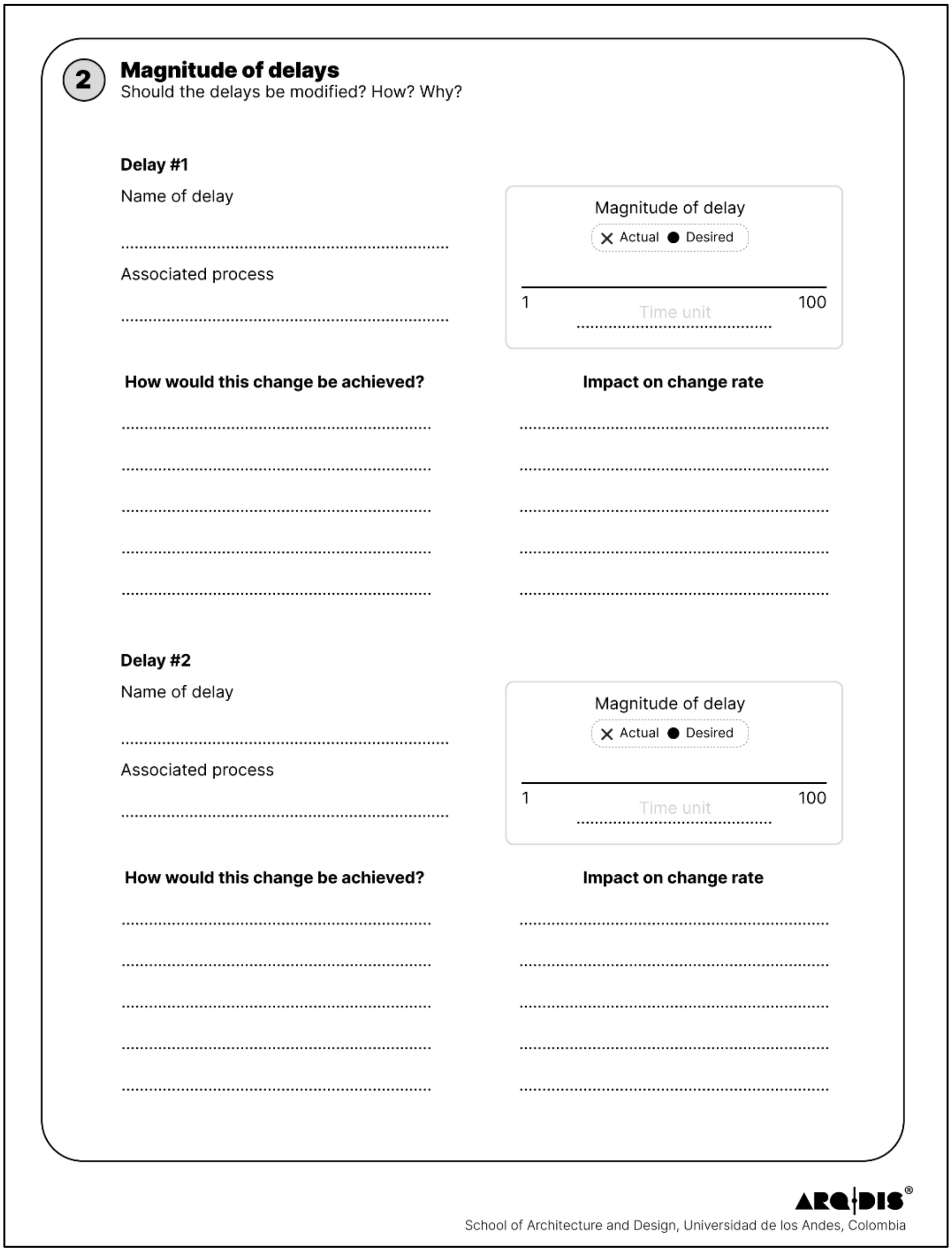

Figure 2. Template for identifying structural leverage point 9.

Tool 2: Leverage points for feedback loops

This tool aims to help designer identify potential impacts of leverage points 8) The strength of negative feedback loops, relative to the impacts they are trying to correct against, 7) The gain around driving positive feedback loops (Figure 3), and 6) The structure of information flows (Figure 4). This tool is completed by following these steps:

1. Enter the name of the variable of interest within the accumulation drawing.

2. For each stage, indicate whether the current net flow associated to the variable of interest is positive (+) (the stock increases) or negative (-) (the stock decreases). Note that each stage has only one behavioral pattern.
3. Considering the client's interest, what would be the desired net flow at each stage? Indicate with a (+) if it should be positive (for the stock to increase), and with a (-) if it should be negative (for the stock to decrease).
4. Indicate the polarities of each loop and consider their dominance in each stage and the role they play in producing the current behavior.
5. Mark with an "X" whether the loop affects the inflow or outflow of the variable of interest (or both).
6. Considering the desired behavior of the net flow and the specific function of the dominant loops at each stage, what opportunities are there to strengthen or weaken the loops? Mark if you would strengthen or weaken it at the specific stage.

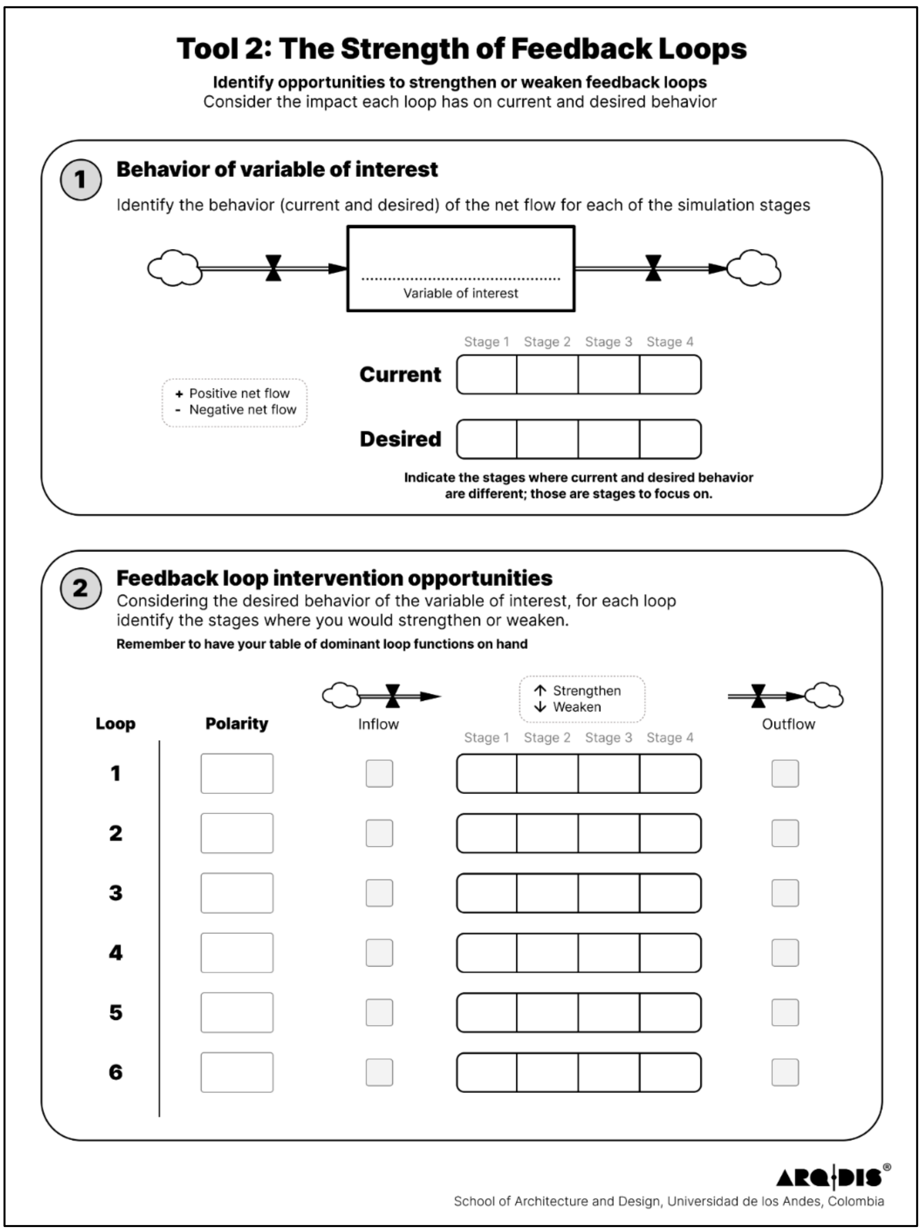

Figure 3. Template for identifying structural leverage points 8 and 7.

Finally, designers are presented with an image of the Stocks and flows model with corresponding feedback loops and are asked to identify if there are opportunities to add new Stocks (leverage point 10), or new information links that create new feedback loops (leverage point 6) (Figure 4).

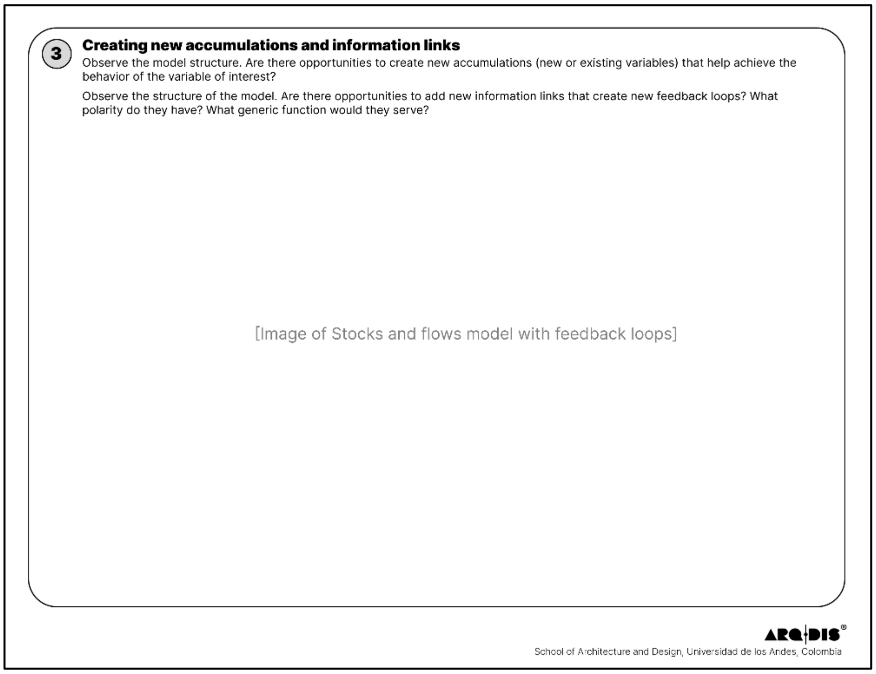

Figure 4. Template for identifying structural leverage points 10 and 6.

IV. Results

Tool testing

The tools were first tested in an academic context using the classroom case regarding auto theft in a city; they have not yet been tested in the context of an ongoing real-world project. Students were asked to accomplish the goal of ensuring that the number of vehicles circulating does not decrease at any time. The use of Meadows' leverage points invites students to look for intervention points in the system structure that are not directly related to the variable of interest.

By the time of the pilot, students had already constructed a dynamic hypothesis based on structural analysis and loop dominance and were required to identify structural leverage points. After piloting some of the most important results were:

Leverage points 10 and 9.

- Most students identified the addition of an inflow to the accumulation of interest as a leverage point. This was because they were seeking to change the accumulation behavior from decreasing (current) to increasing (desired). It should be noted that students are aware that changing stock behavior is not just a matter of the quantity of flows, but of making the magnitude of the sum of the inflows greater than the sum of the outflows (the net flow being positive).
- No student suggested eliminating outflows from the variable of interest, although this would likely produce a desired change in net flow. Students recognized that this type of intervention would result in a transcendental change to the system and would be almost impossible to achieve in operational terms.

- Most students identified leverage points in adding inflows or outflows to other stocks in the system that are not the variable of interest. They added inflows to a stock that had an increasing behavior and had a positive effect on the variable of interest (since it is part of a balancing loop that reduces an outflow). They also added outflows to a stock that had an increasing behavior but had negative effects on the variable of interest (since it is part of a vicious reinforcing loop that increased an outflow).
- Students are aware that stock and flow interventions also modify loop dominance.
- All students identified the change of the magnitude of a delay as a leverage point. This delay was associated with the useful time of vehicles and the way they suggested this could happen shows great diversity: Increase vehicle maintenance, improve the condition of roads, improve driver's license issuance policies, make stricter policies regarding technical and mechanical inspection of cars, promote policies to reduce the number of traffic accidents, reduce the cost of insurance, improve driving culture, improve the quality of driving courses to reduce accidents, improve driving habits, promote the purchase of used cars.

  Leverage points 8, 7 and 6.
- In terms of feedback, most students identified leverage points in strengthening a dominant reinforcing feedback loop that produced desirable effects (virtuous) and weakening dominant balancing and reinforcing (vicious) feedback loops that produced undesirable effects; these effects are positive or negative in terms of the desired pattern of behavior of the variable of interest. Students were divided as to whether they should strengthen or weaken dominant balancing feedback loops. Very few students identified as leverage point to strengthen a non-dominant loop that could produce desirable effects.
- All students that included new information links created balancing loops.

V. Discussion

Although we recognize these tools are not exhaustive in all the possible ways that leverage points can be impacted (they do not prompt for the elimination of stocks, or creation of material delays, or elimination of flows) we consider this is a starting point to invite for thinking in operational ways in which the system behavior can be changed. Piloting of these tools has only been done in an academic setting and has not yet produced significant statistical results – although this will not likely be the aim. These tools facilitate the process of identifying leverage points that will inform the design process. We believe that some of the successes of these tools are:

- They are guiding questions that promote systems thinking. In this sense, we believe that they promote the process of designing interventions based on sound foundations and understanding of the system.
- They invite to think about systemic interventions through connecting structure with behavior. This is relevant for systemic design since it has not traditionally used behavior over time as a design criterion.
- They promote adding inflows to stocks that have desirable effects on the problem to reinforce their positive effect on the behavior of the variable of interest, and outflows to stocks that have undesirable effects to reduce their effect on the variable of interest. We believe this is a recognition of the power of stocks in a system.
- They encourage intervening other stocks that are not the variable of interest. This demonstrates a systemic view of problems and opens up the range of design possibilities within a system.

- They invite creativity in ways to operationalize leverage points. It is not just a matter of changing some numerical values or hypothesizing in abstract terms, but an opportunity to think *how* it could be done.
- They showcase how system change can be leveraged on virtuous loops that produce desired behaviors and the effects of limiting vicious loops.

We also recognize that our tools have some limitations and opportunities for improvement such as:

- Poor identification of new possible reinforcing feedback loops. We recognize that it is easier to think in balancing feedback loops, but we would like to incorporate prompts that invite to think in virtuous feedback as a possible high leverage point of intervention.
- Limited prompts that invite to create material delays and eliminate stocks and flows.
- There seems to be confusion as to when it is better to strengthen or weaken dominant balancing feedback loops. The main nature of these balancing structures makes it difficult to decide, but we would like to develop better heuristics for making these decisions.
- These tools are part of a system of tools, hence require previous development of stock and flow simulation models in order to delve its true potential. They are also dependent on a facilitator that guides the exercise.
- Next steps for the development of these tools would be to develop tools for addressing transcendental leverage points (Leverage points 5-1), design tools to be easily adaptable to the type of model being worked on and also test them in a real ongoing project.

VI. Conclusions

Systemic design has the potential of being enhanced by a more rigorous application of System Dynamics concepts and we believe that there is immense potential for designing tools that promote this. The aim of the research is to leverage the full potential of System Dynamics in design processes considering the dynamic nature of the problems they address and taking advantage of the potential that simulation models can offer. In the case of the tools presented here this rigor is evident in the recognition of leverage points related to stocks and flows and loop dominance, which systemic design does not usually take into consideration. As system dynamicist, but also as designers, we recognize that closing the gap between design thinking and system dynamics through tools that support the design process is a plausible future. From an educational perspective we recognize as success the fact that students are capable of identifying diverse systemic leverage points in relation to developing system thinking competencies. Our aim is to continue to develop tools to transcend the educational space into design practice and to create new tools from interdisciplinary work.

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Annex 1 – Class case model