Tell me ‘how’ or ‘why’ –
A Heuristic to Choose between Qualitative and Quantitative Systems Analysis

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Abstract

The purpose of this paper is to provide a heuristic that can help to decide whether qualitative or quantitative system dynamics modeling is useful in organizational modeling projects. The heuristic depends on the initial problem formulation, in form of a question to be answered. The argumentation is based on conceptual musings and on two short case studies to exemplify the usage of the heuristic. The value of the paper lies in the offering of an easy-to-use approach for a highly relevant decision in practical settings. Further research in this area should focus on a more theoretical distinction between quantitative and qualitative modeling.

1. Introduction

The given paper deals with one of the oldest and still most pressing issues in system dynamics: “when to map and when to model”. While the earlier literature in system dynamics (SD) is quite definite on this point—namely that system dynamics should always be based on quantitative modeling, further on abbreviated as QMOD—, some doubts have been explicated during the last decades. Mostly, proponents of qualitative mapping (further on abbreviated as QMAP) do not deny that deriving behavior from a complex model based on human cognitive skills alone is virtually impossible; their claim is that mapping of system structures per se (i.e., without succeeding simulation) has value (Senge, 1990, Coyle, 2001, Wholstenholme, 2004). In some cases, their argument continues, that it is even preferable to quantification and simulation because—when empirical data is lacking or spurious—simulation results might be distracting or plainly wrong (Coyle, 2000 and 2001). While proponents of a more simulation-focused approach do not doubt the usefulness of mapping, they hardly see reasons to omit simulations as long as resources permit it, because it always adds further knowledge about the system that is studied (Homer and Olivia, 2001). In addition, some methods have been proposed to mitigate possible dangers of quantification (see, for instance, Mooy et al., 2001).

While this issue still awaits general treatment and solution, we propose a heuristic to be used in SD projects to give an indication whether one should aim at quantitative modeling (i.e., the

classical system dynamics approach) or whether a qualitative treatment will be sufficient. The heuristic focuses on the problem articulation step in every SD project. It offers a classification scheme for SD problems and relates each class of problems to either the QMAP or the QMOD approach. To operationalize the classification scheme for each class, a so called guiding question is formulated that has proven to be useful to decide about the method of choice in practical applications of SD. Because only limited work on practical guidelines for deciding between QMAP and QMOD exists (for instance, McLucas, 2000), we deliberately strive for a 90 % approach, meaning we assume our heuristic to be helpful in the majority of cases, without suggesting it to be an optimal decision algorithm in every respect.

The motivation for the paper stems from the difficulties that arise in many projects when project members do not know at the projects' set-up if they should aim for quantification or qualitative mapping. Another circumstance in which the heuristic might be helpful is the situation, when a project has already taken-off and the project team gets stuck and asks if they should proceed with quantification or qualitative work. In such situations, the heuristic might be helpful to refocus by applying the proposed guiding questions. The target group for the paper is thus the SD practitioner, but we believe that the question of why the heuristic is useful might also be of interest for the more scientifically inclined reader.

The paper is structured in three major parts. It starts with a short discussion of the difference between QMAP and QMOD and some terminological remarks in that context. After that, we introduce our heuristic problem classification scheme. The heuristic's usage and usefulness is illustrated in the following section of the paper based on two case studies from SD projects, where the heuristic has offered a chance to pre-estimate whether quantitative mapping or qualitative modeling would be appropriate. The paper closes with some brief conclusions and issues for further research.

2. Qualitative mapping versus quantitative modeling

In the SD literature there is no clear consensus about a standard terminology describing the two operational modes of SD. For the qualitative operational mode there are for example at least three terms in use: qualitative mapping, qualitative modeling and in some contexts the term system thinking can be found. Especially the latter term, which was used in this context by Senge (1990), is misleading, as there exists a full body of literature outside of the SD community, which uses this term to describe all systems techniques in the field of Soft Operations Research, of which SD can be seen as a subset (Lane, 1994). This situation is unfortunate as it complicates the communication about the mode of operation in SD projects. Therefore, in the remainder of this paper we will use the following terminology: qualitative mapping (QMAP) and quantitative modeling (QMOD), acknowledging that actually these are the extremes of a continuum (Wolstenholme, 1999).

We will understand QMAP in this context as the effort to understand the causal structure (including feedback loops) of a system of interest via qualitative tools like Causal Loop Diagrams, Policy Structure Diagrams, and Stock and Flows Diagrams (without quantification). QMAP does not comprise the quantification of parameters or variable relationships in the diagrams that are constructed. This also means that it only relies on the use of qualitative policy and decision descriptions and on mental simulation of dynamic effects. QMAP should not be mistaken with a rather specific and distinct simulation approach which is called 'qualitative simulation', stemming from the field of artificial intelligence (Dolado, 1993).

In contrast to QMAP, quantitative modeling (QMOD) refers to the effort of understanding the complex dynamic behavior of a system (including the relationship of the systems behavior to the policies that are applied to steer the system) via quantitative modeling. It is characterized by the use of Stock and Flow Diagrams (SFDs), the quantification of model parameters and variable relationships, the quantification of policy and decision concepts, as well as the statistical analysis of simulation outputs.

3. How to define and categorize a system dynamics problem

The heuristic that we want to propose here is based on the observation that every organizational SD project must start with a clear problem articulation. It proposes to implement this problem articulation step by the help of two guiding questions that—if found appropriate—define a given problem as either being of a qualitative or a quantitative nature.

Based on this classification scheme, the heuristic recommends the use of qualitative mapping (QMAP) in the case of a structural problem and the use of quantitative modeling (QMOD) in the case of a dynamic problem. With this approach, we follow Richardson's (2001) notion that mapping supports structural insights and modeling can yield dynamic insights. The heuristic avoids the quasi-religious "to map or to model" debate that often complicates the process of using SD in a project and which was shown to not being helpful (Wolstenholme, 1999). Rather, we try to link the right problems to the right methodology instead of trying to support the use of either approach in an "either or" fashion for every problem one can think of.

The guiding questions of the heuristic can be stated as follows:

- **QMAP-question:**

  How are variables X1, X2, X3 … causally related?

  A QMAP problem is usually a structural problem (focus is on closed causal feedback loops)!

- **QMOD-question:**

  Why has (have) variable(s) X (X1, X2, X3 …) („reference mode") developed this way between times T1 and T2 („time horizon")?

  A QMOD-problem is usually a complex dynamical problem!

One should note, however, that the heuristic is applicable only, when the result of the modeling project are supposed to be insights into the structure and/or structure-behavior relationship of an issue. If exclusively the past or future behavior of a variable is to be replicated or forecasted ("how has variable x developed?" or "how will variable x develop?"), we do not consider system dynamics as the primary method of choice to answer this question. The heuristic cannot be used reasonably for this kind of projects.

As the heuristic puts emphasis on a very structured beginning of an SD project, it seems worthwhile to complement the above stated guiding questions by some additional questions that one might ask before starting an SD project. These additional questions have been

developed together with the guiding questions in the course of our practical applications of SD in the last years and have proven very helpful to facilitate a focused and problem oriented project start. A list of these questions and a proposal for a documentation scheme that can be used in the project definition phase is displayed in Figure 1.

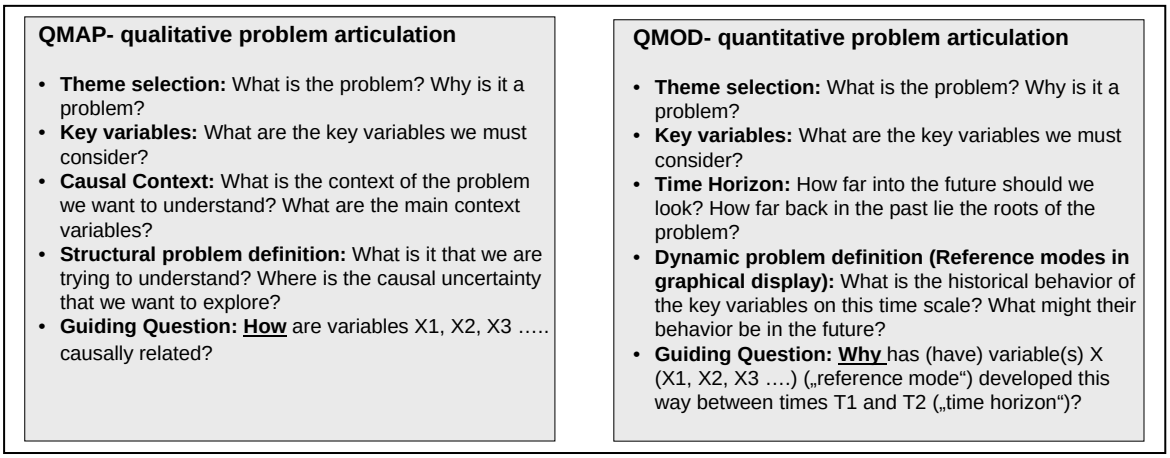

Figure 1: Problem articulation and documentation template for the proposed heuristic to distinguish between qualitative and quantitative SD problems

4. Examples

To illustrate the use of the above described heuristic, we will present in the following two short descriptions of case studies that were conducted at Lufthansa German Airlines (further on called Lufthansa) in the frame of a strategic program called “Future European Operations”.

The goal of the first case study was to investigate the relationship between the main levers of a sales department at Lufthansa to the overall costs that are related to the efforts of the sales department. The exercise was conducted in the form of a group modeling session, which was performed with six participants in a single workshop of approximately three hours duration. The guiding question that was put in place for this exercise and that qualified it for a QMAP process can be stated as follows:

“*How are the main levers of the sales department causally related to the overall cost caused by the sales department at Lufthansa German Airlines?”*

It shows the typical “how” character of the problem articulation phrase and is thus eligible for a QMAP approach. The result of the workshop was a single Causal Loop diagram (see Figure 2) that displayed nicely the causal relationship and loops that are contained in the above problem articulation. The resulting CLD was judged to be very helpful by the participants of the workshop because of the following characteristics:

- Structural clarity of the causal relationships,
- Surprising structural complexity of the map—especially the number of loops (displayed in Figure 2 as the numbers in the red boxes) that are connected to the main variables of the map surprised all participants,

- Discovery of a cost number that was influenced but not controlled by the sales department,
- Quality of the discussion that took place while the map was constructed.

It is interesting to note that the participants of the workshop did not feel the need to continue in the exercise with some form of quantification, but they were very satisfied by the results achieved. This clearly points to the fact that the given problem was qualitative in nature and was thus addressed in an adequate way by the chosen QMAP approach.

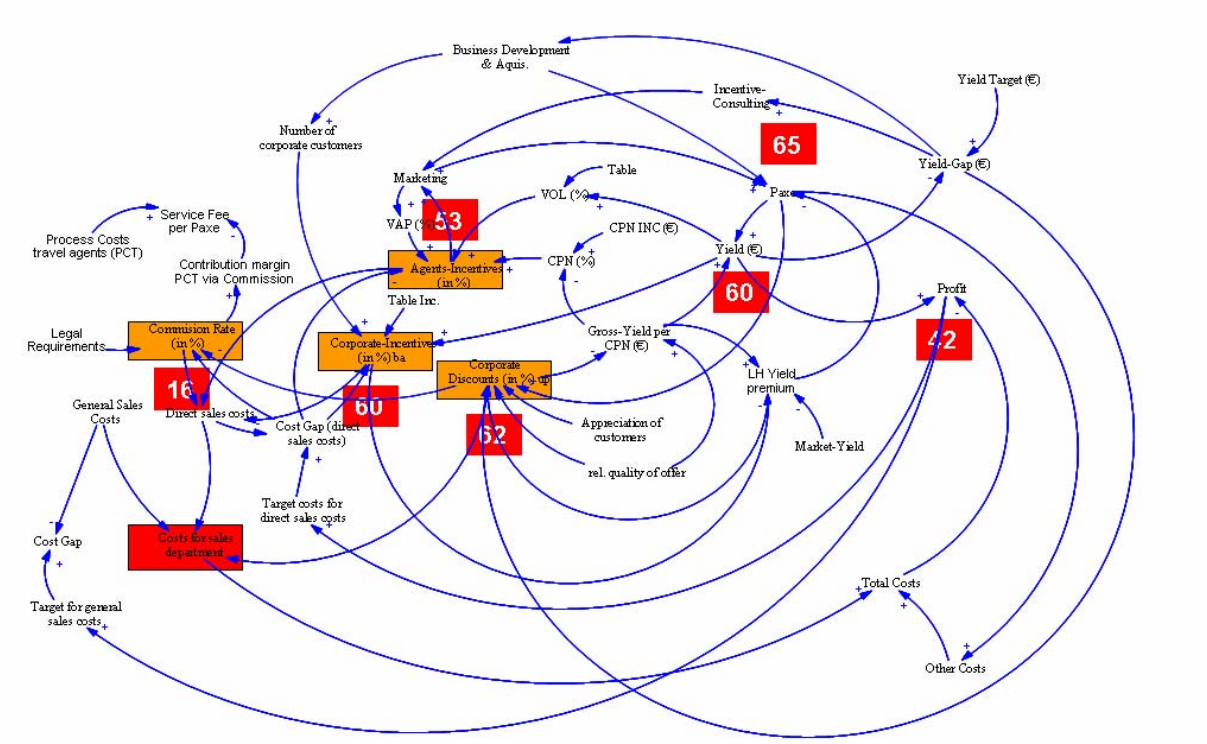

Figure 2: CLD that resulted from a three hour workshop with the project team in Case Study 1

The other case study refers to a longer SD project that was also performed in the framework of the "Future European Operations" program at Lufthansa. This project was related to the problem of right sizing the cockpit personnel. The project was motivated by the fact that the relationship between supply and demand for cockpit personnel showed a typical 'bullwhip' pattern (Forrester, 1961), over the last years. Therefore the guiding question for this project might be formulated as follows:

"Why does the relationship between demand and supply for cockpit personnel at Lufthansa show a 'Bullwhip Effect' of the magnitude observed in the last 15 years?"

This problem articulation has the typical "why" character and therefore qualifies for a QMOD approach. Thus, in the project the use of quantitative modeling appears to be favorable and was implemented in the actual project process that also led to some interesting dynamical insights (e.g. sensitivity of duration of training times on the overall personnel productivity). The core structure of the developed model is displayed in Figure 3 in form of an aging chain for the cockpit personnel at Lufthansa.

Again the experience in this project supports the idea of the heuristic: that the formulation of a guiding question can be helpful to decide which SD process is adequate for the problem at hand. In the case of this project the heuristic would have clearly suggested the use of a QMOD approach, which in practice was also chosen to be the process of choice.

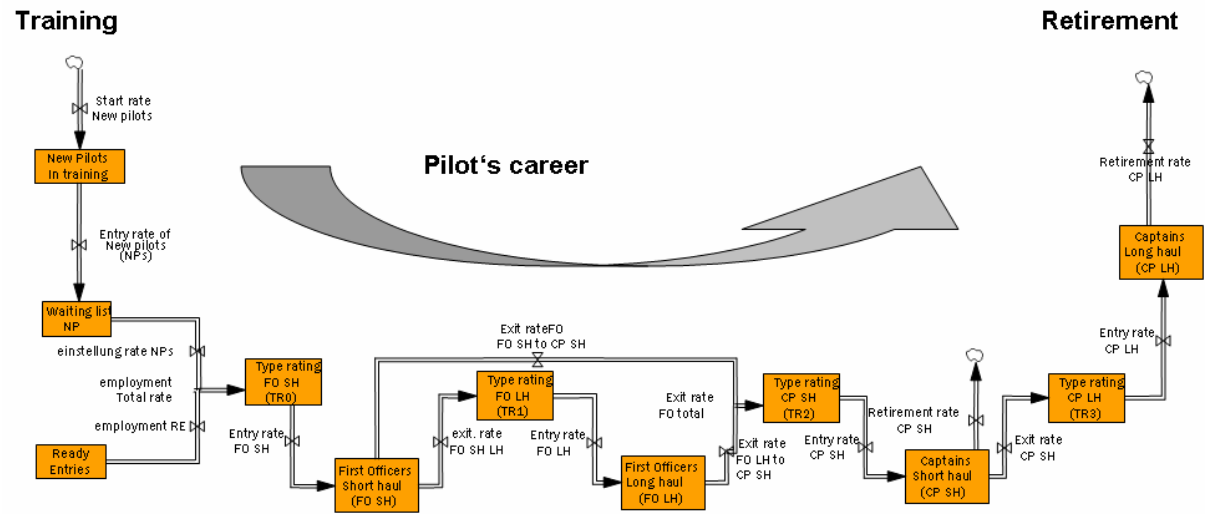

Figure 3: SFD of the pilot aging chain as it was documented in the framework of Case Study 2

Summarizing the insights of these case studies one can state that the proposed heuristic can support a clear problem articulation at the start of a given SD project and thus can help to find an adequate process approach for a problem at hand. Through this support the heuristic also clearly increases the chances of a successful process as it helps to focus on a suitable approach right at beginning of an SD project and consequently also helps to minimize the usage of given resources.

5. Conclusion and further research

If we summarize the findings of this paper we can state the following major insights and strands for further research:

- The question of whether a given SD project is trying to address a qualitative or a quantitative problem can be answered via the proposed heuristic.
- QMAP or QMOD are two modes of operation in an SD based projects and are not in conflict to each other, but are the tools of choice for their respective types of problems.
- The answer to the old question "to map or to model" does not lie in a tool discussion but must be looked for in the problem perception of the person or group that defines the character of a given SD problem. So, a discussion about the experience you have while using both tools in different contexts does not really clarify the issue. Only when you start thinking about your motivation for action, then you have the chance to choose the right tool in a conscious way. QMAP and QMOD are in that respect

complementary process designs that can be related to two distinct problem perspectives and thus represent two modes of observation.

- In addition to the last issue, also the target group of an organizational modeling project might make a difference. In other words, even when the question to be answered is the same, the methods might differ depending on the experience, personalities, power, and hierarchical position of the people involved (Wolstenholme, 1999; Powell and Coyle, 2002). Thus far, our heuristic does not take into account such differences.
- In many real world projects, qualitative and quantitative methods are combined. Does this imply that actually two questions are to be answered with the project? Or, is one mode (for instance, QMAP) the necessary precursor of the other (i.e., QMOD) and what are effective ways of their combination?

These conclusions clearly ask for further research on the topic of how to define an SD problem and how to approach it after its definition in the most suitable and effective way. Additionally, it seems worthwhile to focus more sharply on the question of what problems are actually SD problems and what and who makes them an SD problem. Finally, it seems that also the observer behind the "SD-camera" must become the focus of our attention, to be able to further enhance the use of SD for practical applications.

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