Information Value Production of Influence Diagrams versus Level-Rate Models: The Perception of Decision-Makers [†] [‡]

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Abstract

This paper examines the debates on the use and contribution of influence diagrams, or the display of more qualitative dimensions of feedback structures, versus the use of level-rate models or quantitative models in system dynamics (SD). The question of interest in this paper relates to the perception of decision-makers on the use value of influence diagrams and of level-rate models. This paper aims to understand the perception of decision-makers familiar and unfamiliar with SD methods, on these issues as raised in the SD literature by Coyle (2000, 2001) and Homer and Oliva (2001). This paper reports on an exploratory research that analyses the statistical significance, or lack thereof, in comparing the viewpoints of two groups of decision-makers; one that had familiarity with SD and one that had not. The results are mixed, and by an interesting twist, substantiate some dimensions of the opinions of both Coyle (2000, 2001) and Homer and Oliva (2001).

Keywords: influence diagrams, level-rate models, decision-makers, computer models, perceptions, information.

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Introduction

The system dynamics (SD) literature has questioned the genuine contribution and added value of SD methods and models. In particular, there have been recent debates about the use and contribution of influence diagrams, which display qualitative structures of feedback loops, versus the use of level-rate structures or quantitative models. On the one hand, Coyle (2000, 2001) emphasizes that information risks may be greater for the model end-user if the quantification of variables leads to erroneous results. For example, this may refer also to models that include variables quantified with "soft" data and information. On the other hand, Homer and Oliva (2001) state that quantification almost always adds value to the study of a problem, including the careful use of "soft" data, and that influence diagrams (ID) are insufficient for analysis.

This debate is not new and can be found under various forms in the management information systems literature. For example, research on decision support systems has found that decision-makers are more likely to lend credibility to "soft" information like anecdotes, rumors, and informed opinions, than to results produced by computerized decision support systems (Silince and Saeedi, 1999). However, the literature emphasizes that decision technology and human intuition can be used as complements: both have inherent strengths and weaknesses (Hoch, 2001). A corporate anthropology perspective would submit that a model in itself has little or no value, but that relationships amongst model users are more important in generating knowledge and "shared vision". Individuals tend to "believe" in models they have developed themselves, or in models developed by individuals they "believe in"; or who are, in their view, credible model builders (Schrage, 2000). It is important to recognize, this debate takes place amongst, and opinions are issued, by researchers, rather than by decision-makers or expert users themselves.

To take the debate beyond discussion, this study examines the perceptions of decision-makers regarding the use value of influence diagrams compared to the use value of level-rate models. The objective of the paper is to compare the perceptions of decision-makers familiar and unfamiliar with SD methods, and to analyze in part how their perception relate to the issues raised in the exchange between Coyle (2000, 2001) and Homer and Oliva (2001). The remainder of this paper reports on an exploratory study of the perceptions of two groups of decision-makers: one that had familiarity with SD and one that had not. In the next section, the design employed in the research process is described. A summary of empirical results is presented, and a conclusion follows.

Research Design

The conceptual framework for this study follows from the hypothesis by Raghunathan (1999) that raw data and expertise can be processed through information technology (IT) to generate results that can be further processed by decision-makers to support decision-making (see figure 1 below).

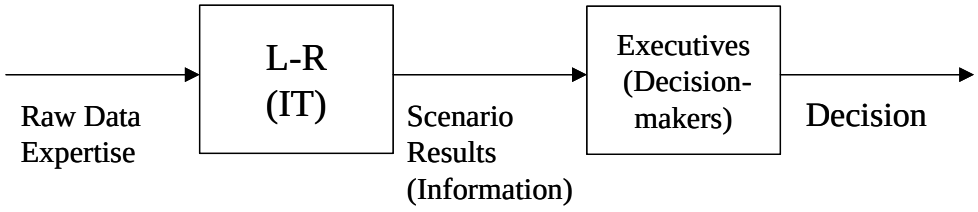

Figure 1. Production decision model (adapted from Raghunathan, 1999)

Five main steps were followed in the research design:

1) Development of an SD model (including an ID, a level-rate model, and simulation results);
2) Presentation of models to participants familiar and not familiar with SD;
3) Development of a questionnaire;
4) Administration of a questionnaire to participants; and
5) Analysis of the results from the questionnaire using simple means test.

First, an SD model was designed according to the approach detailed in Roberts et al. (1983), similar to the one by Sterman (2000). A context for a problem, the influence diagram, and a level-rate model were specified and calibrated. The situation structured in the model is analogous to the one presented in Goodman (1989) on the dynamics of a housing community. This new model was calibrated to show the dynamics of the widely publicized rental housing shortage (or "crisis") for particular markets segments that has existed in the City of Montreal area (Quebec, Canada) for a number of years. The model by Goodman (1989) was chosen because of its intuitive appeal for describing this well-known housing situation, but mostly for its generic character that could be adapted to a situation familiar to potential groups of participants in the study. Moreover, it contained "soft" elements that could help a potential participants appraise the "value" of having this type of information as part of a model. Finally, the model can be displayed on a simple slide during a presentation, making it easier for participants to see the "whole" picture and all feedback relationships involved. The model was calibrated with historical secondary data sources (Statistics Canada; 2001a,b; *Société de l'habitation du Québec*, 2000, 2002a, 2002b, 2003; Canada Mortgage and Housing Corporation, 1992-2002, *Institut de la statistique du Québec*, 2002a, 2002b; newspaper and magazine articles, etc).

The structure of the original Goodman (1989) model was slightly amended to account for the situation in the new market to which it was applied. For example, Goodman's (1989) feedback loop illustrating the availability land going into development is not an issue in the Montreal market so was removed from the model. Because the model was mainly concerned with the rental housing market, rather than the overall housing market, two more feedback loops were added as displayed in figure 2. One feedback loop accounts for the outflow of the rental population from the rental market to the property market. The second feedback loop accounts for the incoming population from other regions in the province or from immigration.

These two changes were necessary to insure that the model would reproduce credible results with respect to the times series available for the 1992-2001 period and to appraise results generated by the model. The two "soft" elements in the original model, that is the "attractiveness for migration multiplier" and the "housing construction multiplier", were incorporated into this new model taking the same values as in the original model (Goodman, 1989). The model was subjected to a series of sensitivity analyses to examine of the congruence between the historical data available and the results produced by a "business as usual" simulation depicted by the movement of the level variables in the model. The modified Goodman level-rate model is shown in figure 3.

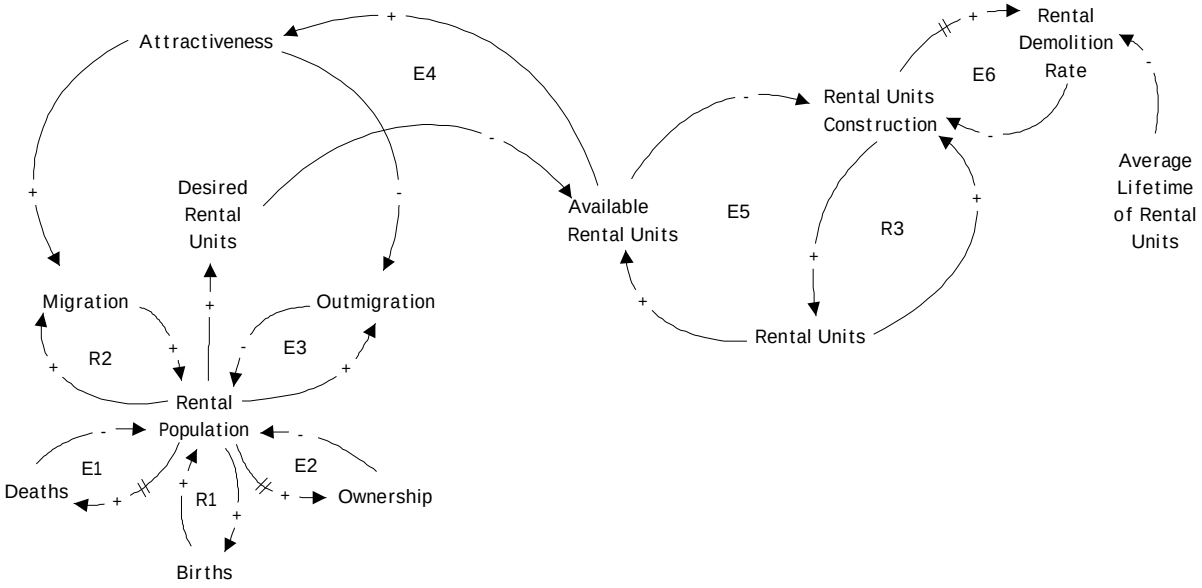

Figure 2. Influence diagram of rental housing dynamics

Second, a presentation was elaborated to describe all the elements of the model for participants. The presentation included an overview of the SD modeling process, and emphasized for the participants the intricacies of applying the SD approach. A particular emphasis was placed on detailing the feedback loop structure using the influence diagram, and for describing the level-rate model (including the use of soft variable relationships). The historical congruence of the model was presented for the 1992-2001 period, and three "scenario" results obtained from the level-rate model were presented. These scenarios amount to a comparison of sensitivity analyses looking at exogenous parameter changes on three topics: (1) the expectation of an increase in normal construction, (2) the expectation of an increase in migration, and (3) the expectation of a life-style change affecting the number of units per person.

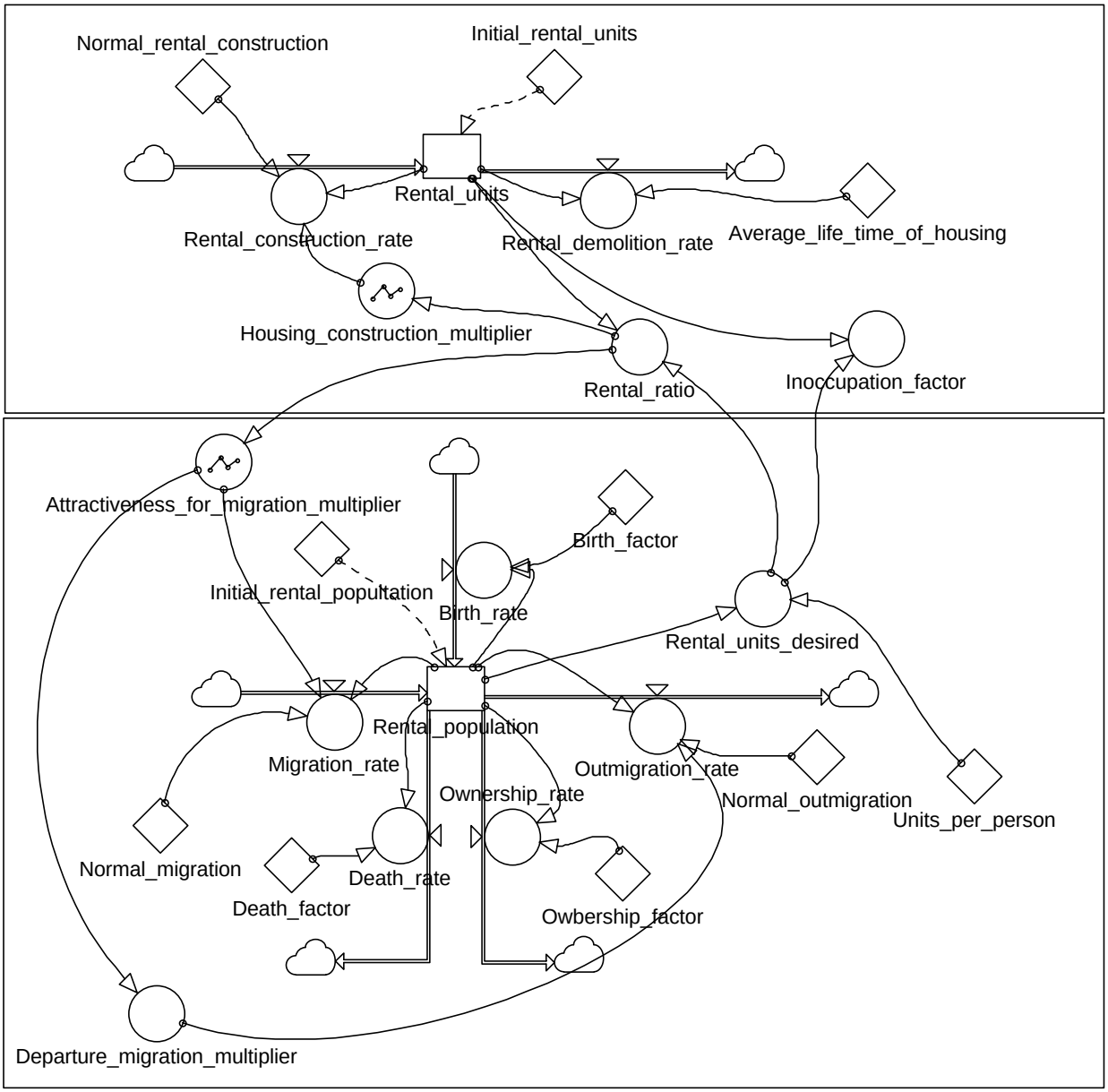

Figure 3. Level-rate model of rental housing dynamics

Third, a questionnaire was designed with structured and semi-structured questions. Questions addressed several topic areas: (1) participants' previous training in decision technology in general and their professional use of such software, (2) their perceptions of the influence diagram, (3) their perceptions of the level-rate model, (4) comparisons of their perceptions between the influence diagram and the level-rate model, (5) an open-ended question asked the participants to make a choice between the ID and the level-rate models and to justify that choice. The questions from (6) to (9) asked about socio-demographic information (years of experience, nature of the position held (operational, tactical, strategic), etc.). Questions (2), (3), and (4) were structured-type questions with responses on a Likert-type scale from 1 to 5

(ranging from "strongly agree" to "strongly disagree"). The formatting, general layout, and ordering of questions followed recommendations found in Dillman (1999). The questionnaire was pre-tested once with a group of 19 participants, all candidates in a master's program in MIS at the University of Quebec at Montreal. These pre-test participants were graduate students enrolled in a research methods seminar who had received training on the design and administration of questionnaires in the previous weeks. One advantage of that group, in addition to the fact they were familiar with general principles of questionnaire design and administration was that it possessed a group profile similar to the profile of potential participants. Some of the participants had taken an SD course in other settings. Several comments were made about the presentation and the questionnaire; and both were subsequently refined in preparation for data collection.

Fourth, presentations were made and the questionnaires were administered during the fall 2003. This led to many challenges. First, it was difficult to find a group of participants familiar enough with SD to be able to lend judgement on these methods, a requirement of the study. Second, because of scheduling and other difficulties it was not possible to have all participants attend the presentation and participate in the data collection session at the same time. The presentation and the questionnaire had to be repeated, and thus, a written script was developed to follow each time. The participants identified were mostly executive MBA candidates attending a degree program. The presentation was shown to a group of executive MBA candidates at the University of Quebec at Montreal that had taken a 3 credit SD course (in which they were trained with a dedicated software and completed a major case study of a technology enterprise in which they elaborated an influence diagram, built and calibrated a quantitative model). The SD group included 27 participants, and the RE group had a total of 20 participants. The RE group consisted of experts on the subject matter of the model: real estate. The questionnaire was repeated twice to insure a sufficient number of participants with this expertise. These groups included executive MBA candidates specialized in real estate (RE) management and a group of senior analysts and directors at the Canada Mortgage and Housing Corporation. The presentation and data collection process were executed three times, excluding the pre-test.

Fifth, the data collected was summarized using descriptive statistics and simple tests on the homogeneity of the variance, prior to conducting tests on the mean (Student and Aspen-Welch[1] *t* tests), to compare results between the two groups of participants.

Research Results

This section presents the results of the research in three parts. The next section examines participants' perceptions of the information produced by influence diagrams. Then results about perceptions of level-rate models to support decision-making are detailed. Perceptions of soft variables used in level-rate models are examined. The last section concludes with the

[1] The Aspen-Welch t-test was used to calculate the t ratio when the difference in the variance between the two groups of participants for a particular question, as determined by Levene's F-test, was shown to be statistically significant.

participants' perceptions of the information produced by the influence diagram and the level-rate model.

Perceptions of influence diagrams

Results for the three questions addressing participants' perceptions of the information produced by influence diagrams are presented in table 1. In all cases, the variance was found to be non-homogeneous ($\rho = 0.05$). For all three questions, the mean difference between the two groups was statistically significant.

The SD participants were more likely to agree with the statement that an influence diagram helps understand a system, while RE participants were neutral, showing a statistically significant difference between the groups ($\bar{x}_{SD} = 2.21$, $\bar{x}_{RE} = 3.00$, $\rho = 0.004$). The results obtained for the statement that an influence diagram would help make a decision were almost the same as for the one on helping understand a system ($\bar{x}_{SD} = 2.23$, $\bar{x}_{RE} = 3.15$, $\rho = 0.003$).

The RE participants were less likely to perceive a more intuitive prospective inference from influence diagrams than SD participants, showing a statistically significant difference between the groups ($\bar{x}_{SD} = 2.00$, $\bar{x}_{RE} = 2.74$, $\rho = 0.019$).

Table 1 : Perception of the information produced by influence diagrams[†]

Statement	Mean		Levene's F test – homogeneity of variance		t test between two means	
	$\bar{x}_{SD}$	$\bar{x}_{RE}$	($\rho = 0.05$)	Interpretation	($\rho = 0.05$)	Interpretation
The information produced by an ID helps understand a system	2.21	3.00	0.000	Reject Ho	0.004	**Reject Ho**
The ID would help you make a decision	2.23	3.15	0.047	Reject Ho	0.003	**Reject Ho**
The ID allows for a more intuitive prospective inference	2.00	2.74	0.004	Reject Ho	0.019	**Reject Ho**

[†] The results are calculated by the mean on the Likert scale defined as follows: 1: strongly agree, 2: agree, 3: neutral, 4: disagree, and 5: strongly disagree.

The results of analysis showed that participants with an SD background tend to perceive influence diagrams positively, but only mildly so. However, SD participants rated the influence diagram more positively than the RE participants on this set of questions. The SD group perceived influence diagrams as reliable information sources to describe the structure of a system, while the RE group remained neutral.

Perceptions of level-rate models

The second set of statements, reported in table 2, examined perceptions about the use of level-rate models and results by both SD and RE participants. The goal of this set of questions is to appraise whether decision-makers have confidence in the information produced by computer-based level-rate models.

In response to the statement about the information produced by the level-rate model helps understand a system, the results showed no statistically significant differences between the means for the two groups of participants. Both SD and RE participants are leaning towards agreement ($\bar{x}_{SD}$ = 2.18, $\bar{x}_{RE}$ = 2.67, ρ = 0.09).

On whether level-rate models add a useful value to decision-making, the difference between RE participants and SD participants were found statistically significant different ($\bar{x}_{SD}$ = 2.00, $\bar{x}_{RE}$ = 2.50, ρ = 0.044). The SD participants clearly agreed with the statement, while RE participants were at mid-point between agree and neutral.

In response to the statement on whether level-rate models are a rational technological mean to conduct convincing analyses, similar results were obtained than for the previous question. In this case, SD participants were near agreement and RE participants near neutral, showing even stronger statistically significant differences between both groups ($\bar{x}_{SD}$ = 1.96, $\bar{x}_{RE}$ = 2.85, ρ = 0.003). The SD group perceived level-rates models add useful value for decision-making and that computer technology helped support convincing analyses.

One question addressed the issue of multiple data sources used in model calibration and the potential for misleading results. The result to this question showed no statistically significant differences, but SD participants were at mid-point between disagree and neutral, while RE participants were neutral ($\bar{x}_{SD}$ = 3.50, $\bar{x}_{RE}$ = 3.05, ρ = 0.09).

The two statements about "soft" variables in level-rate models generated a set of mixed results. In response to the statement that soft variables in the level-rate model make scenario results improbable, SD participants were was at mid-point between neutral and disagree, while RE participants were neutral ($\bar{x}_{SD}$ = 3.50, $\bar{x}_{RE}$ = 2.90, ρ = 0.032). However, this difference between the two groups of participants was sufficient to obtain a statistically significant difference. But, both groups of participants were neutral on whether the soft variables included in the level-rate model would make scenario results more realistic ($\bar{x}_{SD}$ = 2.81, $\bar{x}_{RE}$ = 3.00, ρ = 0.45). It can be concluded that SD participants rejected the notion that "soft" variables made scenario results improbable, but both groups did not perceive that results were more realistic due to soft variables. These results challenge the arguments by Coyle (2000), that the quantification of soft variables might be misleading, and by Homer and Oliva (2001) that SD can handle soft information.

Table 2: Perception of the information produced by level-rate models[†]

Statements	Mean		Levene's F test – homogeneity of variance		t test between two means	
	$\bar{x}_{SD}$	$\bar{x}_{RE}$	(ρ = 0.05)	Interpretation	(ρ = 0.05)	Interpretation
The information produced by the L-R model helps understand a system	2.18	2.67	0.018	Reject Ho	0.090	Accept Ho
The results from the L-R model add a useful value to decision-making	2.00	2.50	0.157	Accept Ho	0.044	**Reject Ho**
The L-R model is a rational technological mean to conduct convincing analyses	1.96	2.85	0.001	Reject Ho	0.003	**Reject Ho**
The L-R model is calibrated with multiple data sources and results can be misleading	3.50	3.05	0.968	Accept Ho	0.090	Accept Ho
Soft variables in the L-R model make scenario results improbable	3.50	2.90	0.786	Accept Ho	0.032	**Reject Ho**
Soft variables in the L-R model make scenario results more realistic	2.81	3.00	0.451	Accept Ho	0.453	Accept Ho

[†] The results are calculated by the mean on the Likert scale defined as follows: 1: strongly agree, 2: agree, 3: neutral, 4: disagree, and 5: strongly disagree.

Perceptions of influence diagrams and level rate models compared

The set of questions in table 3 aimed at studying the perceptions of both groups regarding influence diagrams compare to level-rate models.

The first statement asked participants to rate whether "The ID and the results from the L-R models are complementary". The SD participants responded near agree, but RE participants were at mid-point between agree and neutral. This resulted in a statistically significant difference of opinion between the two groups of participants groups ($\bar{x}_{SD}$ = 1.73, $\bar{x}_{RE}$ = 2.45, ρ = 0.003).

The influence diagram and the level-rate model were neutrally perceived to be reliable information sources for understanding the real estate rental market amongst RE participants, while SD participants were more in agreement with the statement, resulting in a statistically significant difference ($\bar{x}_{SD}$ = 2.35, $\bar{x}_{RE}$ = 3.15, ρ = 0.013).

Table 3: Perception of the information produced by influence diagrams and level-rate models[†]

Statements	Mean		Levene's F test – homogeneity of variance		t test between two means	
	$\bar{x}_{SD}$	$\bar{x}_{RE}$	(ρ = 0.05)	Interpretation	(ρ = 0.05)	Interpretation
The ID and the results from L-R models are complementary	1.73	2.45	0.351	Accept Ho	0.003	**Reject Ho**
The ID and the results from the L-R model are reliable information sources to understand the real estate rental market	2.35	3.15	0.043	Reject Ho	0.013	**Reject Ho**
The results from the L-R models have more information value than the ID	1.77	2.25	0.646	Accept Ho	0.074	Accept Ho

[†] The results are calculated by the mean on the Likert scale defined as follows: 1: strongly agree, 2: agree, 3: neutral, 4: disagree, and 5: strongly disagree.

Finally, both groups were rather in agreement in response to the statement about whether the results from the level-rate models have more information value than influence diagrams, for which SD participants and RE participants have shown no statistically significant difference ($\bar{x}_{SD}$ = 1.17, $\bar{x}_{RE}$ = 2.25, ρ = 0.074). But the means showed a trend towards an agreement between the two groups of participants, which would support the arguments of Homer and Oliva (2001), leaning towards quantification.

Conclusion

The goal of the research was to take a closer look at the debate about the use of influence diagrams, which are qualitative representations of feedback structures, and of level-rate models and results, which are quantitative output from quantitative simulation, to help with decision-making.

The issues raised by the debate in the SD literature are found also in other fields. The goal of the research presented here is to help improve our understanding of the information needs of decision-makers. Most, studies have provided comments on the debate using the experience and opinion of academic researchers. As was seen, taking the issues to decision-makers introduced a new perspective to the debate. It also highlighted possible difficulties involved in the process of assessing the relative contribution of both the influence diagram and the level models independently or in conjunction.

In particular, the results showed that across all three sets of questions examined, the SD group tend to be more enthusiastic about SD-related methods than the RE group. For example,

familiarity about the method created less doubt about the contribution of influence diagrams to describe a system amongst SD participants, while the lack of prior exposure to influence diagrams by participants in the RE group did not help convince them of they had much informational value. In general, quantitative information seemed to fare better with both groups.

Further research on this topics will help understand how the fit between the SD method, including, influence diagrams and formal level-rate models and the information needs of decision-makers can be improved or better satisfied.

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