

Nothing so practical as a good theory; Five ways to use system dynamics for theoretical contributions

Vincent de Gooyert

Institute for Management Research, Radboud University

P.O. Box 9108, 6500 HK, Nijmegen, The Netherlands

Telephone: +31 (24) 361 55 78

E-mail: v.de.gooyert@fm.ru.nl

Abstract

The ubiquitous practical relevance of system dynamics makes it easy to overlook the scientific impact that system dynamics has had. Studies on building theory with simulations suggest that there are very different ways of arriving at a theoretical contribution, which brings up the question how system dynamics is used to arrive at theoretical contributions. This paper provides a systematic review of system dynamics based theoretical contributions in management theory between 1990 and 2016. The results help pointing out which ways have proven to be specifically helpful for contributing to theory with system dynamics, and which opportunities for the future still exist.

Keywords: literature review, theoretical contribution, management literature

Word count: 3.677

Introduction

The practical impact of system dynamics is widely acknowledged. System dynamics has shown to be capable of delivering huge real world impacts, amongst others by sparking debates through delivering new insights, and by saving organizations and societies millions of dollars or more through providing high quality policy options. Because of its ubiquitous practical relevance, it is perhaps easy to overlook the *scientific* impact that system dynamics has had. This would be very unfortunate, because the impact *inside* academia, although not as much in the limelight as the impact outside academia, certainly has left its marks. Especially the management literature has seen considerable theoretical contributions that were derived from system dynamics based studies, as can be seen by the Jay Wright Forrester awards that have been awarded in this domain. In management theory, system dynamics has shown to be an excellent methodology for showing how existing theories are flawed, for extending existing theories, and building new theories in unexplored terrain.

To make sure system dynamics' practical impact does not draw our attention too much away from its scientific contribution, this paper provides a systematic review of the several ways in which system dynamics has been impacting management theory. In

doing so, this study helps smooth the way for future contributions, by showing what has worked in the past, and what opportunities can be discerned towards the future.

Background

Before we can answer the question how system dynamics helps arriving at theoretical contributions in management theory, we have to know what a theoretical contribution in management theory in general entails. According to Whetten (1989, building on Dubin, 1978) a theory consist of four elements. A comprehensive and parsimonious description should be given of *what* (variables, constructs, concepts) explains a phenomenon of interest, *how* the factors are related, *why* they are related (what are the underlying causal relationships), and for which contexts (*who, where when*) these relations hold (Whetten, 1989, p. 490-492). Whetten (1989) then adds that the most fruitful and at the same time the most difficult contributions take place in finding new answers to questions as to *why* factors are related (Whetten, 1989, p.493). In general, this description of a theoretical contribution should appeal to system dynamicists, since identifying the causal relations responsible for phenomenon, either through causal loop diagrams or stock and flow diagrams, is often at the core of our research (Sterman, 2000).

More recently, Harrison et al., (2007) discussed how simulation modeling can help at arriving at theoretical contributions in management research. They distinguish between three types of simulation models: system dynamics models, agent-based models, and cellular automata models (Harrison et al., 2007, p. 1237-1238). Building on Axelrod (1997), they suggest that seven different uses of simulation models exist: *predictions* where empirical confirmation of relationships in simulation output provide indirect support for unobserved processes, *proof* where simulation output shows that the suggested relationships are able to produce certain types of behavior, *discovery* where the interaction of processes result in unexpected consequences, *explanation* where models result in behavior as in *proof* but with the addition that conditions under which the outcomes are produced are also illuminated, *critique* where simulation is used to asses preexisting explanations, *prescription* where simulations show more efficient ways of organizing, and *empirical guidance* where simulations help develop new empirical strategies for testing relationships that the simulation model uncovered (Harrison et al., 2007, p. 1238-1240). Davis et al., (2007), who also discuss simulation modeling based theoretical contributions, argue that most studies are either theory-testing or theory-creating but that simulation studies are especially useful for the ‘sweet spot’ in between the two extremes (Davis et al., 2007, p. 480).

It is an open question whether system dynamics based theoretical contributions in management theory typically fall within one of the seven proposed uses of simulation models by Harrison et al. (2007), or whether system dynamics has been used in a variety of ways. It is also an open question whether system dynamics based theoretical contributions in management theory indeed find themselves in the ‘sweet spot’ between theory-testing and theory-creating, or not. Answering these questions is relevant, because it shows which strategies apparently have been fruitful so far, and what opportunities there still exist for the future.

Method

This study applies a systematic literature review of system dynamics based theoretical contributions to management theory. To find theoretical contributions to management theory with considerable impact, I confined the search to top management journals:

Academy of Management Review, Academy of Management Journal, Journal of Management, Organization Science, Journal of Management Studies, Strategic Management Journal, and Administrative Science Quarterly. I used Google Scholar to find relevant articles, because this usually results in more hits than databases like Web of Science, ScienceDirect, and EBSCOhost. I searched for the exact phrase ‘system dynamics’ (not case sensitive) in any part of the article. The date range was specified as 1990-2016, and the search was performed on February 3, 2016. As an additional check, I took a few examples of high impact system dynamics articles that I happen to know of, and confirmed whether they would show up in this search, which they would. As a next step, I manually removed those articles that do not use system dynamics to provide a theoretical contribution, for example because they provide a literature review themselves, or because they focus on a methodological contribution rather than a theoretical contribution. Other articles were excluded for example because system dynamics only showed up in a biography of one of the authors, in the appendix, or in the references, because system dynamics was only briefly mentioned, or because the term system dynamics referred to something different from what we understand as system dynamics.

All articles were classified as either quantitative (including numerical simulation runs) or qualitative (causal loop diagrams or stock and flow diagrams without simulation runs). They were classified as either inductive (theory-creating), deductive (theory-testing), or both. With the seven ways of using simulation models presented by Harrison et al. (2007) as a starting point, the articles were classified according to how system dynamics was used to arrive at a theoretical contribution to management theory. New categories are added if articles can not be clearly put in one of the existing seven categories.

Results

Searching on system dynamics in top management journals between 1990 and 2016 yielded 124 hits. After excluding all the hits that did not represent a system dynamics based theoretical contribution to management theory, 25 articles remained. Table 1 below shows how those articles were distributed over the seven management journals.

Journal	# Articles
OSc	9
ASQ	5
SMJ	4
AMJ	2
JoM	2
JoMS	2
AMR	1

Table 1: Total number of system dynamics based theoretical contributions per major management journal

The full list of the 25 articles is shown in Table 2 below, and the titles of the respective articles can be found in the references.

#	Author	Journal	Year
1	Lomi, Larsen, and Ginsberg	JoM	1997
2	Sastry	ASQ	1997
3	Sterman and Wittenberg	OSc	1999
4	Crossland and Smith	SMJ	2002
5	Nickerson and Zenger	OSc	2002
6	Perlow, Okhuysen, and Repenning	AMJ	2002
7	Repenning	OSc	2002
8	Repenning and Sterman	ASQ	2002
9	Rudolph and Repenning	ASQ	2002
10	Black, Carlile, and Repenning	ASQ	2004
11	Romme	OSc	2004
12	Gary	SMJ	2005
13	Vancouver, Tamanini, and Yoder	JoM	2008
14	Rudolph, Morrison, and Carroll	AMR	2009
15	Azoulay, Repenning, and Zuckerman	ASQ	2010
16	Kunc and Morecroft	SMJ	2010
17	Lomi, Larsen, and Wezel	OSc	2010
18	Walrave, Van Oorschot, and Romme	JoMS	2011
19	Goh, Love, Brown, and Spickett	JoMS	2012
20	Rahmandad	OSc	2012
21	Etzion	OSc	2014
22	Anderson and Lewis	OSc	2013
23	Martinez-Moyano, McCaffrey, and Oliva	OSc	2013
24	Van Oorschot, Akkermans, Sengupta, and Van Wassenhove	AMJ	2013
25	Rahmandad and Repenning	SMJ	2016

Table 2: System dynamics based theoretical contributions in major management journals in the period 1990-2016

Six of the 25 articles proved to be qualitative rather than quantitative. That is, a theoretical contribution was made using causal loop diagrams or stock and flow diagrams without using formulas and data to calculate and compare simulation runs. Fourteen articles were deductive, eight were inductive, and three were both, that is they were in the ‘sweet spot’ between theory-construction and theory-testing (Davis et al., 2007). A full list of the classifications is presented in Table 3 below.

#	Journal	Year	Qnt./Qual.	Ind./Ded.	Use of system dynamics
1	JoM	1997	Quantitative	Deductive	Discovery
2	ASQ	1997	Quantitative	Deductive	Critique
3	OSc	1999	Quantitative	Deductive	Critique
4	SMJ	2002	Quantitative	Deductive	Explanation, synthesis
5	OSc	2002	Quantitative	Deductive	Explanation, synthesis
6	AMJ	2002	Qualitative	Inductive	Exploration
7	OSc	2002	Quantitative	Deductive	Explanation, synthesis
8	ASQ	2002	Qualitative	Inductive	Explanation, synthesis
9	ASQ	2002	Quantitative	Inductive	Explanation, synthesis
10	ASQ	2004	Quantitative	Inductive	Exploration
11	OSc	2004	Quantitative	Inductive	Exploration
12	SMJ	2005	Quantitative	Deductive	Explanation, synthesis
13	JoM	2008	Quantitative	Deductive	Critique
14	AMR	2009	Quantitative	Inductive	Exploration
15	ASQ	2010	Qualitative	Inductive	Exploration
16	SMJ	2010	Quantitative	Deductive	Critique, extension
17	OSc	2010	Quantitative	Deductive	Discovery
18	JoMS	2011	Quantitative	Deductive	Explanation, synthesis
19	JoMS	2012	Qualitative	Deductive	Synthesis, critique
20	OSc	2012	Quantitative	Both	Synthesis, discovery
21	OSc	2014	Quantitative	Both	Synthesis, discovery
22	OSc	2013	Quantitative	Deductive	Critique, discovery
23	OSc	2013	Qualitative	Deductive	Explanation, synthesis
24	AMJ	2013	Qualitative	Inductive	Exploration
25	SMJ	2016	Quantitative	Both	Exploration, synthesis

Table 3: Classification of system dynamics based theoretical contributions in major management journals in the period 1990-2016

Articles typically have elements of multiple uses of system dynamics, but often one or two stand out. In Table 3, for each article it is mentioned which one or two uses of system dynamics are most prominent. Below follows a description of the various ways in which system dynamics is used in management theory to provide theoretical contributions.

Explanation

Eight out of the 25 articles used system dynamics to show how a set of causal relationships can be responsible for a specific phenomenon. A typical starting point in these articles is something like: ‘current theories fail to explain the observed phenomenon’. Repenning and Sterman (2002) for example observe that organizational theories do not explain why useful innovations often go unused: “existing theory offers little to explain why”, and “the structures, processes, and feedbacks that influence whether an organization learns or stagnates, whether a promising improvement program is adopted or rejected, remain largely unknown” (Repenning and Sterman, 2002, p 266).

Two of these eight articles, after observing an unexplained phenomenon, continue by building new theory from the ground up. Six of the eight articles continue by deducing explanations from existing theories.

Exploration

Six out of the 25 articles used system dynamics to explore new theoretical territory. These articles all build theory from the ground up, for example using ethnography (Perlow et al., 2002), fieldwork (Azoulay, 2010) or a case study (Van Oorschot et al., 2013). Three out of the six explorative studies use causal loop diagrams and/or stock and flow diagrams to specify the resulting theory, while the other three studies also use simulation runs to show the relative importance of factors, and typical behavior like that of systems approaching or crossing thresholds. These studies typically end with propositions for further empirical investigation.

Discovery

Six out of the 25 articles used system dynamics to discover new insights through comparing simulation runs. Rather than looking at the implications of causal relationships that had not been considered yet, these studies discover new implications of causal relationships that were already known. For example, Lomi et al., (1997) use an existing model to “examine the boundaries between regions of stable and unstable behavior that can be found on a policy-making space” (Lomi et al., 1997, p. 568).

Critique

Six out of the 25 articles used system dynamics to critique existing theories. Through formalizing the existing theory, these studies reveal internal inconsistencies. Sastry (1997) for example starts with stating: “a simulation model that formalizes the conventional theory of punctuated organizational change highlights a problem: under a wide range of conditions, organizations appear to fail following reorientation” (Sastry, 1997, p. 237). Similarly, Vancouver et al. (2008) state: “we use modeling to see whether the uncertainty reduction hypothesis, which underlies much of the socialization literature [...] is viable” (and even go as far as saying that “better theory means dynamic computational theory, Vancouver et al., 2008, p. 2).

Synthesis

Twelve out of the 25 articles use system dynamics to synthesize several existing theories. A typical starting point in these articles is something like: ‘a phenomenon is complex, therefore, synthesis of several existing theories is needed to understand the process behind the complex phenomenon’. Crossland and Smith (2002) for example combine theories on demand queues and theories on information cascades to “evaluate the probable related effects that may occur” (Crossland and Smith, 2002, p. 417). Some articles use two hitherto separate literature streams rather than specific theories to synthesize existing knowledge. Rahmandad and Repenning (2016) for example build on learning curve literature and organization failure literature: “by connecting the two disparate literatures, an explicit theory of capability erosion offers the possibility of new explanatory mechanisms to understand firm heterogeneity and an enhanced understanding of organizational demise” (Rahmandad and Repenning, 2016, p. 652).

Discussion

For scholars wishing to provide a theoretical contribution with system dynamics to management theory, the findings have several implications. The findings show which outlets are apparently 'friendly' to such contributions. Moreover, it shows what kind of contributions are apparently accepted. Of course it is certainly possible to provide contributions outside of the beaten paths, but at least this overview shows you what the beaten paths are, and as such may help when searching for references of articles showing (and thereby perhaps justifying) similar approaches as you are taking.

Between 1990 and 2016, 25 articles have provided a system dynamics based theoretical contribution in major management journals. Table 2 in this paper presented the list of articles and for anyone with the ambition of providing a theoretical contribution in management theory, this list can be seen as 'recommended' (or 'required') reading.

Whether an average of about one article per year is a lot or not is hard to say without comparing it to other methods that have been used to derive theoretical contributions, but it is perhaps safe to say that system dynamics in management theory is still far from a well established research strategy. With the notable absence of any system dynamics based articles in the period 1990-1996, and half of the articles originating from the last eight years, it does however seem that it is becoming more mainstream rather than less.

The findings show that system dynamics is used in vary different ways: critiquing a single theory is very different from synthesizing remote research streams, is very different from building theory from the ground up. This can be seen as a warning to researchers before embarking on such a study: you should have very carefully thought through how in your particular study system dynamics is going to be useful in providing a theoretical contribution. For example, while textbooks on system dynamics typically focus on running simulations (e.g. Sterman, 2000), surprisingly, six articles presented a causal loop diagram and/or a stock and flow diagram without any formulas or data.

The seven uses of simulation modeling as presented by Harrison et al. (2007) did not suffice when categorizing the 25 articles found in this study. In twelve of the articles, there was a clear focus on synthesizing theories. These articles build on hitherto separate streams of literature, and by investigating the implications of these new combinations of theories, new theoretical contributions are made. Apparently, this is a very fruitful way of using system dynamics to derive theoretical contributions, with almost half of the articles falling in this category, but this use has up till now been overlooked, since it does not fall in any of the categories mentioned by Harrison et al. (2007). Also, all of the synthesizing studies appear to combine this strategy with at least one other way of using system dynamics to arrive at theoretical contributions. This could be a signal that synthesis on it self is not seen (by the authors or by the reviewers) as a sufficient justification for a theoretical contribution in a major management journal. Perhaps making synthesis as a research strategy more explicit and showing how such a strategy has been fruitful in the past (as this paper does), will help with justifying similar contributions in the future.

Harrison et al. (2007) did not take into account that system dynamics can be used for theoretical contributions in a qualitative manner, without simulation runs. These qualitative studies however fitted neatly in the categories of *explanation*, *exploration*, and *critique*, either combined with a focus on synthesis or not. Several

categories mentioned by Harrison et al. (2007) were not found in the system dynamics articles, namely *proof*, *prescription*, and *empirical guidance*. Perhaps that future studies might deliver such contributions.

Although Davis et al. (2007) state that simulation modeling is specifically useful in the ‘sweet spot’ between theory-construction and theory-testing, only three articles seem to combine both an inductive and a deductive research strategy. These articles are relatively recent (2012, 2013, and 2015), which could result from the authors being inspired by the 2007 article by Davis et al. Perhaps these recent examples have paved the way for similar types of contributions in the future.

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