Generic models for business applications

Towards a framework for identification and assessment

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Abstract

This thesis proposes a framework for identifying and assessing generic system dynamics models in business and suggests a list of candidate models. Results are meant to support isee systems, inc. in its aim to make system dynamics more accessible to managers and to further develop knowledge in the field. The main contributions of this study are a) synthesizing the current discourse not only theoretically by a literature review, but also empirically by interviews with experts b) offering concrete steps in form of an operative framework and c) relating problems with the concept of generic models to critical problems in the field. The main limitation of this study is that practical testing of the framework was not possible. Results of the empirical study suggest that the operative framework needs to be further developed because there is substantial disagreement on underlying theories in the conceptual framework. Therefore, the operative steps can only be seen as tentative and as a starting point for further research.

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Foreword - Drawing a map

The process of writing this thesis showed to me in an impressive way how important clear narratives are. Therefore, this short foreword is meant to guide the reader in practical terms through a quite abstract topic. When I chose generic models as my thesis topic, I did not anticipate the philosophical ramifications of this undertaking. What seemed a rather typical approach in science – that is, generalization, standardization and the building of a body of theory – quickly turned out to be a rather contested issue in the field of system dynamics. While some scholars perceived the identification of generic models similar to the quest for the Holy Grail of system dynamics, others strongly and repeatedly warned me of the perils of such a quest and that working with generic models could be misleading or even dangerous.

Nevertheless, some proponents of either idea had one thing in common: They were doubtful that this could be a topic for investigation in the confines of a master's thesis and conducted by someone with such short-time experience in system dynamics (that is, eighteen months of master's studies). Luckily, I can report that neither of these sides had to worry for two reasons. First, I did not set out to find the Holy Grail of system dynamics. Rather, I intended to draw a rough map that would show paths towards insightful and useful system dynamics models. Second, as a young traveler who has not seen much of the system dynamics world yet, I did not make up the coordinates and details of the map myself, but asked experienced travelers to contribute their own sketches. The result of this thesis is a combination of these sketches in one map, that is, a conceptual and operative framework for identifying and assessing generic models. While this map does not (yet) contain highly accurate and detailed drawings, it will hopefully give some direction to future researchers. Ideally, they will venture out and test the map practically to see if it is leading system dynamicists down some interesting paths.

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1. Introduction

1.1. Relevance of generic models for the field

Generic models are a subset of generic structures and can be defined as stock and flow structures that represent a particular situation or problem in general and that can potentially be transferred from one case to another, that is, they are for example applicable in different companies or cities without major adjustments in the model structure. Due to their transferability, they are expected to bring gains in efficiency and modeling quality to the field. The given definition is used in this thesis, but needs to be regarded as a working hypothesis, since there is much confusion in the literature on what generic models are. For the purpose of this study, generic models are defined in a way that summarizes consensus from major publications on this topic. Considered publications include those by El Sawah et al. (2015), Lane (1998), Lane & Smart (1996), Corben (1995), Paich (1985) and Forrester (1993, 1973). These scholars use three different terms to refer to closely related concepts, which are *general models*, *generic models* and *canonical situation models*. Two common characteristics are frequently referred to when generic models are described, which only vary slightly in their formulation. These commonly used characteristics are that they are *general* or *generic* and that they apply to a *particular problem, particular situation* or *canonical situation*. Forrester refers to these *situations* as *problems that managers typically face*, and claims that there should be a list of about twenty generic business models that would be applicable to the majority of such problems (Forrester, 1993). There is an agreement in the literature that they are formulated as quantified stock and flow structures as opposed to causal loop diagrams. Moreover, it is agreed that generic models are a subset of generic structures, a concept that includes other types of generalized model structures.

To understand the relevance of generic models, they have to be considered as part of the wider topic of generic structures, which may play a key role for the development of system dynamics as a field (Paich, 1985). In the words of Lane & Smart (1996), the development of such structures may be considered as the *"quest for the Holy Grail"* (p. 94) of system dynamics. Whether or not this is perceived as an overstatement, the general idea still appears to be true twenty years later, considering the expected usefulness within and beyond the field of system dynamics. *Within the field* of system dynamics, generic structures may be useful for education of beginning modelers (Forrester, 2007, 1993; Wolstenholme, 2003; Richmond, 1985), for software development (El Sawah et al., 2015; Bauer & Bodendorf, 2006; Tignor & Myrtveit, 2000), and consequently for increasing the overall efficiency and quality of modeling work (Forrester, 2007; Bauer & Bodendorf, 2006; Burns & Ulgen, 2002). Generic structures can be important for diffusing system dynamics principles and insights *beyond the field*, that is, for consulting managers in organizational interventions, for enabling managers to use or build models on their own (Burns & Ulgen, 2002; Corben, 1995; Paich, 1985), for integrating system dynamics models more easily with other computer simulation methods (El Sawah et al., 2015) and for communicating systemic insights in other scientific fields and to the general public (Meadows, 2008; Wolstenholme, 2003; Senge, 1990; Richmond, 1985). It is however contested that all types of generic structures may be useful for the stated purposes. Especially when considering system archetypes, some scholars are concerned that they could be misunderstood or misused by non-modelers or when teaching beginning modelers (Homer, 1996; Forrester, 1994). This is a risk that has to be considered when assessing the usefulness of generic models. Thus, a critical question is with which users and in which settings generic models can be useful. However, such research has hardly been done.

Research on generic models and generic structures so far has been rather discontinuous and fragmented (El Sawah et al., 2015). While scholars refer to different terms, in general, there is a three-part classification of generic structures: first, generic models and canonic situation models; second, abstracted microstructures, building blocks, generic flow templates, and molecules; and third, system archetypes. The latter two types were defined and categorized most precisely and are available in catalogs in a concrete form (as model structures). Generic models have been developed least of all. Despite some controversy about their relevance and the discontinuous progress of research, there is still vital interest in the potential of these models. In his latest outlook on the future of system dynamics as a field, Forrester (2007) repeated his observation that generic models should be available as a clearly documented catalog. Several recent publications refer to or suggest new generic models (see Appendix A - Literature). El Sawah et al. (2015) provide the most recent overview of the state of research on generic structures and argue that more concrete knowledge about the design of generic models (in their paper referred to as canonical situation models) is needed.

1.2. Relevance of generic models for isee systems

The potential that generic models hold within and beyond the field make it an interesting concept for isee systems, inc, one of the main companies that develop system dynamics software. In the context of the given thesis, the author collaborated with the company and joined its team as an intern. isee systems' vision is *"to improve the way the world works, by creating Systems Thinking-based products that enable people to increase their capacity to think, learn, communicate, and act more systemically"* (isee systems, inc., 2015). In 1985, the company introduced STELLA®, the first icon-based system dynamics software with the goal to enable *"the other 98%"* (Richmond, 1985, p. 714) of non-modelers to use system dynamics as a learning device. Ever since, isee systems has been searching for innovative and effective ways of communicating insights that arise from system dynamics models. Generic models are expected to be a useful tool for the clear communication of problematic behaviors and effective policies.

isee systems is particularly interested in developing a set of generic business models. The availability of such a catalog could inform future service and software development, which would allow for better support of managers in solving business problems. An expected consequence of this would be an expansion of the market for computer simulation software in system dynamics. That is, the objective is not to increase the market share in the given market, but to develop new markets. Such markets consist of potential clients that are not yet familiar with system dynamics. If wider audiences became acquainted with the method, there would be more demand for system dynamics projects and more people would be attracted to the field of system dynamics. Thus, a catalog of generic models is expected to be vital for sustained progress in the development and growth of the field. This has been illustrated in a similar context in a causal loop diagram (Figure 1).

Eberlein & Chichakly (2013) describe the development of a common modeling standard in system dynamics software, called XMILE. This standard facilitates the construction of XMILE model libraries that are accessible to developers within and beyond the field of system dynamics. This allows for integration of system dynamics applications with other tools and is therefore assumed to reach a wider base of users. These users then increase demand for system dynamics projects, which would enable more people to find employment in system dynamics and increase funding and availability of system dynamics education. Hence, there would be an increase in system dynamics modelers, who in turn would be able to expand the XMILE model libraries. A similar causality is expected to apply to a library of generic models (K. J. Chichakly, personal communication, February 18, 2015).

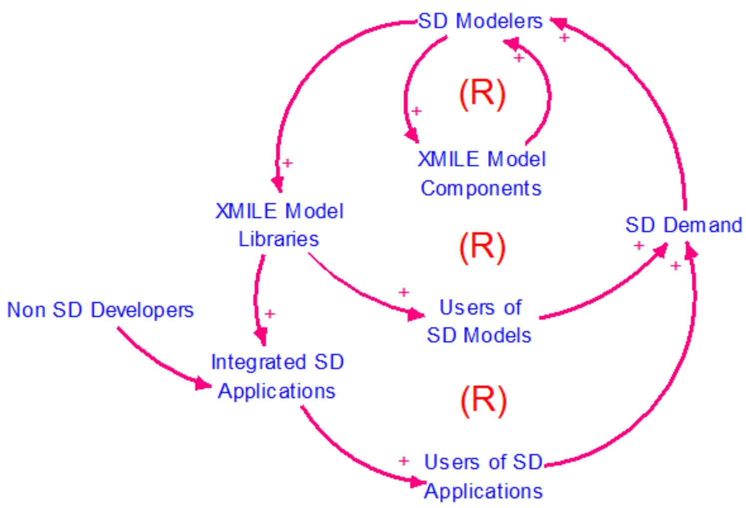


Figure 1: Causal loop diagram of XMILE impact on the field (isee systems, inc., 2014)

1.3. Problem statement and research questions

The research problem of this thesis is how to identify and assess generic models for business and management applications. The problem is based on Jay Forrester's claim that there should be about twenty unique models that can encompass a majority of problems that managers typically face (Forrester, 1993, 2007). According to isee systems, the main challenge is to find ways to identify these models. The identification process is not a straightforward matter, since there is a lack of agreement on the definition so far. Lane & Smart (1996) summed up the difficulty of defining generic structures in an anecdote, quoting John Sterman's statement *"I know one when I see one"* (p.87). While there has been significant progress on defining and identifying other generic structures such as molecules and archetypes, Sterman's statement still holds true for the definition and identification of generic models. That is, experts may be able to identify a generic model when they encounter one, but their reasoning is not always explicit and accessible to others. This tacit reasoning by experts needs to be revealed explicitly so that others may be able to identify generic models as well. The research questions are formulated similarly to the set of questions identified by Paich (1985), which shall ensure consistency and continuity with other research.

1) How can generic models be identified?

   1a) How can generic models be defined?

   1b) By which criteria can generic models be identified?

   1c) Which existing models may be candidates for a list of generic models?

2) How can generic models be assessed?

   2a) For which purposes and users can generic models be useful?

   2b) By which criteria can generic models be categorized and classified?

1.4. Research strategy and objectives

A qualitative research strategy involving interviews with experts is chosen to address the given research questions. These questions are rather open ended and require descriptive answers, therefore an *"interpretative approach concerned with understanding the meanings which people attach to phenomena"* is suitable (Ritchie & Lewis, 2003, p.3). In this study, the understanding and meanings of expert modelers are inquired. As established above, so far experts have relied much on their intuitive and tacit knowledge for the identification and assessment of generic structures. To make this unstructured knowledge more explicit and accessible, a concept from the field of knowledge management is applied in this study. Ihrig & MacMillan (2015) suggest *"to identify, map and leverage* *some of your company's most strategic assets"* (p.81) by constructing a conceptual framework with experts. In system dynamics, models can be identified as key assets and are best analyzed with modeling experts. The descriptive answers from the interviews are captured in a clearly structured conceptual framework, which allows for the development of concrete operative steps for the identification and assessment of generic models. Summing up, the objective of this research is to develop a conceptual framework, an operative framework and to identify a list of potential candidate models that may be included in a catalog of generic models.

The main contribution of this thesis lies in three areas. First, the state of research is synthesized and reviewed with experts, putting the previously oftentimes vague and dispersed discourse on generic structures and generic models into focus. Capturing this discourse in a conceptual framework should enable a more precise and rigorous discourse on generic models in the field. Second, an operative framework is suggested that could guide future studies in making concrete steps in the identification and assessment of generic models. Third, generic models are discussed in light of problematic issues for system dynamics as a field, such as knowledge management, teaching beginning modelers and using models to support managers. Summing up, the research questions will be addressed as shown in Table 1.

Research question	**Result**
1a) How can generic models be defined? 2a) For which purposes can generic models be useful and to whom?	Conceptual framework
1b) By which criteria can generic models be identified? 2b) By which criteria can they be categorized and classified?	Operative framework
1c) Which existing models may be candidates for a list of generic models?	List of candidate models

Table 1: Research questions and related results

2. Literature review

Six types of publications were considered as major sources for the development of the conceptual and operative framework and for finding candidate models. The first three sources are publications from within the field of system dynamics and the latter three sources offer theoretical and practical insights about generalization. First, theoretical studies from system dynamics were analyzed which discuss the concept of generic structures, generic models, generalization and model simplification. Concepts that were considered as related include microstructures, building blocks, components, molecules, generic processes, generic models, canonical situation models, system archetypes, standard models, standard structures, standard cases (derived from Warren, 2014) and best practice. Special attention was given to criteria and frameworks that have been used for building, identifying, assessing and using such structures. Second, applied studies were reviewed that explicitly refer to or propose new examples of generic structures. These provided a more practical, operative insight about identification and assessment criteria.

Third, major textbooks in system dynamics helped to gain an understanding of the relevance of generic models for the field and for finding possible candidate models. Fourth, knowledge management literature was considered to explore the relevance of a framework for identification and assessment for the field of system dynamics. Fifth, the role of generalization in science was reviewed to understand how models can be judged as generic from a non-modeler's perspective. This theoretical take on standardization is complemented by a sixth source that offers a practical approach to standardization. The process that led to the identification and indexing of design patterns in object-oriented programming by Gamma et al. (2001) is discussed as a preparation for developing the operative steps of the framework. The catalog of molecules by Hines et al. (2005) serves as an example as well.

2.1. The role of generalization in science

Creating standards and generalizing is at the heart of science. Theories and hypotheses that describe the way the world works are derived from generalizations of particular observations. As such, they are only ever an abstracted, incomplete representation of reality. Therefore, *"Cronbach argues that generalisations should be seen as working hypotheses or extrapolations rather than as conclusions"* (Ritchie & Lewis, 2003, p. 268). A similar notion is found in the field of system dynamics, where models are described as dynamic hypotheses or dynamic theories that are necessarily imperfect generalizations from reality (Sterman, 2000; Forrester, 1993). Both in the case of theories and in the case of system dynamics models, it is important to be cautious about drawing inferences from such a general theory or model about a particular case (Forrester, 1993). However, both theories and models are helpful for understanding reality and for finding patterns in phenomena that would otherwise appear as random or disjunctive. Both can function as guidelines for decision making, as long as their tentative nature is kept in mind and as long as they are customized to the particular problem context. When applying a general insight, an important realization is that *"generalisation requires congruence between the 'sending' and the 'receiving' contexts"* (Ritchie & Lewis, 2003, p.268). That means that for the successful transfer of a general insight from one situation to another, the user needs to know both the original situation (sending context) and the new situation (receiving context) well. More practically speaking, when using a model or theory that was developed in one organizational or geographical context, the findings can only be transferred to another organization or region when both contexts are well known. While this observation seems rather obvious, there is still rather little knowledge on generalization in qualitative research as well as in system dynamics.

There is *"not a clear and agreed set of ground rules for the conditions under which qualitative research findings can be generalised or what this process involves"* (Ritchie & Lewis, 2003, p. 264) The same is true for system dynamics, which lacks a common, widely accepted operative framework for the comparison, replication or reuse of model structures (Groesser & Gabriel, 2014). Models are often developed customized to the given situation and there are few attempts of reusing model structures. The concept of generic structures can be one approach to address the problem of replicability and reuse. Considering that standardization and generalization are such a central part of any science, the value of generic structures for the development of system dynamics as a field becomes clearer. Moreover, some inferences for the identification, assessment and use of generic models can be made, considering that it will be valuable to clearly describe for which specific problem situation a model was developed (sending context) and in which new problem situation it shall be used (receiving context). This description of the context of use could be an extension to existing reporting guidelines, for example those set forth by Rahmandad and Sterman (2012).

2.2. The role of generalization in system dynamics

Forrester (1973) developed system dynamics with the idea to establish a general theory of behavior in industrial systems. During the over fifty years of development in the field, two problems have become apparent which prevent more clear achievements towards this objective. First, a central principle is that models should not be built in a way that represent only the given case, but to build *general models* that represent a theory about a *class of systems*. However, much system dynamics work until today is not done in a generic, but in a customized way. Applied research makes up to fifty-five percent of all publications in the System Dynamics Review, within which models are often constructed customized to a particular problem situation (Orefice & Moraes, 2015). That means, there are many cases of e.g. modeling an energy transition in a specific setting as opposed to a theoretical approach to modeling the general problem of energy transition.

Second, the average quality of work in system dynamics has recently been evaluated as unsatisfactory (Homer, 2013; Forrester, 2007) and the overall replication and reuse of system dynamics studies has been found to be low (Groesser & Gabriel, 2014). Scholars link this problem to slowed growth of the field (Homer, 2013; Forrester, 2007), that is, the number of practitioners and publications has been stagnating in the recent decade (Orefice & Moraes, 2015; Bigman, 2014). Altogether, these problems have prevented the field from building an easily accessible and well managed knowledge base (Forrester, 2007; Richardson, 1996). In other words, this can be identified as a knowledge management problem. Richardson (1996) called it *"accumulating wise practice"* (p.1), which he already identified as a key challenge for the field twenty years ago. He refers to generic structures such as building blocks and molecules as sources for insight on wise practice. The availability of such structures could act as a learning device for newcomers to the field and as a reference point to all modelers, which could help to increase overall modeling quality. As such, generic structures and models can be seen as playing a key role for knowledge management in the field and for achieving Forrester's original objective of establishing a general theory of behavior.

2.3. Generic models

2.3.1. Definition

Generic models have not been sufficiently defined at the given state of research. The provided definition of generic models has to be considered as a preliminary or working definition, since it is subject to empirical review and further development of the theory. At this point, the definition that was suggested by isee systems plays a key role, since their objectives are central for the given study.

> *"By generic, I mean they can be reapplied to new applications with only parameter changes and structural changes that can be defined algorithmically (e.g., turning parts on or off, or extending the structure, for example, extending a main chain or a queue-server system)."*
> (K. J. Chichakly, personal communication, February 18, 2015)

Lane & Smart (1996) point out that the term *general model "was first used by Forrester in 1961 to describe the generalisation and simplification of case study models"* (p. 89). Forrester (1993) also described them as "*dynamic computer models"* that would help managers to deal with "*generic management situations"* (p. 14). The concept of a generic situation or problem was taken up by many scholars. Paich (1985) distinguished between three different types of generic structures. His type 1 classification of structures that are *“transferable to new situations within a particular field”* (Paich, 1985, p. 126) was understood and relabeled as *“generic models”* by Corben (1995, p. 189), who defined *them* as *“generalisations”* of a *“specific problem”* (p. 188). Lane referred to these generic models as *“canonical situation models”* and defined them as *“general models of a particular situation”* (Lane, 1998, p.89). A particular situation herein does not refer to a specific situation of e.g. a company or country, but to a situation that is encountered in different companies or countries. That is, a particular situation refers to a class of situations, the same way it was originally understood by Forrester (Lane & Smart, 1996; Forrester, 1973). El Sawah et al. (2015) follow Lane’s definition and describe *canonical situation models* as *“general models”* which describe a *“particular problem situation”* (p. 2).

Besides this emphasis on the generalization of situations in literature, there is a clear agreement that generic models are formulated in the form of stock and flow structures and that they constitute a quantified model that can be simulated (as opposed to qualitative causal loop structures). They are “*represented as fully formulated and calibrated simulation models”* (Lane, 1998, p. 937). They show a basic stock and flow structure that is needed to explain the dynamic behavior in a particular situation (El Sawah et al., 2015; Paich, 1985). When reviewing the history of this terminology, it seems that there is a significant overlap between definitions of the terms *general model*, *generic model* and *canonical situation model*. Although most clearly defined and most easy to distinguish from generic structures, the term *canonical situation model* has not been embraced in later studies. Many authors continue to refer to *generic models*, *generic system dynamics models, generic simulation models*, generic models of specific application domains (e.g. *generic disease model*), *generic system structures* or *generic dynamic theories* (see Appendix A - Literature). Studies which refer to *canonical situation models* can hardly be found. Hence, the term is abandoned for the development of the interview guidelines, and the conceptual and operative framework. Summing up, it can be said that generic models are generally defined as stock and flow structures that are a subset of generic structures and which are applicable beyond a particular case or even beyond a particular problem domain (El Sawah et al., 2015; Lane & Smart, 1996; Paich, 1985; Forrester, 1972).

2.3.2. Disambiguation

Generic models can be distinguished from other generic structures in different ways. Paich (1985) identified three types of generic structures, which were later labeled by Corben (1995), renamed again by Lane & Smart (1996) and extended by El Sawah et al. (2015). Whereas the first three articles provided an overview mostly in form of a list or table, the most recent article provides a visualization that shows overlap between different concepts and terminologies (see Figure 2).

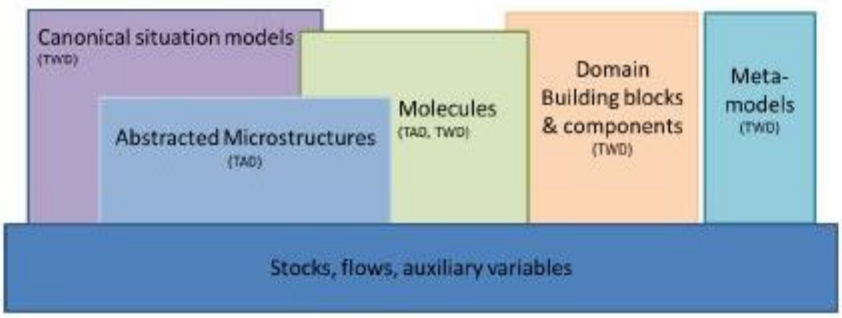


Figure 2: Generic structures disambiguation by El Sawah et al. (2015)
TAD: Transferable Across Domains; TWD: Transferable Within Domains

This visualization is adapted in Figure 3 to show the evolution of the concept according to different publications. As opposed to the graphic by El Sawah et al. (2015) it also includes system archetypes. From this adapted visualization it can be seen that there is great agreement and continuity in the way that type 2, system archetypes, has been described. The terminology of type 1 has changed somewhat, but still only shows two relevant terms. The terminology of type 3 starts to become more diffused when analyzed by El Sawah et al. They distinguish between several different concepts that do not fit neatly into the three-part definitions as set forth by earlier studies. Moreover, they introduce the concept of *system dynamics meta models* as a fourth type of generic structure. These structures are written in high level programming language and include *"domain objects and relationships"* (p. 3).

	Causal loop diagrams	Stock and flow structures		Programming language
	Type 2	Type 1	Type 3	Type 4
Paich (1985)	Structures transferable between problem	Structures generic to one problem domain	Sub-structures that are found as building blocks in many models	
Corben (1995)	Archetypal Structures	Generic Models	Building Blocks	
Lane and Smart (1998)	Counter-intuitive system archetypes	Canonical situation models	Abstracted micro-structures	
ElSawah et al. (2015)	Counter-intuitive system archetypes	Canonical situation models (TWD)	Molecules (TAD, TWD); Abstracted Micro-structures (TAD); Domain building blocks & object oriented components (TWD)	System dynamics meta model (TWD)

Figure 3: Generic structures disambiguation by the author
TAD: Transferrable Across Domains, TWD: Transferrable Within Domains

2.3.3. State of research

In his 1985 article, Paich identified a list of questions that are relevant for the research of generic structures. First, he asked what generic structures are and why they are worthwhile to be researched. Paich (1985), Corben (1995), Lane & Smart (1996), and El Sawah et al. (2015) contributed the most significant work in this respect. Their publications answered the second question "Are generic structures worth researching?" in the affirmative. "What are generic structures?" is a question that is only partly resolved. Paich, Corben, and Lane & Smart identified three types of generic structures, a set which was expanded by El Sawah et al. (2015) to six types that partly overlap.

Paiches third question "How can generic structures be identified?" is only partly researched as well. Most studies focused on type 2, archetypal structures, and type 3, building blocks (Corben, 1995). Several authors contributed significant work on these concepts. Richardson & Pugh (1980) first suggested a set of microstructures and called them *recurring rate or level structures*. Wolstenholme & Coyle (1983) defined four different types of building blocks for modeling. Richmond then defined a set of five *"generic flow processes"* or *"atoms of structure"* (Richmond, 1985, p. 711) which also function as building blocks for models. They were developed further with Peterson (Richmond & Peterson, 1989) and are referred to in the user guide of STELLA® until today (Richmond, 2013). Hines & Eberlein (1996) developed this idea further in their concept of molecules. They constructed a catalog that was updated four times since and contains about 200 structures in its latest version (Hines et al., 2011). Richardson & Andersen (1980) made the first steps to develop a set of archetypical structures representing specific modes of behavior in a stock and flow form (Corben, 1995). Meadows (1982) continued this work but presented four archetypal structures as causal loop diagrams (Corben, 1995). Senge (1985, 1990) developed this concept further and extended the list to eleven archetypes, which were once again classified into four categories by Wolstenholme (2003). These archetypes are abstractions of general behavior and insights gained from stock and flow models that are communicated with causal loop diagrams. A detailed overview on all these developments is provided by Corben (1995).

Concluding, these type 2 and type 3 generic structures seem rather well-defined, categorized and documented. The same cannot be said for generic models however. Both Corben (1995) and El Sawah et al. (2015) feature comprehensive analyses of generic structures, but discuss generic models the least. A keyword search of the System Dynamics Society bibliography (considering only titles and abstracts), reveals merely two papers on canonical situation models, where one explicitly suggest a new canonical situation model (Cody et al., 2011) and the other adapts an existing canonical situation model (Eskinasi & Fokkema, 2006). Searching for generic models, there are about a hundred papers that suggest or refer to a generic model under different terms, e.g. generic simulation model, generic management model etc. However, in these publications a great variety of application domains are referred to and there is no agreed on, publicly available catalog comparable to that by Hines (2005) for molecules or to those by Senge (1990) and Wolstenholme (2003) for system archetypes. Forrester suggested four models in 1993 from his own work, while Lane & Smart (1996) proposed a list of five canonical situation models including some from other scholars. Corben (1995) mentioned two generic models and El Sawah et al. (2015) referred to six canonical situation models, out of which four had not been named in previous studies. For an overview of the keyword search and the lists of generic models, refer to Appendix A - Literature. Concluding, the definition and identification of generic models still poses a significant challenge.

A fourth research problem has only been taken up by Lane (1998) so far: “How can generic structures be validated?” He described three practical criteria for confidence in generic structures, namely *Perceived Representativeness of Models (PRoM*), *Analytical Quality of policy insights (AQ) and Process Effectiveness of the Intervention (PEI)* (Lane, 1998, p. 939). These principles were derived from operations research. Paich stated that a generic structure does not only have to pass all tests that are typically required for customized models, but that a researcher also needs to have an explicit argument that explains the generality of the model. Paich suggested that this could be done by showing that generality applies both regarding the typical behavior patterns and regarding the structure that produces these behavior patterns. He identified five sources that may be useful for establishing that a structural link in a model is justified (common sense, descriptive articles and case studies, descriptive surveys, statistical analysis, previous modeling studies). The small number of publications and the brevity of existing analyses lead to the conclusion that hardly any research has been done in this area.

Paiches fifth and last question reviews how generic structures can be useful, which has been hardly researched. Paich describes the problem that generic structures do not contain the details of specific cases that are typically interesting to decision makers. He argues that generic structures are not useful for solving specific problems, but that they can be mainly used as educational tools for learning about systems. Used as such tools, they can support decision making indirectly, that is, by enhancing the mental models of the decision makers. Finally, Paich claims that this kind of indirect contribution should not be underestimated and that learning about general contexts is as useful as direct analysis of policies. In this sense, generic structures can be very useful to the field of system dynamics. Corben (1995) dedicated this doctoral thesis to making modeling more accessible in management learning and developed a framework for model conceptualization with the aid of generic structures. He used system archetypes for management training and found that there are problems in producing the behavior that was associated with specific archetypes. Consequently, Corben's main concern was to define a set of guidelines for quantifying archetypes.

N	Research question	State of research	Main publications
1	What are generic structures?	partly resolved	Paich (1985) Corben (1995) Lane & Smart (1996) El Sawah et al. (2015)
2	Are generic structures worth researching?	indicated by several studies (on a theoretical level as well as by applications)	Paich (1985) Corben (1995) Lane & Smart (1996) Forrester (2007, 1993, 1961) El Sawah et al. (2015)
3	How can generic structures be identified?	partly resolved	Richardson & Andersen (1980) Richardson & Pugh (1981) Meadows (1982) Wolstenholme & Coyle (1983) Richmond & Peterson (1989), Richmond (1985) Senge (1990, 1985) Eberlein & Hines (1996) Wolstenholme (2003) Hines (2005), Hines et al. (2011)
4	How can generic structures be validated?	hardly researched	Paich (1985) Lane (1998)
5	How can generic structures be useful?	hardly researched	Paich (1985) Corben (1995) Lane (1998) El Sawah et al. (2015)
6	How can generic structures be designed?	hardly researched	Tignor & Myrtveit (2000) El Sawah et al. (2015)

Table 2: State of research on generic structures

Lane (1998) suggested the measurements *Analytical Quality of policy insights* and *Process Effectiveness of the Intervention* for determining if specific generic structures are useful. These indicators direct attention onto the user's experience in an intervention process that applies a generic structure and also reveal if policy insights led to learning effects. The concepts of policy insights is discussed further by Lane (2012). Lane & Smart (1996) also shortly note that generic structures could be used as a sort of toolbox for modeling. A third study that discusses the usefulness of generic structures at length is done by El Sawah et al. (2015). They show that generic structures have been helpful for the integration of system dynamics modeling with other modeling fields. They note that there is too little research on how generic structures can be used operatively. Finally, El Sawah et al. bring up a slightly different question that can be added to the original list of Paich, that is "How can generic and reusable structures be designed?" This is an approach distinct from the identification of structures and was discussed as early as the year 2000 by Tignor & Myrtveit. The state of research is summarized according to Paiches research questions in Table 2.

2.4. Knowledge management in system dynamics

The identification and assessment of generic structures has relied strongly on expert knowledge in the past, as can be seen in the review of the state of research. The process by which experts arrived at their conclusions is often opaque or vaguely described, therefore inscrutable and not replicable. To make the identification and assessment of generic structure accessible to more people in the field, the implicit criteria that experts use need to be made explicit. A helpful starting point for this process if offered by Ihrig & MacMillan (2015), who designed a grid for mapping key assets of a company. In this thesis, the key assets of interest are different types of generic structures. Assets are mapped onto a grid *"along two dimensions: tacit versus explicit (unstructured versus structured) and proprietary versus widespread (undiffused versus diffused)"* (Ihrig & MacMillan, p.83). This can be seen in Figure 4. The grid is applied to the three main types of generic structures in Figure 5. The resulting map is more of a thought experiment than a rigorous categorization. It shall help to visualize general tendencies of the state of research on generic structures.

Tacit Applied Expertise (low on the Y axis) refers to intuition and deep understanding that enables highly experienced practitioners to solve problems. Often, these experts have problems in explaining the reasoning behind their intuition. Nevertheless, results from different experts can be similar, that is, there may be *Expert Agreement*. In contrast to these low amounts of articulation, structured or codified knowledge can be communicated easily and applied by others, since they can refer to a common language or conceptual framework (high on the Y axis). *Explicit General Principles* on this axis means that *"relations among variables are so well known that the outcome of actions can be calculated and reliably delivered with precision"* (Ihrig & MacMillan, 2015, p. 85). *Heuristics* means that people *"can perform tasks using rules of thumb, but causal relationships aren't clear"* (p. 85). In system dynamics, the development of a common language has been done rather successfully for abstracted microstructures, especially for molecules and for qualitative system archetypes, which therefore score high on the Y axis. In contrast, generic models are placed low on this axis, since they have hardly been identified and assessed yet. That means, there are no heuristics or explicit general principles for this process.

The second dimension on the grid compares knowledge that is spread within or beyond an organizational context. Undiffused knowledge is only used by a part of an organization or field and cannot be applied in other parts. In system dynamics, lists of molecules and archetypes are well-documented and readily available to the field (unbounded). Systems archetypes are often referred to in system dynamics literature (107 results according to the keyword search in the System Dynamics Society bibliography) and appear to be widely known beyond the field of system dynamics, considering the public reception of the book *The Fifth Discipline* by Senge (1990). Thus, they are assumed to have many users. Microstructures and molecules appear not to be used that widely yet, considering that there are few system dynamics publications that refer to them (twelve publications in the bibliography). Thus, they are assumed to have few users. The same is true for generic models. While there are more publications on generic models than on molecules, most of the publications do not refer to an established set of generic models but suggest a new generic model. The individual models are unbounded, but not repeatedly used.

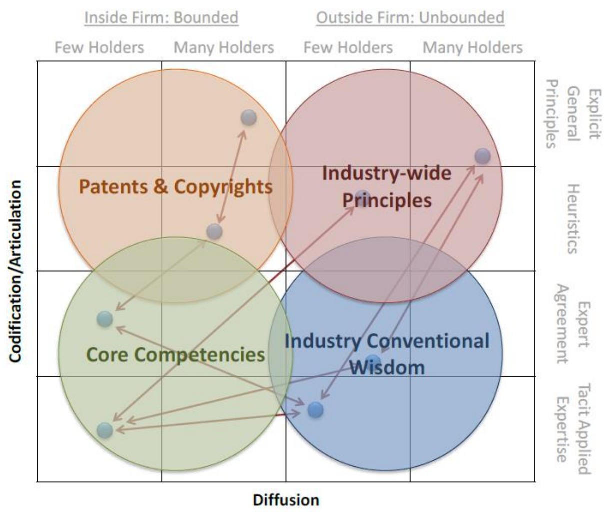


Figure 4: Mapping key assets (Ihrig, Boisot & MacMillan, 2011)

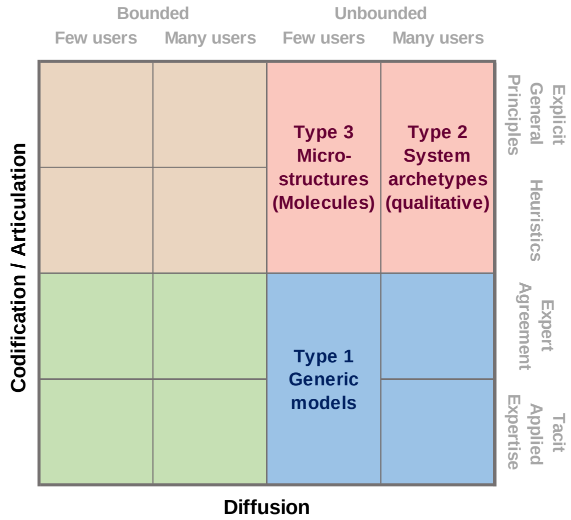


Figure 5: Key assets in system dynamics (Mapped by author)

Ihrig & MacMillan (2015) identify several strategies that may be helpful for moving assets along the codification and diffusion axes. To *selectively structure tacit knowledge* is an approach for codifying knowledge so that it can be shared and used for commercial purposes. A way to capture this knowledge is to elicit and synthesize insights from experts. This strategy is applied by the construction of the framework. Ihrig & MacMillan also note that a danger herein is the possible undesirable distribution of knowledge.

> *"The ease of knowledge sharing is directly proportional to the degree of knowledge codification, of course: A written document or spreadsheet is easier to share than tacit experience" (p. 85).*

The diffusion of generic models by means of a catalog will therefore have to be done carefully. Misunderstanding or misuse of generic models has to be prevented with sufficient documentation and instructions for use. This is true for users both with and without modeling background.

2.5. Design patterns and existing catalogs

System dynamicists frequently refer to a framework which led to a breakthrough in object-oriented programming (El Sawah et al., 2015; Tignor, 2001, Myrtveit, 2000). In the 1990s, there were no standard codes available until a small group of researchers took on the challenge of developing a catalog of standard design patterns (Gamma et al., 2001). This process is considered to be instructive for the development of a catalog of generic structures in system dynamics. Tignor & Myrtveit (2000) compare generic structures to design patterns.

> *"In the Object-Oriented world, design patterns capture generic solutions that have developed and evolved over time and describe them as structures or objects for reuse." (p.1)*

Tignor claims that *"a pattern language in system dynamics is the missing piece preventing the power of design patterns from helping System Dynamics have further reaching impact"* (2001, p.1). Since this approach was first suggested, it was successfully used by Hines et al. (2011) for the construction of a catalog of molecules. In this catalog, molecules are clearly described, sorted in a comprehensive taxonomy, and the adequate use and combination of molecules are documented. Accordingly, isee systems envisions the establishment of a well-documented catalog of generic models:

> *"Everyone one of these generic models requires well-defined input parameters and output results so they can be combined with other generic models. There also has to be clear enough documentation to understand when you would use this model (and when it's not applicable or requires either minor or major modifications to apply it)."* (K. J. Chichakly, personal communication, February 18, 2015)

These observations are shared by El Sawah et al., who conclude that there is "*little research into the process of designing reusable structures, and there is a clear gap between the design of these structures and how they can be used effectively in practice."* (2015, p.1). The catalog of design patterns by Gamma et al. (2001) deals with similar problems by providing a standardized documentation, describing which problem the pattern addresses, in which contexts it is applicable, lists problems with implementation and shows examples, as can be seen in Figure 6.

Design Pattern Name   Jurisdiction Characterization

What is the pattern's name and classification? The name should convey the pattern's essence succinctly. A good name is vital, as it will become part of the design vocabulary.

Intent
What does the design pattern do? What is its rationale and intent? What particular design issue or problem does it address?

Motivation
A scenario in which the pattern is applicable, the particular design problem or issue the pattern addresses, and the class and object structures that address this issue. This information will help the reader understand the more abstract description of the pattern that follows.

Applicability
What are the situations in which the design pattern can be applied? What are examples of poor designs that the pattern can address? How can one recognize these situations?

Participants
Describe the classes and/or objects participating in the design pattern and their responsibilities using CRC conventions [5].

Collaborations
Describe how the participants collaborate to carry out their responsibilities.

Diagram
A graphical representation of the pattern using a notation based on the Object Modeling Technique (OMT) [25], to which we have added method pseudo-code.

Consequences
How does the pattern support its objectives? What are the trade-offs and results of using the pattern? What does the design pattern objectify? What aspect of system structure does it allow to be varied independently?

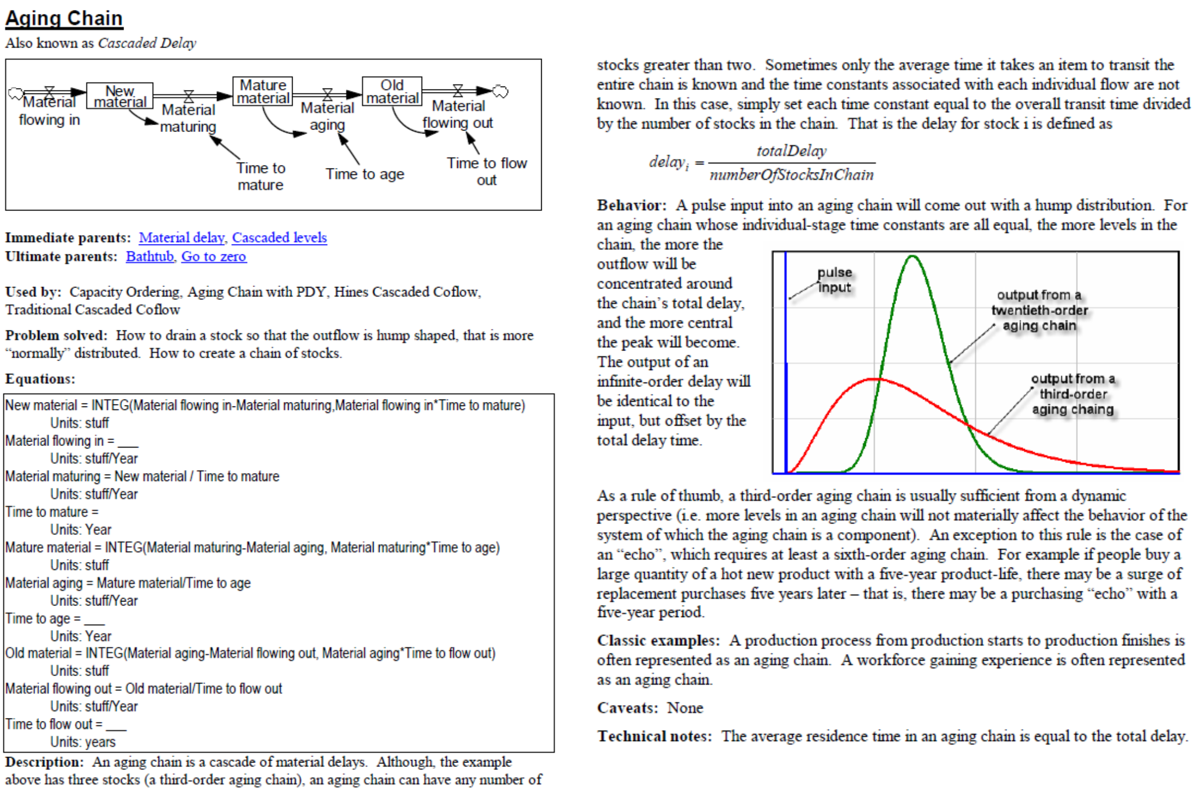
Implementation
What pitfalls, hints, or techniques should one be aware of when implementing the pattern? Are there language-specific issues?

Examples
This section presents examples from real systems. We try to include at least two examples from different domains.

See Also
What design patterns have closely related intent? What are the important differences? With which other patterns should this one be used?

Figure 6: Design patterns template
(Gamma et al., 1993)

Hines' catalog of molecules is documented in a similar way as can be seen in Figure 7. He shows the abstracted structure, its relation to other microstructures, the problem it addresses, the underlying equations, typical behavior, examples as well as caveats of the structure. Moreover, Hines created a taxonomy which captures the relationships between the different molecules as can be seen in Figure 8. Such an overview and detailed documentation can be helpful for the identification and assessment of generic models as well.



Aging Chain

Also known as *Cascaded Delay*

Immediate parents: Material delay, Cascaded levels
Ultimate parents: Bathtub, Go to zero

Used by: Capacity Ordering, Aging Chain with PDY, Hines Cascaded Coflow, Traditional Cascaded Coflow

Problem solved: How to drain a stock so that the outflow is hump shaped, that is more "normally" distributed. How to create a chain of stocks.

Equations:

```
New material = INTEG(Material flowing in-Material maturing,Material flowing in*Time to mature)
    Units: stuff
Material flowing in = ___
    Units: stuff/Year
Material maturing = New material / Time to mature
    Units: stuff/Year
Time to mature =
    Units: Year
Mature material = INTEG(Material maturing-Material aging, Material maturing*Time to age)
    Units: stuff
Material aging = Mature material/Time to age
    Units: stuff/Year
Time to age = ___
    Units: Year
Old material = INTEG(Material aging-Material flowing out, Material aging*Time to flow out)
    Units: stuff
Material flowing out = Old material/Time to flow out
    Units: stuff/Year
Time to flow out = ___
    Units: years
```

Description: An aging chain is a cascade of material delays. Although, the example above has three stocks (a third-order aging chain), an aging chain can have any number of stocks greater than two. Sometimes only the average time it takes an item to transit the entire chain is known and the time constants associated with each individual flow are not known. In this case, simply set each time constant equal to the overall transit time divided by the number of stocks in the chain. That is the delay for stock i is defined as

$$delay_i = \frac{totalDelay}{numberOfStocksInChain}$$

Behavior: A pulse input into an aging chain will come out with a hump distribution. For an aging chain whose individual-stage time constants are all equal, the more levels in the chain, the more the outflow will be concentrated around the chain's total delay, and the more central the peak will become. The output of an infinite-order delay will be identical to the input, but offset by the total delay time.

As a rule of thumb, a third-order aging chain is usually sufficient from a dynamic perspective (i.e. more levels in an aging chain will not materially affect the behavior of the system of which the aging chain is a component). An exception to this rule is the case of an "echo", which requires at least a sixth-order aging chain. For example if people buy a large quantity of a hot new product with a five-year product-life, there may be a surge of replacement purchases five years later – that is, there may be a purchasing "echo" with a five-year period.

Classic examples: A production process from production starts to production finishes is often represented as an aging chain. A workforce gaining experience is often represented as an aging chain.

Caveats: None

Technical notes: The average residence time in an aging chain is equal to the total delay.

Figure 7: Catalog of molecules by Hines et al. (2005)

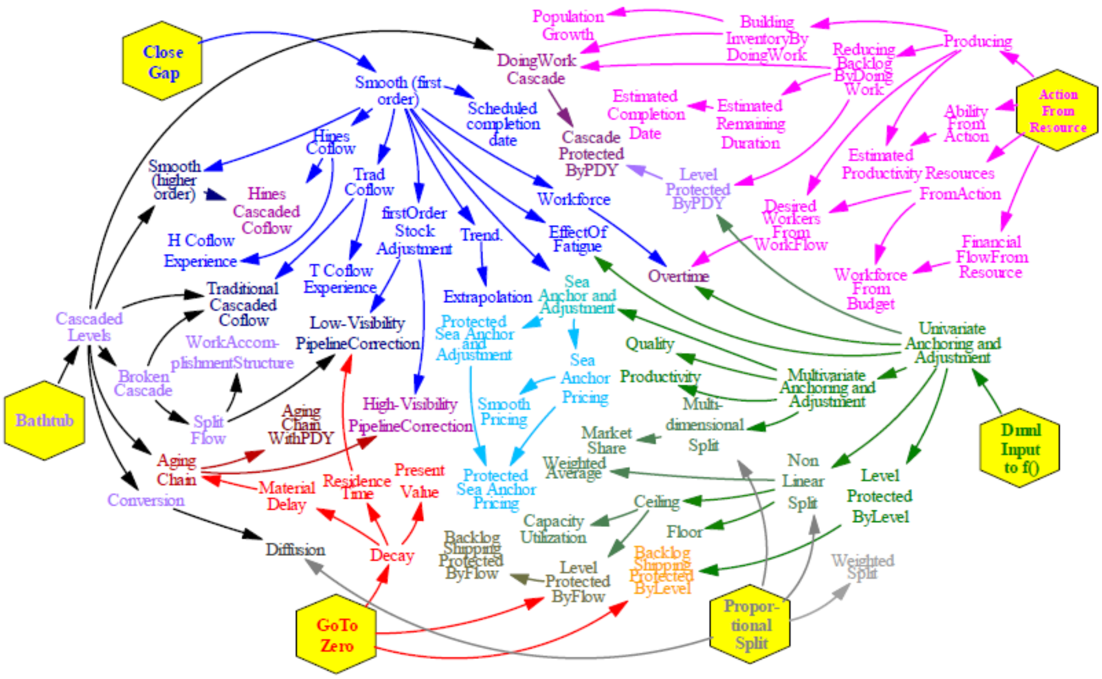


Figure 8: Taxonomy of molecules by Hines et al. (2005)

2.6. Decision making and learning in management

Managers face continued challenges in increasingly complex organizations and organizational environments. Decision making requires the review of multiple, interrelated factors and the consideration of demands from a variety of stakeholders. A main aspect of decision making is therefore the gathering, management and analysis of information. Appropriate tools are required to make sense of such data and to support decision making in the absence of data. One approach to these problems is systems thinking, which allows for a holistic view on problems. System dynamics is an operative and rigorously developed way to think in systems. This methodology allows to work with interdisciplinary data from different business departments, to integrate multiple perspectives from different stakeholders and to deal with a great number of factors that dynamically change over time (Corben, 1995; Forrester, 1973). From the very beginnings of the field in the 1950s, system dynamics was intended to be a tool to support decision making in management (Radzicki & Taylor, 2008; Forrester, 1973).

Forrester (1968) envisioned system dynamics to be a general theory of behavior that is captured in the form of stock and flow models. Such models should not only describe a specific situation of a client, but represent a wider class of problems. In business, these dynamic theories of behavior could cover about ninety percent of situations that managers typically face. The models would serve as an addition to descriptive case studies and allow for a more in-depth study of problem behaviors in organizations. They should be captured in a *"library of generic management situations"* (Forrester, 1993, p.14). A central problem is to determine the exact form in which such a catalog of generic models could best support managers. There are two basic settings for using any kind of model in a business context. First, models can be used for management education and second, they can be used for consulting and policy advice in specific situations.

In management education, a library of generic models could be studied in full undergraduate or graduate programs that prepare future managers for typical problem situations. Here, Forrester (1993) distinguishes between managers as designers and as operators. He compares the first to aircraft designers and the latter to pilots, a frequently quoted analogy. He argues that the design of an organization requires modeling and simulation, similar to the design of an aircraft. Thus, he claims that management designers should fully understand a library of generic models, whereas operative managers may benefit from learning about more general systems insights.

In management consulting, three basic modes of model use have generally been applied. They will here be referred to as modeling for managers, modeling with managers (Akkermans, 1995) and interactive interfaces. First, modeling for managers refers to the expert consultation mode (Schein, 1990), where consultants interview managers, build a model based on the collected data and return with policy recommendations to the client (Akkermans, 1995). If the model is presented in its stock and flow structure to the client, it is often difficult for the client to understand and therefore to find the presented structure credible. Such models are also known as black-box models (Vennix, 1996). Second, modeling with managers is a concept that relies on process consultation (Schein, 1990). Rather than giving expert advice based on the modelers' insights, consultants conduct a participatory modeling process such as group model building, in which clients can define the stock and flow structure in their own terminology and based on their own mental models. These models can be more readily understood and trusted by the client and are referred to as white-box models (Vennix, 1996). Third, interactive interfaces are mostly used as representations of the model in a format that non-modelers are familiar with. This can be in the form of a simple spreadsheet, management games such as the widely used Beer Game and Fishbanks (Sterman, 2000) or contain simplified input devices such as in micro-worlds (Hirsch & Immediato, 1999).

There is disagreement and much debate in the field of system dynamics regarding which mode shall be used in which setting. That is, some scholars claim that without showing the actual model structure, it will be difficult for managers to understand the resulting behavior of a system (Forrester, 1993). Another group however is inclined to believe the opposite and claims that managers will never be able or interested to understand system dynamics models given the limited resources that they have (discussed in Sterman, 2000). Moreover, it has been observed that learning does not necessarily take place if managers are presented with a finished model instead of building their own models (Forrester, 1993). Other scholars disagree and refer to projects where the main insights of dynamic behavior could be communicated without the modeling building process. Most scholars agree that the impact of a model is related to the particular audience (Forrester, 1993) and to the context of the project (Grössler, 2007; Eskinasi & Fokkema, 2006). Generally, there is wide agreement that using a system dynamics model can lead to better results than when no model is used at all (Forrester, 1993). Managers continue to make decisions *"by trial and error, by anecdote, and by imitation of others"* (Forrester, 1993, p. 84), so any explicit dynamic model that challenges the existing mental model of managers may help them to learn about systems and to make better decisions.

When working in either setting or mode of model use, different principles for using and presenting models apply. Managers are not a homogeneous group. The term comprises strategic as well as operative managers, business as well as public managers and managers from different organizational levels. In a decision making context, it has to be clear who the real client is. Sterman (2000) notes that neither the person inviting to a consulting project nor the person paying for the project may be the actual clients. Instead, the client is the person or department whose behavior must change for solving the given problem. Since system dynamics models may offer surprising insights and reveal alternative policy levers, Sterman claims that the core client group may even change during the course of the consulting project. Besides, consultants have to be aware that *"far too many clients not interested in learning but in using models to support conclusions they've already reached or as instruments to gain power in their organizations"* (Sterman, 2000, p. 85). Moreover, even when a system dynamics project is successful from the client's perspective, it may not lead to any substantial change in the organization (Grössler, 2007; Sterman, 2000). A key prerequisite for working with managers is thus to analyze how decisions are actually made in a particular organization, rather than departing from the assumption that the formal model will be the basis for a manager's decision. Consultants have to be aware of the conditions of *"real world problem solving, with all its messiness, ambiguity, time pressure, politics and interpersonal conflict"* (Sterman, 2000, p. 83).

3. Methodology

3.1. Research design

Given the discussed research questions and strategies, the research design is structured as can be seen in Figure 9. In the first empirical part, semi-structured expert interviews were conducted. Obtained data was analyzed deductively according to pre-defined topics and reviewed inductively to reveal previously unidentified issues. The results set the theme and boundaries for the development of the conceptual framework, which in turn led to the development of an operational framework. Moreover, a list of candidate models as identified by the interviewees was constructed. The tentative framework and list were reviewed by experts via a semi-structured questionnaire in Empirical Part II. A second data analysis phase was conducted which allowed for the validation of summarized interview results and for the adjustment of the framework. Finally, results were presented at isee systems. Feedback from this presentation was included in the discussion and conclusion. The framework is subject to further development and should offer a starting point for further steps.

This is a qualitative study, which makes generalized inferences from data subject to biases in the interpretation by the researcher, dependent on the specific research process and on the paradigms and underlying principles in literature that is used for deductive analysis. A central way to dealing with such problems is increased transparency, as suggested by Ritchie & Lewis (2003). To ensure replicability and validity of this study, all processes, underlying rationales and context of the study are therefore documented as transparently as possible. Operative details of the research and summarized data are provided in the appendices. These steps shall maximize understanding of the derived framework and allow to draw lessons for future research designs. Research ethics are discussed to create awareness about problems with studying generalization and generic structures that are linked to the author's background.

To ensure the internal validity of the research for the given purpose, the author had frequent contact with isee systems throughout the research process. Feedback was sought regarding the initial design, the design of the questionnaire and choice of interviewees. Before the construction of the framework, some of the interviewees' most prevalent ideas and concerns regarding generic models were discussed. After the interviewees commented on the developed framework, the framework was presented to isee systems for a final round of feedback.

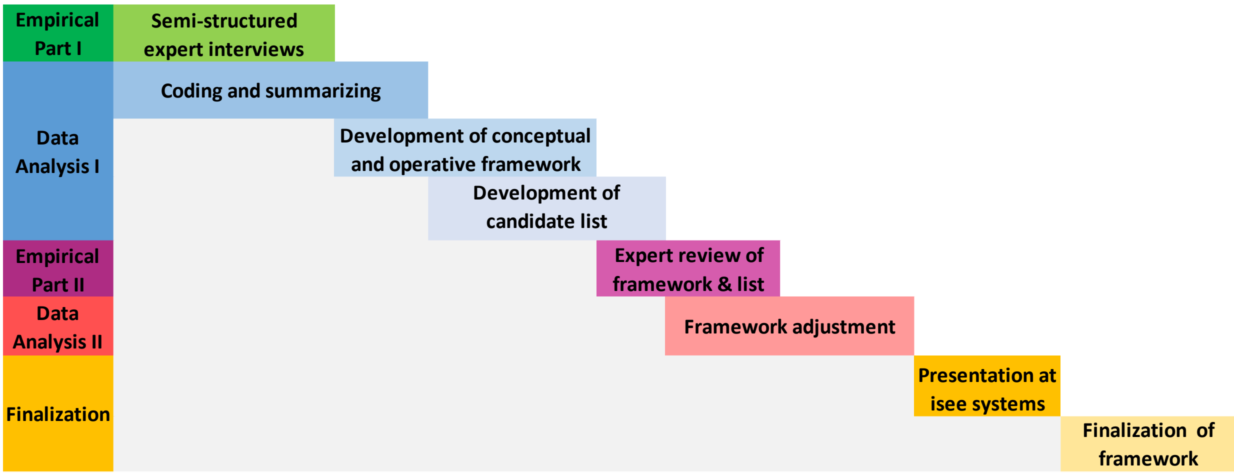


Figure 9: Research design and process

3.2. Choice of literature

To ensure that the most relevant literature would be considered and that there was no undue bias in the selection of sources, five separate steps were taken to identify literature. First, a few key papers were identified that deal with the concept of generic structures, generic models and model simplification in system dynamics. These were known to the researcher already, suggested by isee systems or supervisors and discovered in a simple online search of university data-bases, the System Dynamics Review online search and other online search engines. Second, departing from these publications, a keyword search was administered in the bibliography of the System Dynamics Society (2015) to get an overview of the amount and diversity of work done related to generic structures and closely related issues. Results from this search show a total of about 300 papers that featured keywords in either title or abstract, of which about 100 papers have been excluded since they did not actually deal with generic structures. The procedure of this keyword research and examples of results are documented in the Appendix A - Literature.

Third, general online resources related to system dynamics such as forums, blogs, wikis, model exchange websites and other types of online databases were reviewed. Fourth, literature suggestions from interviewees that were made before, during or after the interviews were considered. Fifth, publications that will be presented at the International System Dynamics Conference in 2015, that were not included in the originally obtained System Dynamics Society bibliography, were included (three papers of relevance). Another interesting publication from this conference is the bibliometric analysis of the System Dynamics Review by Orefice & Moraes (2015). The authors categorized all existing publications into theoretical and applied papers and classified them according to subjects. While their publication was not available early enough to be used for the identification of relevant literature in this thesis, it may prove helpful for future research. The following subject divisions may be relevant to consider when researching generic business models.

- *"Methods", to papers whose subject is learning methods, applied methodologies to education and to groups of scholars and methodological tools;* [14 publications]
- *"Organizational", to papers whose subject is organizational learning, learning processes and training in organizations;* [9 publications]
- *"Strategy and Processes", to papers whose subject is strategy, procedures and organizational processes;* [42 publications]
- *"Policies", to papers whose subject is management and organizational execution policy;* [6 publications]
- *"Organizational Resources", to papers whose subject is organizational resources collection and management, except human resources;* [11 publications]
- *"Conceptual", to papers whose subject is development and analysis of pre-existing and new components of the [sic] System Dynamics, System Dynamics history and honors;* [110 publications]
- *"Tooling", to papers whose subject is analysis and experience with tools and software built to meet System Dynamics"* [9 papers] (ibid., pp. 2-3)

3.3. Data collection

3.3.1. Empirical part I: Expert interviews

Expert interviews were identified as an appropriate research strategy for three reasons. First, at the given low state of research on generic models, a rather open approach is needed for deepening the understanding of generic models that exists in the field (Ritchie & Lewis, 2003). The development of a closed, quantitative questionnaire is not feasible with the available knowledge. Too many concepts were ambiguous and thus a more explorative semi-structured interview approach was chosen. Second, this research strategy is also suggested as appropriate in the knowledge management literature, which refers to the identification of key assets in a company or field by means of making tacit expert knowledge explicit (Ihrig & MacMillan, 2015). Third, as suggested by El Sawah et al. (2015), Gamma et al. (2001) and Tignor (2000), expert insight is needed for the development of standard patterns in a field such as computer simulation. Alternative approaches would have been to bring experts together in a Delphi or focus group process or to work on a community based definition and identification of candidate models, that is, a quantitative, fully structured survey in the field. As mentioned before, at the current state of research, a quantitative study is not a feasible option. A Delphi or focus group was not chosen either since it was not feasible to organize such an intensive process with the given geographic dispersion and given the responsibilities of the interviewees.

Choice of interviewees

Instead of aiming for statistical representativeness, the choice of interviewees in qualitative research shall reflect the diversity of perspectives on the given issue (Ritchie & Lewis, 2003). To capture these perspectives comprehensively, three distinct steps were taken to identify interview candidates. An initial list of twenty candidates was constructed according to main authors who theoretically discussed or practically applied generic structures - or who published other major work such as textbooks that feature models of generic character. This list was reviewed with the two co-presidents of isee systems to ensure that their objectives regarding the study would be met. Five new candidates were revealed and some were deemed to be less relevant (e.g. some authors were mostly using models to work in primary schools, whereas the main interest in this research lay on higher education and management). Finally, the study drew upon the knowledge of experts in the identification of interviewees, that is, they were provided with the list of candidates and asked to nominate other possible candidates. This revealed four new names. The advantage of this 'snowballing' system of identifying interviewees is that experts have a good overview of the field and can refer to candidates that could not be found otherwise (Saunders and Lewis, 2012). In total, twenty-one candidates were approached with personalized e-mails, with a response rate of ninety percent, of which eighty percent agreed to an interview, of which all but one interview was conducted until the end of the study. Two other candidates declined an interview but sent helpful comments. All interviewees have more than fifteen years of experience in modeling, consulting and/or teaching in system dynamics. The final list of interviewees is shown in Appendix B - Interviews.

Semi-structured interview guide

Given the analysis of literature on generic structures, a semi-structured interview guide was developed. For the purpose of validity, objectivity and replicability of this study, the full questionnaire, some underlying principles for the development of the interview guide and details about the process of interviewing are laid out as transparently and operatively as possible in Appendix B - Interviews. The interview guide was developed according to four general criteria. First, the development of the questionnaire was guided by fundamental empirical research tenets as well as by central insights from system dynamics. Second, the general themes of the questionnaire were identified according to questions that were posed but unresolved in the literature. The three themes are clearly linked to the research questions and objectives of this thesis as can be seen in Table 3. The three distinct phases allowed for different approaches of eliciting knowledge. Part 1 set the boundaries for the conversation and helped to uncover people's mental models in rather open questions. This will contribute to the construction of the conceptual framework. Part 2 followed up with discussing rather concrete, operative steps for the identification and assessment of generic models, contributing to the development of the operative framework. Part 3 concluded the interview by asking for concrete examples of models that could be candidates for the generic model list.

Part 1	Conceptual framework: Definition, purpose and users of generic models	1a) How can generic models be defined? 2a) For which purposes and which users can generic models be useful?
Part 2	Operative framework: Identification and assessment of generic models	1b) By which criteria can generic models be identified? 2b) By which criteria can generic models be categorized and classified?
Part 3	List of candidate models: Identification of example models	1c) Which existing models can be candidates for a list of generic models?

Table 3: Contribution of interviews to addressing research questions

Third, the specific questions were constructed with isee systems' objectives and business model in mind, e.g. related to the way in which generic models should be used when working with managers and related to future modeling software and interface development. The questionnaire was reviewed with isee systems, adapted and reviewed a second time. Fourth, the questionnaire was formulated with rather open questions and designed to be rather responsive to the specific interview situation and interviewee. There were twenty main questions and many possible follow-up and clarifying questions. The latter were pre-formulated to elicit concrete statements that would make them easier to compare in the analysis of the interviews. These follow-up questions were not asked to every one of the interviewees, but only when the responses to the open questions would not reveal the points of interest. A total of about sixty to seventy minutes was planned for each interview, which was communicated to the interviewees beforehand. This timeframe was realized in most cases with an average duration of 74 minutes, a minimum of 22 and a maximum of 107 minutes. (The shortest interview was restructured and focused on questions of model quality and validation, which corresponded to the interviewee's area of expertise.)

3.3.2. Empirical part II: Review of the tentative framework and candidate list

In a second step, the interviewees and the interviewee candidates who responded to the original interview request were asked to review the tentative framework and the candidate list of generic models (nineteen out of the original twenty-one, since two had not replied at all). A document of ten pages was sent to them, of which five were actual content that had to be reviewed. The other five pages featured a short introduction, an instruction on how to comment on the document and a questionnaire. The document was comprised of a summary of the interviewees' statements in form of a conceptual framework (which was hardly influenced by the literature) and of an operative framework with four phases that were derived both from the literature review and the interviews.

The feedback remained on a qualitative level, although it was more highly structured than the rather open and responsive interviews. Only a general agreement or disagreement and the reasoning about seven topics was inquired in seven questionnaire items. These items were a combination of one closed and one open question: Likert scaled questions enabled interviewees to indicate if they generally agreed or disagreed with parts of the framework. Each Likert scaled question was accompanied by a text box in which interviewees could specify their answer. Sections for feedback were:

1. Definition
2. Disambiguation
3. Relevance and potential usefulness
4. Potential benefit to different users
5. Mode of use
6. Overall impression of the operative framework
7. Overall impression of the documentation

The complete document was presented without any reference to specific scholars or interviewees to ensure confidentiality of each interviewee's statements. Moreover, this was meant to ensure that interviewees' comments could not be biased in any way by anchoring their judgment on a person, instead of the statement itself. That is, the disagreements between scholars that may exist in the field (as can be seen in the literature) should not be perpetuated in the process of commenting on the framework. Half of the interviewees and one interviewee candidate (in total ten out of nineteen) that had sent written input before, reviewed the framework and responded at least once more. When a point in their feedback was unclear, the researcher attempted to clarify in a follow-up e-mail. Some interviewees sent more than one comment and many sent very thoughtful and detailed replies. The tentative framework including the review questions and the original comments by interviewees can be found in Appendix D - Feedback on the developed framework.

3.4. Data analysis

The content analysis of the given research was twofold. First, due to the semi-structuring of the interviews, coding was conducted deductively, that is, according to codes and categories that were derived from the literature review. Second, the interviews were reviewed inductively to discover topics and issues that were stressed by one or several interviewees but that were not visible in the literature. The detailed documentation of the coding process is available in Appendix C - Interview analysis. Generalization of results is difficult in qualitative studies, but a central and necessary part in this study. Without a certain degree of generalization, a framework could not be constructed, since choices on basic assumptions and rules need to be made. Types of generalization that were reflected in the construction of the framework are inferential, representational and theoretical generalization (Ritchie & Lewis, 2003). Representational generalization is concerned with the question if results from the research sample (interviewees) can be generalized to the parent population (experts in system dynamics). Inferential generalization reviews if results can be inferred to other contexts beyond the sample (the field of system dynamics). Theoretical generalization examines if theories or principles can be drawn from the results for a more general application (Ritchie & Lewis, 2003). In summary that means that data from the interviews has to be generalized in such a way that it allows for the construction of a framework that will be of acceptable internal validity to the interviewees and of external validity in the wider field and beyond the field. The internal validity was checked by

3.5. Research ethics

In qualitative research, transparency about exact steps and reasoning is paramount for replicability and the validation of a study (Ritchie & Lewis, 2003). As a consequence, the researcher took special care to disclose her personal background and the context of the given study; approaches taken and perspectives considered; to describe steps in the development process in an operative, concrete and detailed way; to draw intermediary conclusions and to reflect on the ongoing process. Expected results have been noted explicitly, to reveal any possible impact of the researcher's expectations on the interpretation and analysis of the data.

3.5.1. About the author

A researcher in social science has to consider the problem that they are interacting with or are even a part of the social system that they research. Thus, the setting in which the author operates is shortly described. (Inspired by '*The Electronic Oracle'* by Meadows & Robinson (1985), which dealt with this problem in an exemplary section on their background and biases). The researcher was formally trained in schools and universities in Europe and North America and has specialized in not-for-profit management, sociology and entrepreneurship (bachelor's level) and system dynamics (master's level). Consequently, she is influenced by dominating paradigms in these areas. For example, the expected inherent value of standardization, generalization and efficiency are typical notions that stem from western traditions of thought and academia.

Dominant paradigms are both positivist and post-positivist, such as relativist and discourse ethical perspectives of science. The early specialization in social sciences is expected to have led to a bias towards the latter paradigms, which define reality in their respective social and cultural context.

An absolute notion of relativism is rejected, since generalization and standardization are important in functionalist disciplines such as system dynamics (Jackson, 2000). In this sense, the researcher aims to be pragmatic, that is, the research is inclined to apply useful and feasible concepts, rather than those adhering strictly to some pre-defined ideal. This pragmatist sentiment was reinforced by the researcher's applied management and entrepreneurship studies. Such a perspective is generally expected to be shared within the field of system dynamics, where validity of a model is mostly considered as usefulness or credibility for a specified user group, where interdisciplinary collaboration is valued and where much applied research is done.

A central principle in research ethics is to be conscious of multiple roles in the research process (Smith, 2003). An important disclosure about the context of this study is therefore that the researcher switched roles during the research process from being a student and outsider to the company to being part of the company as an intern. Overall, this role switch was not assumed to create any biases or conflict of interest. As an intern, the researcher gained more insight into objectives, strategies and day to day operative processes. The researcher attempted to make explicit wherever possible if such new insights have informed the research process. Perspectives and interpretations by isee systems have been made visible and distinguished from the researcher's perspective explicitly. For example, while isee systems assumed that generic models will be useful for their business and vital for the development of the field, the author of this study challenges this assumption in her research design. This reflection helps to ensure study results that rely on the input of expert interviews and literature.

3.5.2. Interaction with interviewees

Participants in a study should be fully aware of how their statements will be used and were informed as clearly as possible about context and process of this study (Smith, 2003). At the same time it was attempted to make as little as possible use of theoretical input that might have been able to influence interviewees' responses. Hence, purpose and design of this study, the context in which it was conducted, the format and duration of interviews, the use of the interview results (e.g. direct quotes checked with interviewees to prevent misrepresentation) and future steps in the research were communicated to the interviewees. Communication with interviewees was carefully formulated and responses sent as timely as possible. Final results were sent out upon completion of the study.

4. Results

4.1. Expected results

To reveal the researcher's possible biases, expected results were noted prior to conducting the interviews. An agreement on the basic definition of generic models is expected, but little understanding of how these models can be operatively identified (since there have been so many years with little progress in this respect). It is expected that generic models are believed to be useful for the development of the field. Generic models are believed to be understandable more easily than customized ones and it should be easier to work with them. For the presentation of generic models, software appears not developed enough. Better interfaces such as games are needed to make models more accessible and user-friendly to non-modelers. It is expected that to experts, working with models in stock and flow form is preferable compared to relying on interfaces only. Paich (1985) noted that it may not be necessary to agree on a definition. The researcher however is biased towards the idea that agreement is a desirable state, that a framework should be pragmatic rather than exhaustive and that a well-defined structure and process is preferable to a vague one based on tacit expertise.

4.2. Interview results

Given the qualitative nature of the research and the small sample size, results are presented in a descriptive way that shows diversity and ranges of opinions (Ritchie & Lewis, 2003). In other words, the different topics are described not by quantitative statistics but by general tendencies, such *as tendency to agree*, *tendency to disagree*, *uncertainty*, *source of confusion* and similar expressions. The exact meaning of these expressions is laid out in Appendix C - Interview analysis.

4.2.1. Definition

The definition of generic models is a source of confusion and took up a substantial time of discussion in most interviews (in terms of actual time spent and regarding coded items; that is, codes related to definition were used more than thirty times). Although there is a tendency to agree on the main characteristics of such models, the interviewed experts used a broad range of different terms to sum up these characteristics. Terms used by interviewees were *generic models*, *generic systems*, *canonical situation models* and *generic structures*. During each interview it became clear that generic models are presented as stock and flow structures that are fully quantified and that can be simulated as opposed to conceptual stock and flow diagrams or causal loop diagrams. This was either explicitly mentioned or derived from the structures that were discussed with interviewees. However, when asked for a definition, this structure or form of presentation was not given in the most immediate response. Instead, there was a tendency to first refer to the usefulness generic models, that is, they were defined as *widely applicable* or a similar expression (*broadly applicable, applicable to many situations* etc.). This applicability meant either transferability across particular cases in one domain or transferability between different domains. In this sense, generic models were also referred to as representing a class of systems. Besides this wide applicability, the most frequently referred to idea was that these models hold a *key insight*, specified by some as *policy* or *surprising insight*. According to a few interviewees, the concept of a *key* or *surprising insight* is a problem in itself, because it has not been sufficiently defined what exactly makes an insight key or surprising. So far, there is little certainty on what generic models have in common other than these two characteristics.

Five other characteristics were named by a smaller number of people. First, generic models show a range of typical behavior patterns or dynamics. Second, these models should be small, respectively, they should have a narrow boundary. That means, they should consist of a minimum amount of stocks that are necessary to reproduce the typical behavior pattern. Some specified that there would typically be no more than 2-4 stocks and others referred to 2-3 loops. However, a few of these interviewees stressed that any higher number of stocks or loops should not be a reason for excluding a model from a list of generic models. The world model and the national model that Jay Forrester is working on were named as examples of such larger generic models, although interviewees were uncertain if these models should be seen as generic models. One interviewee referred to the problem of choosing boundaries by stating that it is key to have a sufficiently simple model so that it can be communicated and to have a sufficiently complex model to produce the behavior. Third, generic models were described as structures that are repeated over and over again or that can be reused. The elements that could be reused were specified as stock and flow structures and equations, which would remain the same when transferred to another case. Fourth, for transferring a generic model to a specific context, these models would only require changes in variable names and parameters or need small extensions or reductions of structure. Fifth, to be transferable to a new case, the generic model would have to be well-documented. The two most frequently mentioned (applicable, insightful) and the five other characteristics were used for defining generic models in the conceptual framework (see Appendix D - Feedback on the developed framework).

When asked if they see an agreement on the definition in the field, a rough third of the interviewees responded that they believed there was a fair amount of agreement, a third were uncertain and another third perceived the confused terminology as a problem in the field.

4.2.2. Disambiguation

The differences between generic models and other types of generic structures was only discussed shortly with each interviewee (related codes used about fifteen times). Interviewees mostly focused on qualitative systems archetypes. A majority of them stated that generic models are less generic than archetypes. Qualitative archetypes show structure in more abstract terms and infer behavior through (more fallible) mental simulation, whereas stock and flow diagrams show the concrete structure in more tangible stocks that have a specified unit, that are quantified and from which behavior can be inferred by (more rigorous) computer simulation. To be simulated, generic models also need to contain some links that can typically be abstracted in a causal loop diagram, that is, causal loop diagrams can contain fewer elements. The difference to microstructures or molecules was hardly addressed, although it was clear that they are small reusable structures that function as building blocks. It was noted by one interviewee that there is a lot of research on systems archetypes, but that there is hardly any research on generic models and microstructures.

4.2.3. Purpose and usefulness

The purpose of generic models was discussed more than any other topic and fraught with controversy (purpose is the most used code with more than forty times). While teaching was referred to as the primary purpose, the use for policy advice was doubted and there was hardly support for the idea that generic models could be something like the *Holy Grail* for the field. There was a wide tendency to agree that generic models can be used for teaching, although some concerns were expressed as well. One interviewee pointed out that Forrester's main intention for having a set of twenty general models was to use it for teaching and not for case-specific work. Generic models could be useful for beginning modelers by acting as a reference point, that is, students could learn from replicating such thoroughly validated and high quality models. This is expected to speed up the learning process and to improve the overall quality of modeling work in the field. However, some interviewees also voiced concerns that students would learn modeling in a less profound way when using generic models and that they may violate assumptions that were made when building the model. Constructing a model from scratch was referred to as a tremendous learning experience, which would be missing when students simply operated with generic models. This was observed by interviewees who have taught for many years and who stopped sharing their models with students and instead let them build models from scratch with the aid of text-based case studies.

Another frequently cited benefit was that generic models would be helpful to increase quality, efficiency and speed of modeling efforts in the whole field. One interviewee argued that someone creating a list of generic models would be a market leader, since students, intermediate and expert modelers could equally benefit from having generic models as a reference point. Some experts stated that they would be able to build models more quickly and efficiently, especially when they do not want to build models from scratch. More efficient modeling would help to lower costs and prices in consulting, which would make it possible to have an impact in organizations without asking for large investments. This decrease in costs for consultants was expected to occur more than just once, because consultants could include insights that were gained from one project in the generic model for further use. That is, by continually improving the generic model it may become more representative of the given management problem and therefore would once again need fewer customizations in future projects. Moreover, there is a belief that there are many practitioners who build models but never received formal system dynamics training. Generic models could help to improve their modeling efforts.

There is a tendency towards disagreement about the use of generic models for policy design, that is, when trying to solve a problem in a specific case. Some interviewees see potential in it and state that generic models sometimes would not even need to be customized to reveal relevant policy levers. That is, a generic model can contain well researched policy levers in typical management problems that come from dynamic analysis and that managers may not typically be aware of. Building a model with a client from scratch may take a long time and lead to a model that captures a lot of small detail that seems important to the client, but that may not reveal the root causes of a business problem. Generic models could prevent modelers from getting trapped in such irrelevant details. In the words of other interviewees, root causes would lead to the identification of key insights. That is, generic models can be used as a starting point for discovering insights and as a tool to communicate these insights. In contrast to this view, other interviewees claimed that applying generic models by customizing them to the client's specific case has never worked in their experience. They warn that trying to fit a problem into a generic model is a dangerous approach. While the behavior in a specific case may be similar to that of a generic model, it is not certain that the policy approaches from that model will work in the specific case. Generic models could then be strongly misleading because they would lead to superficial analysis and to premature identification of key behavior and related policies.

Despite these uses in teaching and for increasing modeling quality, only a few interviewees explicitly referred to the growth of the field as a benefit, that is, it did not seem to be a main point. Several experts contested the idea of generic models as such and referred to insightful, impactful, successful or best practice models instead. Forrester's idea of models that can address typical management problems is then interpreted not so much as a call for generic models, but more as a call for accumulating wise practice (as originally expressed by Richardson, 1996). Best practice models could be understood as such wise practice, without the drawback of claiming to be generally applicable and directly transferable to other cases.

According to some interviewees, the purpose, preferred use or perceived usefulness distinguishes generic models from other generic structures. Archetypes are mainly understood as a tool for communicating behavioral insights and can therefore also be used to explain the essence of a generic model. However, they were not referred to as tools for developing modeling skills. The purpose of microstructures was identified as building blocks, which can be used both for building customized models as well for building generic models. These statements make the distinction between the three generic types rather clear by specifying both a distinct purpose for each structure and by suggesting that each of the three structures can be used to support the other. Interestingly, hardly any of the experts stated that they use molecules or archetypes in their own work. While one had used archetypes in the past, they switched at some point to using an even simpler concept of text based (as opposed to causal loop diagram) take-home lessons. As opposed to these publicized structures, many of the interviewees reuse many of their own structures that worked well in the past.

Summing up, generic models are mainly seen as a device for teaching and for starting up management consulting processes. While hardly any interviewee was strictly against the use of generic models, few described them as central for the field and many had concerns about their usefulness in management consulting. The main concern herein was that generic models hold the inherent promise to be applicable without many changes in specific cases and that they can therefore be misused as a shortcut to quick solutions. The terminology of best practice, wise practice, insightful models, models that matter or impactful models was seen as less problematic. This notion is supported by the tendency that the interviewed expert modelers hardly make use of generic structures as published by Senge, Wolstenholme (archetypes), Richmond or Hines (microstructures), but that they reuse some of their own structures which they consider as insightful or useful.

4.2.4. Users

There was a tendency for interviewees to primarily define generic models by their usefulness for different groups. Several interviewees stated that a discussion of generic models should depart from identifying potential users first. However, the actual discussion of users hardly took a central role in the interviews, that is, not much time and not many clear ideas were dedicated to this topic (code used about twenty times). Overall, the term *user* was a source for some confusion. When discussing managers as users of generic models, interviewees interpreted the term in two distinct ways. First, for some interviewees *user* meant the person actually interacting with the model, that is, using computer input devices to manipulate the model, possibly even without assistance (referred to as model builders by an interviewee). For others, *user* was interpreted as person that is interacting with the model only through or by help of a trained modeler, consultant or facilitator, that is, they do not control the input devices directly and certainly not without assistance (referred to as model consumer by an interviewee). It seems that due to this confusion, there was uncertainty about the potential users of generic models. Interviewees had strongly differing opinions, hopes and doubts about using generic models with managers. When referring to students, this problem did not come up. It seemed clear that a student as user means direct interaction with the model, since the focus lay on modeling students who aim to improve their modeling skills (something managers are likely not mainly concerned with or interested in at all when trying to solve a specific problem).

The most common concern was that non-professional model builders, that is, users that do not have system dynamics training and who interact with the model directly and without assistance, may misunderstand and draw potentially misleading conclusions from generic models. This is especially relevant when managers aim to infer policies from the generic model and prematurely apply them to their specific case. This can be ineffective or even counterproductive for solving the manager's problem, and finally ensue both decreased effectiveness and therefore decreased confidence in the methodology of system dynamics. This problem is connected to the initial hope that managers could become modelers, a view that is deemed to be less frequent in the field today. Some interviewees stated that modeling is simply too hard to be done by managers themselves, which is why using or adjusting generic models directly and by themselves will be unsuitable for this group. Interestingly, this problem was also expected when managers use a model with assistance by a consultant, that is, as model consumers. A few interviewees stated that consultants would have to make sure that their clients understood that they are operating with a generic model and that this means that insights from this model may not fully apply to the client's specific situation. It became clear that in both cases the narrative with which the models are presented, matters greatly.

A distinction between different types of users in management was introduced by the interviewer. Forrester's (1993) differentiation between *enterprise designers* and *enterprise operators* was explained and interviewees were asked about the value of this concept for determining how useful generic models may be for different user groups. Forrester compared enterprise operators to pilots of a plane, people who generally know the structure of planes but whose understanding is limited to operating the controls. He drew the analogy further by comparing enterprise designers to aircraft designers and claimed that modern organizations need designers who fundamentally understand the structure and resulting behavior in organizations. Hence, he suggested that there should be management studies in which students would study the envisioned set of approximately twenty generic models thoroughly so that they may be able to design an organization effectively.

Several interviewees did not find this analogy helpful. There was a tendency to agree that both designers and operators should use models to understand a system on a fundamental level.

First, a concern shared by a few experts was that social systems are different from planes, in that they are more complex and in that they need to be redesigned 'in-flight'. That means, social systems cannot be simply stopped ('landed') and maintained the same way that planes can. Second, it is contested that there is a difference between these two types of managers. A few interviewees stated that even in case of a plane, the pilot or at least the maintenance people should understand the system or be able to give feedback to the designer. One interviewee interpreted Forrester's distinction as a powerful idea, but concluded that all managers should perceive themselves as designers, because each type of manager makes decisions that influence the day to day operations which all have a long term effect. This idea was shared by some interviewees, who expressed that both groups could benefit from using generic models. A few interviewees took this idea even further, stating that managers *could* not only use these models, but *should* be able to use such models. In one interviewee's words, being able to successfully run a company or department is a manager's main job. Not understanding structure and dynamic behavior often leads to problems that do not allow managers to adequately fulfill their job, which is why managers should try to understand models. A less strong viewpoint was expressed by two other interviewees. They believe that both groups can use generic structures and that it may be helpful if enterprise designers were modelers themselves and if they used generic models. For enterprise operators it may be sufficient to understand the core lessons from these models, that is, they could use system archetypes. Summing up, it seems that there are only vague ideas about types of user groups and their characteristics, although it is clear that different user groups may have different needs and capacities to work with models.

4.2.5. Types of use

The discussion of formats and available software with which generic models can or should be presented was closely connected to the discourse on user groups. It was therefore discussed as extensively (code used more than thirty times). One issue was whether or not managers would be able to use generic models without assistance by a trained modeler or facilitator. Most interviewees doubted that managers would be able to use models appropriately without assistance and that the guidance by a modeler will always be critical. One interviewee remarked that people could use generic models on their own, but that this would mean that valuable insights will not get shared with a wider community. Thus, the ideal use would always be with a facilitator and with a group. Another issue was the format that should be used to present generic models. Interviewees tended to agree that the format depends on the user group and on the specific purpose. Purposes included learning about systems and designing policies for specific problems. Formats that were discussed focused on either interacting with a stock and flow diagram directly or using a form of game or interface. In general, interviewees had widely diverging opinions on the usefulness of either approach. Generally, only one or two interviewees were proponents of one specific format. However, they did not necessarily perceive the format as a main problem when using generic models, since most problems with a specific format applied to customized models as well.

The main insight from the discourse is that interviewees did not regard the usefulness of available formats and software as the key problem – and therefore neither as a relevant policy lever for increasing the understanding of managers. Instead, several interviewees claimed that the key problem is communication, that is, the narrative with which system dynamics is explained to managers. One critical point was to clarify that a model is generic and that it can only be used for gaining general insights, not for prediction. Another vital point was to realize that managers make decisions based on mental models, not formal models. Some experts claimed that the representation of the model does not matter to managers, but that getting an answer that is relevant for solving the manager's business problem does. Consequently, it is important to present results from system dynamics modeling in a format that is familiar and easily accessible to managers. This can be done in the form of spreadsheets, graphs, equations, slide presentations, storytelling and by using terms and narratives that exist in the given organization. While some interviewees believe that a deeper understanding cannot be gained without presenting the stock and flow structure, other interviewees shared their experience that clients rejected this kind of presentation. One interviewee used an analogy to describe the problem: Managers are interested in results, not the underlying model, the same way that consumers use a radio or car without being interested in the details of the underlying technology. Another interviewee remarked that the successful integration of key insights into day to day decision making is not guaranteed even when these insights were communicated successfully. In other words, managers may gain a deep understanding of a fundamental problem, but may still not be able to implement decisions due to the organizational environment that they are operating in. Thus, the interviewee claimed that successful learning and policy design are just a first step and that consultants should guide implementation efforts as well.

Summing up, the diversity of opinions regarding this topic was stronger than in any other topic. It is important to note that most of the controversial points did not mainly concern generic models, but applied to customized models as much. A major disagreement concerned the use of qualitative (can be understood as archetypes, interfaces, management games, text based take home lessons) versus quantitative methods (using the actual stock and flow structure). This is seen as a paradigmatic problem in the field of system dynamics rather than a problem with generic models. A major insight was that there are problems that are more important than the choice of the format or software, such as the narrative with which models or model insights are presented.

4.2.6. Identification and assessment

As expressed by one interviewee, there may not be much agreement on the definition of generic models, but there may be a fair amount of agreement on models that are considered as standard. This topic was discussed rather extensively (related codes were assigned thirty times). One person stated that a definition of generic models has to be derived from looking at different example models and from examining what they have in common, rather than defining the concept first and identifying generic models based on that. This view was shared by a few other interviewees, who believe that finding a common definition of generic models is not that relevant and that the concept of generic models is not so useful. Instead, they refer to terms like insightful models, case studies, best practice or simply good practice. Several interviewees suggested to identify generic models by reviewing examples of successful system dynamics work. Moreover, they state that not just specific successful cases, but that numerous cases of work in a given topic need to be reviewed. One interviewee remarked that the term generic implies that there needs to be an elaborated body of literature which supports a certain structure. He suggested that not only publications on models should be reviewed, but that the problems that are modeled should be a starting point. Besides this idea for identifying generic business models, two other approaches focused on key stocks. First, it was proposed that any firm could be represented as interlocking asset stocks as used in balance sheets. If some of these assets stocks are repeatedly encountered as a source for problematic dynamics, this could lead to a considerable amount of transfer of insight between industries. Second, a core idea was that there are three things that exist in the majority of business cases and which can be replicated in each model, which are customers, staff and capacity. These ideas may also be useful for creating a taxonomy of generic models (interlocking asset stocks) and for categorizing models.

Forrester's statement that there may be about twenty models that could be used to deal with ninety percent of problems that managers face, was generally contested. Several interviewees believe that the given numbers were used light-heartedly and that they do not matter as such. Still, interviewees believed that the number of models should be small, agreeing that twenty may be a good approximation. When asked for model examples, most interviewees claimed that they would not be able to name more than ten and actually were able to name less than ten. Despite their doubts about Forrester's idea, several interviewees stated that it would be useful to have a list of generic models. Some claimed that several system dynamicists actually have their own list of structures that they frequently reuse, but that most of them are reluctant to share their list.

When asked who can or should identify generic models, opinions diverged and no clear answer was found. Several interviewees felt like there could and should be no central authority, that is, that different people could work on identifying generic models in different application domains. It was suggested that it will not be possible for a few people to do this in isolation and that it would have to be part of the scholarly process that is already in place. However, it was expected that time and focus to develop these models would be hard to come by. Some interviewees stated that progress in the identification of generic models is not likely unless some individuals dedicate themselves to doing so. Others agreed that it would only take a small number of people to work on this problem. One interviewee identified software developers as a likely group to take on this task. Interestingly, two of the experts remarked that they could not be the ones to assert that a model is generic, in that they are not able to judge what would be useful for others.

Summing up, a concrete process of identification, assessment and categorization did not become clear. The main ideas were to do a meta-analysis of existing models or to start from typical problems or key stocks. While some interviewees considered the idea that twenty models could help with a majority of business problems as an overstatement, they remarked that it is helpful to construct a list of models that are useful to study. This list could be brought forth by a small number of people, but would have to be discussed in the community.

4.3. Framework development

The interview results were captured in a conceptual framework which served as a basis for the development of the operative framework. Both these frameworks were presented in a tentative form to the interviewees and contained seven sections with questions that allowed for a critical review. The tentative form and the detailed collection of feedback is summarized in Appendix D - Feedback on the developed framework. Overall, there was mixed feedback regarding most items. First, in the conceptual framework, a tentative definition was presented as a set of characteristics that were derived from the interviewees. Each interviewee's definition was reflected in this list, so that each interviewee may be able to identify at least with a part of it. This approach worked out in so far as half of the interviewees tended to agree with the definition. The other half disagreed, reasoning that not all items were true for every generic model, especially concerning the reuse and transferability *beyond* application domains and the small size of the model. Due to this feedback, the set of characteristics that all generic models would share has to be shorter. The excluded characteristics may still be helpful as categorizing criteria, that is, for distinguishing between models with different levels of general applicability.

Second, the disambiguation was met with little agreement due to different reasons, but mostly with the argument that the distinction to other structures it too sharp. It has to be noted that a few interviewees here used the overall term of *generic structures* as if they were differentiated from structures such as building blocks or archetypes. However, in the provided disambiguation, it was explicitly the term *generic model* that was differentiated from other generic structures such as building blocks or archetypes. That is, as explained in the literature review, generic models, building blocks and archetypes are all generic structures. Possibly, a visualization is key to make a differentiation of terms clear. Third, the discussion of the relevance of generic models was mostly confirmed by interviewees' comments. Fourth, regarding the potential users of generic models, interviewees tended to agree or strongly agreed. Some experts repeated their concern of using generic models with managers respectively for policy advice. Fifth, interviewees mostly agreed with the summarized discourse on the different ways to use generic models, although many restated their preferred use and basic assumptions regarding usefulness. Sixth, two experts strongly agreed, two tended to agree and two disagreed with the proposed operative framework. The disagreement stemmed mostly from the perception that the process is overly complicated. The same was true for the catalog template. According to this feedback, the general explanation of the framework as provided in the original document was expanded in the following section. Other remarks on the framework were included in the discussion and conclusion.

4.4. Operative framework

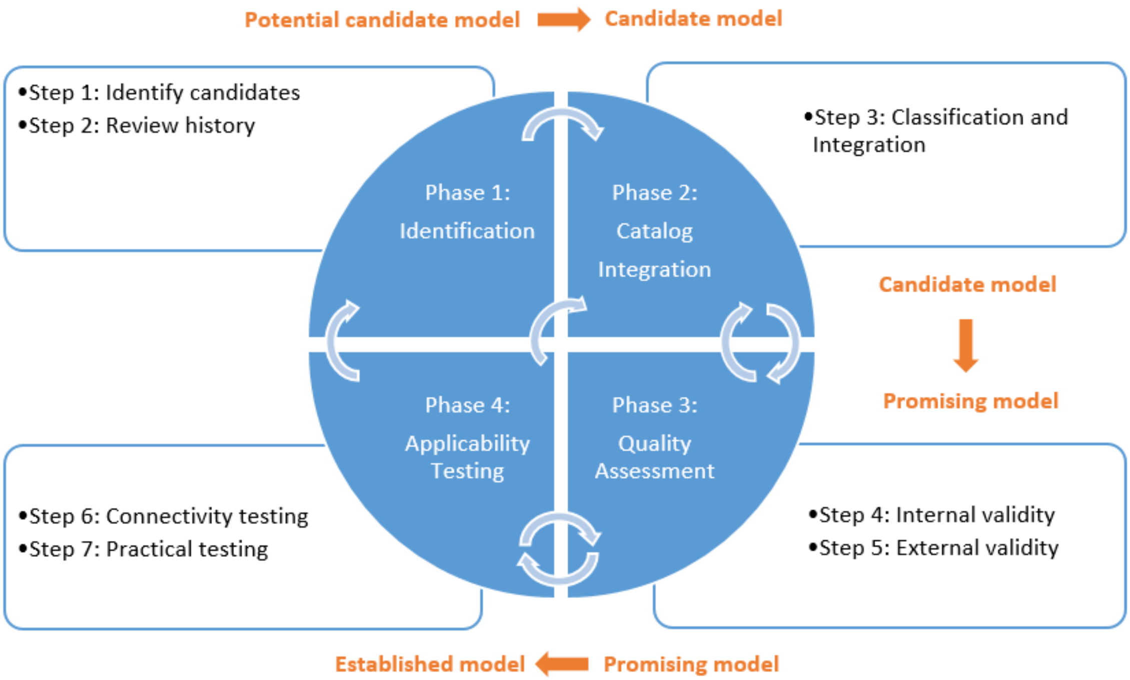


Figure 10: Operative framework

In Step 1, a list of potential candidate models is established by considering a variety of sources. In Step 2, the existing history of these models is reviewed to filter out models that do not fit a basic set of criteria. When passing these criteria, the **Potential candidate model** becomes a **Candidate model** and is included in the catalog in Step 3, where it is classified and related to the other model candidates. In Step 4 and 5 the model formulation is tested thoroughly according to established standards of validity and reporting. The results of this quality assessment are continuously documented in the catalog (as indicated by blue arrows between phases in the diagram above). This way, a **Candidate model** can become a **Promising model** because it passes further criteria for being a valuable structure. In Step 6 and 7 the **Promising model** can become an **Established model**. Not only the quality of the model itself becomes validated, but the usefulness and reusability in practical applications will be tested thoroughly. Different steps and phases are described in detail in Table 4.

The researcher set out with the view expressed by isee systems that the most difficult part will be to identify generic models. In the framework, *Identification* is only a first phase. This is because the identification actually depends strongly on the other three phases, that is, on the latest state of research regarding model quality and applicability. Hence, a phase is needed to integrate the results from *Quality Assessment* and *Applicability Testing*. This integration is done by means of a *Catalog* which captures the state of the research on candidate models. The main purpose of this framework is therefore the alignment of processes and documentation of existing efforts. Most steps are already being done, especially validity testing in Steps 4 and 5, and testing the success of applications in Step 7 (e.g. in group model building literature). However, these steps are not done consistently in the field. Building a catalog as shown in Step 3 would help to collect results from different publications in a standardized way and can therefore make study results more comparable. Step 1, identification of potential candidate models, Step 2 of reviewing their history, and Step 6 of testing how they can be connected, are processes that have hardly been done yet. Step 1 is done as a first attempt with this thesis, by providing a list of potential candidate models.

The framework reflects the agreement of interviewees that the development of generic models has to be an iterative and continued process, which is shown by the blue arrows that connect the four phases. The different steps can happen simultaneously and are not meant to be pursued consecutively. That is, this framework is not meant to be applied completely by one person alone, for example as a project where each phase is conducted after the other. It would probably take the dedication and focus of a doctoral study of several years to complete a full identification and assessment cycle for one model. Instead, the overview of phases is meant to function as a guideline, which several future studies can refer to. For example, a future study could be dedicated to phase 1, identifying and reviewing the history of one potential candidate model. Results can be documented in a publicly accessible catalog. Another study may exclusively deal with external validity of a specific model, documenting results in the catalog. Thus, a feasible way of using this framework is that several people may work on several phases simultaneously. Key for these efforts will be the continuous update of the catalog by thorough documentation of new insights. As opposed to molecules and system archetypes that were mainly brought forth and documented by two or three people, the identification of generic models will likely require a more joint effort in the field.

Phase 1: Identification

Step 1 - Identify candidates

Approach: List several potential candidates by literature review, conversation with experts. Define keywords and search criteria. Consider most frequently studied fields, models that are often reused/ cited.

Possible Sources: major publications in business/ in System Dynamics, System Dynamics Review publication list, Case Repository, Society events, Special Interest Groups, prize winning work (e.g. Jay Forrester Award, Barry Richmond Award,…), other publically available model libraries

Step 2 – Review history

Approach: Review one model of the identified candidates more closely. Conduct extensive literature research on different versions, applications and history of the model.

Criteria: Move on to Phase 2 depending on frequency of reuse/citation, number of users, amount of versions available, amount of available literature on this or similar models.

Phase 2: Catalog Integration

Step 3 – Classification and integration

Approach: Categorize and assign tags according to available information. Frequently update according to Quality Assessment and Applicability Testing results.

Criteria: see Catalog and Documentation template

Phase 3: Quality Assessment

Step 4 - Internal validity

Approach: Review validation tests previously conducted. Apply model structure and behavior tests as described in system dynamics literature. Document results in catalog.

Step 5 - External validity

Approach: Assess what makes it generic, transferable, widely applicable. Document results in catalog.

Phase 4: Applicability Testing

Step 6 – Connectivity testing

Approach: Test how model is compatible, connectable and consistent with other generic models. Document results in catalog.

Step 7 - Practical testing

Approach: Test usefulness of models when working with managers. Document results in catalog. Refer back to Quality Assessment phase if unsatisfactory results, adjust model, repeat testing.

Table 4: Detailed overview of the framework

4.5. Lists of potential candidate models

According to feedback of interviewees, a list of potential candidate models was established as shown in Table 5. First, a list of seventeen models was derived from the interviews. Since interviewees often referred to different versions of the same general topic and because partly there was no reference to a specific modeler, the models are not attributed to a specific author. Second, this list was presented to interviewees, of which four filled in the table as shown in the Appendix section Overview of feedback on the framework. Others commented more generally in text form and did not make a statement about established, promising or candidate level. A total of twelve models was identified. No model was identified as *Candidate Model*, nine models were recognized as *Promising Candidate* and nine were identified as *Established Model*. The most established models are a form of Supply chain model and Market growth model. Other models that were named several times are the Project management model, the Inventory-workforce model, Rework model and Limits to growth. Two or fewer interviewees identified Management of pharmaceutical products, Bass diffusion model, Corporate growth, Capital investment, Underachievement and Underinvestment as relevant models.

Model description	**Established Model**	**Promising Candidate**	**Candidate Model**
Bass diffusion model	X	X	
Capital investment model		X	
Corporate growth	X		
Inventory-workforce model	XX	X	
Limits to growth	X	XX	
Market growth model	XXX		
Management of pharmaceutical products	XX		
Project management model	XX	XX	
Rework model	XX	X	
Supply chain model	XXXX	X	
Underachievement		X	
Underinvestment		X	

Table 5: Tentative list of generic models

5. Discussion

The results of this study are evaluated in light of previous research and discussed according to their contribution to answering the research questions. The qualitative interview results largely confirmed tendencies that were discussed in the literature review and also expanded the spectrum of related issues. The idea that a model can be generic was partly contested, since interviewees felt that there could be more than one formulation for one and the same problem. This perception is consistent with Cronbach's statement that generalizations should be seen as working hypotheses rather than as conclusions (Ritchie & Lewis, 2003), as remarked in section 2.1 The role of generalization in science. Thus, it will be critical to explicitly define generic models as dynamic working hypothesis rather than as the *correct* or *best* formulation of a problem. Interviewees did not discuss replicability as an inherent value of generic models, so there was little explicit recognition that generic models may play a role in standardization in system dynamics. This may be an implicit assumption though, since interviewees frequently referred to possible improvements of overall modeling quality in the field. In accordance with Richardson (1996), interviewees generally identified generic models as a reference point for beginning modelers, as discussed in in 2.2 The role of generalization in system dynamics. However, they did not assign generic models a central role in system dynamics as envisioned by Forrester (1973, 1993, 2007).

When comparing the section 2.3.3 State of research on generic models with statements by the interviewees, it becomes clear that not only the concept of generic models, but the wider concept of generic structures has hardly become established in the field. Much confusion still exists regarding both the definition and disambiguation of the different types of generic structures. One notion that is central to the definition of generic structures in general is that they can be reused, an idea that was contested by some interviewees when considering generic models. A key point here seems to be that there needs to be an explicit differentiation between models that are transferable within domains and that can be transferred across domains, which was integrated in the visual differentation by El Sawah et al. (2015). Moreover, interviewees criticized the characteristic that generic models are usually small, which was described in the definition of the conceptual framework. They argued that there are some larger structures which also qualify as generic models. Moreover, a strict cut-off point between generic models and molecules was questioned. When constructing a catalog, it may therefore be useful to allow for the inclusion of models that have different levels of generality. When a very short, text-based disambiguation was presented to interviewees in the conceptual framework, many tended to disagree although their argument was not inconsistent with the text that was presented by the researcher. It seems therefore advisable to include a visualized differentiation in future studies where a possible overlap and the relationship between different generic structures becomes clearer.

As discussed in 2.4 Knowledge management in system dynamics, misunderstanding and misuse of generic models are possible threats when knowledge becomes more widely available. This concern was often expressed by interviewees and discussed as a major problem when considering the usefulness of generic models. In this thesis, the issue was addressed by making standardized reporting in form of a catalog a key phase in the operative framework. Ideally, transparency about the origins, possible use and possible caveats of a generic model would enable modelers to appropriately use generic models. Future research will have to address this matter explicitly and carefully as well. A part of the operative framework was to suggest a documentation template for the catalog of generic models, similar to those shown in 2.5 Design patterns and existing catalogs. The template that was shared with interviewees was commented on the least and was partly criticized as being hard to follow. This became especially apparent when interviewees referred to a missing section that was actually included in the template, but under another term. Thus, the template sections will have to be more thoroughly explained to be useful to modelers. Moreover, a catalog will have to include introductory sections like “How to use this catalog” and “How to selected a generic model”, which is similar to sections in the object-oriented design pattern catalog by Gamma et al. (2001). These sections could not be written in the given thesis and will have to be developed in future research.

The discourse on using generic models for 2.6 Decision making and learning in management reflected the discourse on using models in general in this context. The diverging opinions that were encountered in the literature were discovered in the interviews as well. The only difference may be that the concerns that already exist for the use of any kind of model were even stronger when considering generic models. As opposed to customized models, generic models were only considered to be viable for management education and for starting up consulting projects. Since there are not enough comparative publications and controlled studies regarding the use of generic models, an important step forward would be to conduct thorough empirical studies (which can draw from research designs and evaluation criteria e.g. from group model building effectiveness studies).

The reflection of interview results with previous literature allows for providing an answer to the stated research questions. First, the identification of generic models was based on researching the definition, some criteria for identification and a tentative list of candidate models. Second, the assessment of generic models depended on identifying purposes and users as well as categorizations and classifications. During the course of the research it became clear that there are two questions that are key for the identification and assessment of generic models, which are 1a) “How can generic models be defined?” and 2a) “For which purposes and users can generic models be useful?” Since they were found to be largely unresolved, questions 1b), 1c) and 2b) can only be answered tentatively and addressed in form of a tentative operative framework and potential candidate model list.

1) How can generic models be identified?

1a) How can generic models be defined?

1b) By which criteria can generic models be identified?

1c) Which existing models may be candidates for a list of generic models?

The main research problem as described by isee systems was as an identification problem. It has become clear that the identification of generic models is not a straightforward matter, since defining generic models, finding criteria and constructing a candidate list were more challenging than expected. The state of research is developed too little and yielded only vague results, which leads to persistent confusion about key concepts. Hence, interviews largely centered on the discussion of these concepts and only allowed for a few operative identification criteria which were only shortly mentioned, but not sufficiently described in the operative framework. Consequently, the constructed list of potential candidate models is limited to input by interviewees and could not be assessed by the researcher. In the end it was not possible to show actual generic stock and flow example models in this thesis, since there was too much uncertainty on the basic definition and characteristics. Any chosen model may have been easily rejected as generic model by experts in the field.

The limited validation of the potential candidate list and the lack of displayed generic stock and flow example models are two key limitation in the results of the thesis. In retrospect, it may have been possible to prevent this problem by choosing a different research design. The topic was approached from a meta-perspective, first defining and discussing generic models as a concept, second constructing a framework and finally identifying candidate models. Instead, the study could have started by first identifying potential candidate models purely from literature and second, validating these models by discussing them with experts. The advantage of such a design would have been a more thoroughly validated list of candidate generic models, whereas the disadvantage would have been that research would be anecdotal and difficult to replicate by others. Given the conducted research design, future studies can hopefully use the operative framework as a starting point.

2) How can generic models be assessed?

2a) For which purposes and users can generic models be useful?

2b) By which criteria can generic models be categorized and classified?

The assessment of generic models was strongly defined by the discourse on different purposes and users. The central purpose that was defined by interviewees was seen in system dynamics and management education rather than policy design. This is consistent with Paich (1985) and Forrester's (2007, 1993) intention to use a library of general models for management education. Moreover, interviewees stated that intermediate and expert modelers would also benefit from the availability of a catalog of generic models. The approach to categorization and classification of generic models in such a catalog can be answered least in the given research. Few concrete suggestions were put forward by interviewees. In the operative framework, classifications are mainly based on a tag system (e.g. application domain tags; structure, behavior, feedback tags). Finally, a limitation of this study is that the operative framework could not be applied with a concrete example, that is, no potential candidate model was described in form of the documentation template. This was not feasible given the basic level of developed criteria and documentation sections.

6. Conclusion

6.1. Relevance of generic models for the field

Concluding, the 1.1 Relevance of generic models for the field and 1.2 Relevance of generic models for isee systems will be reviewed. When considering the problem of developing and growing system dynamics as a field, it has not become clear if generic models may or may not help with a central problem in the field. This problem is the communication of system dynamics and of insights derived from system dynamics models. In general, it seems system dynamicists need to worry less about the immediate availability of a comprehensive catalog or the exact format of that catalog. Instead, an area of concern should be to deal with persistent paradigmatic differences, since proponents of more qualitative system dynamics modeling seem to have rather different views when compared to proponents of quantitative modeling. This problem is not likely resolved without thorough comparative empirical research into the effectiveness of using qualitative or quantitative presentations of models. Apparently there is an interest in and need for both types of modeling, so potentially, each representation of models may be useful in a different context. Another area of concern should be to enforce standard reporting standards in the field. To date, they are still hardly applied and replicability is hardly achieved. When future modeling work is reported more consistently, it may become clearer which models are of high quality and which ones may be reusable for other cases in the same domain, or even across domains. That is, generic models may come forth by the simple act of better documentation.

When considering the problem of increasing impact in management, it seems system dynamicists need to worry less about the availability of generic models, since they are expected to encounter similar problems and advantages that are present when working with customized models. The key problem here seems to be the way in which models are presented to clients. Available technology is considered as sufficient by interviewees, but communication has to be improved on two levels. First, it has to be clear to clients what they can and cannot expected from using a model and second, insights from models need to be integrated into existing narratives and terminology of an organization. Finally, it does not only matter how managers perceive models, but how modelers view managers. Generally, system dynamicists refer to managers as a strongly generic term and with strongly generalized characteristics. Specific groups of managers may have greatly varying interest and capacity to deal with models. Thus, using generic models with different groups may yield very different results in consulting projects.

Concluding, future studies need not follow the given research design to further define and assess generic models. Rather, they can follow step 1 and 2 of the operative framework for identifying potential candidates and for assessing a single structure one at a time. This can be done either in individual interviews or group panels. Then, researchers can document results as shown in phase 3. Otherwise, they can skip the first step completely by using the candidate list provided in the thesis and proceed immediately to step 2 and 3. Instead of aiming to construct a highly validated list of generic models in a short time, it may suffice to just have a tentative list to start from, which will allow for applicability testing.

6.2. Recommendations for isee systems

Four key lessons can be drawn from this conclusion for isee systems' aim to make modeling more accessible to managers. First, it is recommended to support the continued research on generic models by taking over step 3 of the operative framework, that is, offering a catalog that integrates existing knowledge and that is publicly accessible. The catalog can be started with the potential candidate list of generic models that was suggested in this thesis. Second, the term generic models does not necessarily have to be used in this catalog. Since there is so much remaining confusion on the matter, it may be an obstacle for crowdsourcing information on such models. As a consequence, it may be preferable to start with a less contested terminology such as *insightful models*, *wise practice* or *models that matter*, which may be more easily understood and supported by a wide group of people. Third, probably it would be best to focus the efforts of identifying such models on two or three applications instead of trying to find twenty models immediately. Valuable lessons can already be learned from identifying, assessing and presenting a small list of models, which can make future research on this topic more effective and efficient. Fourth, the company should define both the specific purposes and the specific user group that it wishes to address. That is, the expected benefits from using generic models have to be specified for different groups of managers or stakeholders. This step is crucial for understanding how generic models have to be designed and presented so that they may be useful for isee systems, its clients and the field of system dynamics.

7. References

Akkermans, H. A. (1995). *Modelling With Managers.* (Unpublished doctoral dissertation). University of Eindhoven, The Netherlands.

Bauer, C., & Bodendorf, F. (2006). Enhancing system dynamics modeling using a component-based approach. *I.J. of Simulation*, 7 (6). Retrieved from http://ijssst.info/Vol-07/No-6/Paper3.pdf

Bigman, M. (2014). *Assessing Growth of System Dynamics as a Student-Practitioner Field*. (Unpublished master's thesis). Radboud University Nijmegen, The Netherlands.

Burns, J. R., & Ulgen, O. (2002). A Component Strategy for the Formulation of System Dynamics Models. *Proceedings of the 20th International Conference of the System Dynamics Society*. Palermo, Italy: The System Dynamics Society.

Corben, D. A. (1995). *Improving the accessibility of modelling for management learning : a systems thinking approach using ithink*. University of Stirling, United Kingdom. Retrieved from http://dspace.stir.ac.uk/handle/1893/2184

Cody, J., Cavana, R. Y., & Pearson, D. (2011). Maintaining Disparity: Thresholds of Defection. *Proceedings of the 29th International Conference of the System Dynamics Society*. Washington, D. C.: System Dynamics Society.

Eberlein, R. L., & Chichakly, K. J. (2013). XMILE: a new standard for system dynamics. *System Dynamics Review* 29(3), 188–195.

Elsawah, S., McLucas, A., & Ryan, M. (2015). Generic and reusable structure in systems dynamics modelling: roadmap of literature and future research questions. *Tentative Schedule of the 33rd System Dynamics Society.* Retrieved from http://conference.systemdynamics.org/current/upload/tentsched.html

Eskinasi, M., & Fokkema, E. (2006). Lessons learned from unsuccessful modeling interventions. *Proceedings of the 24th International Conference of the System Dynamics Society*. Nijmegen, The Netherlands: The System Dynamics Society.

Forrester, J. W. (1968). Industrial Dynamics: After the First Decade. *Management Science, 14*(7), 398–415.

Forrester, J. W. (1972). *Principles of Systems. Text and Workbook.* (Second Preliminary Edition, 6th printing). Cambridge, MA: Wright-Allen Press.

Forrester, J. W.(1973). *Industrial dynamics.* (8th printing). Waltham, MA: Pegasus Communications.

Forrester, J. W. (1993). System Dynamics and the Lessons of 35 Years. *In:* DeGreene, K. B. (ed.), *A Systems-Based Approach to Policymaking* (pp. 199–240). Norwell, MA: Kluwer Academic Publ.

Forrester, J. W. (1994). System Dynamics, Systems Thinking, and Soft OR. *System Dynamics Review,* 10(2/3), 245–256.

Forrester, J. W. (2007). System dynamics - the next fifty years. *System Dynamics Review, 23*(2-3), 359–370.

Ihrig, M., Boisot, M., & MacMillan, I. (2011). Forget IP. Mine strategic knowledge instead. *Harvard Business Review Blog*, May 6, 2011. Retrieved from https://hbr.org/2011/05/stop-obsessing-with-ip-rights

Ihrig, M., & MacMillan, I. (2015). Managing Your Mission Critical Knowledge. *Harvard Business Review*, January-February issue, 80-87. Retrieved from https://hbr.org/2015/01/managing-your-mission-critical-knowledge

Jackson, M. C. (2000). *Systems Approaches to Management*. London, United Kingdom: Springer.

Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (1995). *Design Patterns: Abstractions and Reuse of Object-Oriented Designs.* Retrieved from http://www.cs.duke.edu/courses/compsci308/cps108/fall00/readings/patterns-orig.pdf

Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (2001). *Design Patterns: Elements of Reusable Object-Oriented Software.* (22nd printing). Boston, MA: Addison-Wesley.

Groesser, S., & Gabriel J. (2014). Opportunity to improve: the first large scale empirical analysis about the replicability of system dynamics studies. *Proceedings of the 32nd International Conference of the System Dynamics Society.* Delft, The Netherlands: System Dynamics Society.

Gröβler, A. (2007). System Dynamics Projects That Failed to Make an Impact*. System Dynamics Review*, 23(4), 437–452.

Hines, J. (2005). Molecules of Structure. Building Blocks for System Dynamics Models. Version 2.02. Retrieved from http://www.systemswiki.org/images/a/a8/Molecule.pdf

Hines, J., Malone, T., Herman, G., Quimby, J., Murphy-Hoye, M., Rice, J., Gonçalves, P., Patten, J., & Ishii, H. (2011). Construction by replacement: a new approach to simulation modeling. *System Dynamics Review,* 27(1), 64–90.

Hirsch, G. B., & Immediato, C. S (1999). Microworlds and Generic Structures as Resources for Integrating Care and Improving Health*. System Dynamics Review,* 15(3), 315-316.

Homer, J. B. (1996). Why we iterate: scientific modelling in theory and practice. *System Dynamics Review,* 12*,* 1–19.

Homer, J. B. (2013). The aimless plateau, revisited: why the field of system dynamics needs to establish a more coherent identity. *System Dynamics Review,* 29(2), 124–127.

isee systems, inc. (2014). *Introduction to XMILE*. Retrieved from http://xmile.systemdynamics.org/wp/wp-content/userup/Introduction-to-XMILE.pdf

isee systems, inc. (2015). *About us.* Retrieved from http://www.iseesystems.com/AboutUs.aspx

Lane, D. C., & C. Smart (1996). Reinterpreting 'Generic Structure': Evolution, Application and Limitations of a Concept. *System Dynamics Review,* 12(2), 87–120.

Lane, D. C. (1998). Can We Have Confidence in Generic Structures? *Journal of the Operational Research Society,* 49, 936–947.

Lane, D.C. (2012). What Is a 'Policy Insight'? *Systems Research and Behavioral Science*, 29(6), 590–595.

Meadows, D.H., & Robinson, J. M. (1985). *The Electronic Oracle: Computer Models and Social Decisions*. John Wiley & Sons.

Meadows, D.H. (2008). *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green Publishing Company.

Myrtveit, M. (2000). Object Oriented Extensions To System Dynamics. *Proceedings of the18th International Conference of the System Dynamics Society.* Bergen, Norway: System Dynamics Society, 155–156.

Orefice, R., & Moraes, E. (2015). A bibliometric analysis of System Dynamics Review. *Tentative Schedule of the 33rd System Dynamics Society.* Retrieved from http://conference.systemdynamics.org/current/upload/tentsched.html; accessed at

Paich, M. (1985). Generic Structures. *System Dynamics Review,* 1(1), 126–132.

Radzicki, M.J., & Taylor, R.A. (2008). Origin of System Dynamics: Jay W. Forrester and the History of System Dynamics. In: *U.S. Department of Energy's Introduction to System Dynamics*.

Rahmandad, H., & Sterman, J. (2012). Reporting Guidelines for Simulation-based Research in Social Sciences. *System Dynamics Review,* 28(4), 39–411.

Richardson, G. P., & Andersen, D.F. (1980). Toward a Pedagogy of System Dynamics. *System Dynamics, TIMS Studies in the Management Sciences,* 14, 91–106.

Richardson, G. P., & Pugh, A. L. (1981*). Introduction to System Dynamics Modelling with Dynamo*. Cambridge MA: Productivity Press.

Richardson, G. P. (1995). Problems for the Future of System Dynamics. *Proceedings of the 1995 International System Dynamics Conference: System Dynamics '95*. Tokyo, Japan: International System Dynamics Society, 222–234.

Richmond, B. M. (1985). STELLA: Software for Bringing System Dynamics to the Other 98%. *Proceedings of the 1985 International System Dynamics Conference*. Keystone, Colorado: International System Dynamics Society, 706–718.

Richmond, B. M., & Peterson, S. O. (1989). *A User's Guide to Stella*. Lyme, NH, High Performance Systems.

Richmond, B. (2013). *Introduction to Systems Thinking with iThink®.* Lebanon, NH: isee systems, inc.

Ritchie, J., & Lewis, J. (eds.) (2003). *Qualitative Research Practice: A Guide for Social Science Students and Researchers.* London, United Kingdom: Sage Publications.

Saunders, M., & Lewis, P. (2012). *Doing research in business and management: An essential guide to planning your project.* Pretice Hall: Financial Times.

Senge, P. M. (1990). *The Fifth Discipline: The art and practice of the learning organization.* New York, NY: Doubleday/Currency.

Smith, D. (2003). Five principles for research ethics. *Monitor on Psychology, 34*(1). Retrieved from http://www.apa.org/monitor/jan03/principles.aspx

Schein, E. H. (1990). A general philosophy of helping: process consultation. *Sloan Management Review,* 31(3), 57–64.

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World.* New York, NY: Irwin/McGraw-Hill.

System Dynamics Society (2015). *Bibliography*. Retrieved from http://www.systemdynamics.org/bibliography/

Tignor, W. W., & Myrtveit, M. (2000). Object Oriented Design Patterns And System Dynamics Components. *Proceedings of the 18th International Conference of the System Dynamics Society.* Bergen, Norway: System Dynamics Society.

Tignor, W. W. (2001). Design Pattern Language and System Dynamics Components. *Proceedings of the 19th International Conference of the System Dynamics Society.* Atlanta, Georgia: System Dynamics Society.

Vennix, J. A. M. (1996). *Group model building. Facilitating team learning using system dynamics.* Chichester, United Kingdom: Wiley.

Warren, K. (2014). Standard Cases: Standard Structures: Standard Models. *Proceedings of the 32nd International Conference of the System Dynamics Society*. Delft, Netherlands: System Dynamics Society.

Wolstenholme, E. F., & Coyle, R. G. (1983). Development of System Dynamics as a Rigorous Procedure for System Description. *Journal of the Operational Research Society,* 34(9), 885–898.

Wolstenholme, E. F. (2003). Towards the Definition and Use of a Core Set of Archetypal Structures in System Dynamics. *System Dynamics Review,* 19(1), 7–26.

Appendix A - Literature

Keyword search

The following keywords were used for searching publications in the System Dynamics Society bibliography, Radboud University Library catalog and other sources.

'general'	'standard model'	'canonical situation'
'generic'	'standard cases'	'canonical situation model'
'generic structure'	'standardization'	'archetype'
'generic model'	'best practice'	'archetypical'
'generalization'	'component'	
'standard structure'	'molecule'	

An excerpt from the search in the bibliography shows how often and in which way the searched terms were used in different publications.

Term	Results
generic model	72
generic system dynamics model	19
generic simulation model	4
generic dynamic model/theory	3
generic [application] model	9
generic [other term]	12

Example results:

Arthur, D. J. W. and G. W. Winch (2002). Making System Dynamics Accessible to SME's Through User-Parameterised **Generic Models**. Proceedings of the 20th International Conference of the System Dynamics Society. Palermo, Italy, The System Dynamics Society.
Choucri, N. D. and R. Berry (1995). Sustainability and Diversity of Development: Toward a **Generic Model**. Proceedings of the 1995 International System Dynamics Conference: System Dynamics '95. T. Shimada and K. Saeed. Tokyo, International System Dynamics Society. 1: 30-39.
Graham, A. K. and N. D. Scogi (1985). **Generic Models** as Educational Tools: Teaching About Managing Technology Conversions. Proceedings of the 1985 International System Dynamics Conference Keystone, Colorado, International System Dynamics Society. 1: 331-346.
Hirsch, G. B. (2006). A **Generic Model** of Contagious Disease and Its Application to Human-to-Human Transmission of Avian Influenza. Proceedings of the 24th International Conference of the System Dynamics Society. Nijmegen, The Netherlands, The System Dynamics Society: 71.
Morecroft, J. D. W. and T. K. Abdel-Hamid (1983). A **Generic System Dynamics Model** of Software Project Management. Proceedings of the 1983 International System Dynamics Conference. Chestnut Hill, MA: 237-252.
Natchimuthu, S. K. (1999). **Generic System Dynamics Models** for a New Product Development Process, Michigan Technological University: vii, 91.
Pruyt, E. (2010). Scarcity of Minerals and Metals: A **Generic Exploratory System Dynamics Model**. Proceedings of the 28th International Conference of the System Dynamics Society. Seoul, Korea, System Dynamics Society.

Sancar, F. H. and R. J. Cook (1985). Aids for Customizing **Generic System Dynamics Models**: A Community Development Example. Proceedings of the 1985 International System Dynamics Conference. Keystone, Colorado, International System Dynamics Society: 744.
Bossel, H. and H. Schafer (1989). "**Generic Simulation Model** of Forest Growth, Carbon and Nitrogen Dynamics, and Application to Tropical Acacia and European Spruce." Ecological Modelling 48: 221-265.
Pfahl, D., M. Stupperich, et al. (2004). PL-SIM: A **Generic Simulation Model** for Studying Strategic SPI in the Automotive Industry. Proceedings of 5th International Workshop on Software Process Simulation Modeling, ProSim 2004.
El-Minisy, M. and K. Wahba (2007). A **Generic Dynamic Model** for Managing Channel Conflict in the Egyptian Lubricants Distribution Channels. Proceedings of the 2007 International Conference of the System Dynamics Society. Boston, MA, The System Dynamics Society.
Akcam, B., A. M. Cresswell, et al. (2006). Testing a **Generic Dynamic Theory** of Collaboration in the World Trade Center Case. Proceedings of the 24th International Conference of the System Dynamics Society. Nijmegen, The Netherlands, The System Dynamics Society: 42.
Andersen, D. F. and J. Sturis (1988). "Chaotic structures in **generic management models**: pedagogical principles and examples." System Dynamics Review 4(1-2): 218-245.
Schwarz, I. A. (1978). A **Generic Regional Model** for Interdisciplinary Impact Analysis. Second International MAB-IUFRO Workshop on Tropical Rainforest Ecosystem Research. Jakarta.
Veldhuis, G., P. v. Scheepstal, et al. (2014). Development of a **generic Smart City model** using MARVEL. Proceedings of the 32nd International Conference of the System Dynamics Society. P. Davidsen and E. Rouwette. Delft, Netherlands, System Dynamics Society.
Chomiakow, D. (2007). A **Generic Pattern** for Modeling Manufacturing Companies Proceedings of the 2007 International Conference of the System Dynamics Society. Boston, MA, The System Dynamics Society.
Dudley, R. G. (2005). A **Generic Look** at Payments for Environmental Services: Plan or Scam? Proceedings of the 23rd International Conference of the System Dynamics Society. Boston, The System Dynamics Society: 65-66.

Existing lists of generic models

#	Source of list	Term used	Model description	Model source
1	Forrester (1993)	generic management situations	stability and fluctuation in a distribution system	Forrester, J.W. (1968). Industrial Dynamics. Waltham, MA: Pegasus Communications.
2	Forrester (1993)	generic management situations	sales budget and capital investment as they often restrict growth	Forrester, J.W. (1968). Market Growth as Influenced by Capital Investment. Industrial Management Review, 9(2), 83-105.
3	Forrester (1993)	generic management situations	promotion chains and evolution into a top-heavy distribution of management personnel when growth slows	none provided
4	Forrester (1993)	generic management situations	imbalances between design, production, marketing, and service as these influence market share.	none provided
(2)	Corben (1995)	generic model	Market Growth and Investment Model	Forrester, J.W. (1968). Market Growth as Influenced by Capital Investment. Industrial Management Review, 9(2), 83-105.
5	Corben (1995)	generic model	Research and Development Project Model	Richardson, G., & Pugh, A.L. (1981), Introduction to System Dynamics Modelling with Dynamo. Cambridge MA: Productivity Press.
(2)	Lane & Smart (1996)	canonical situation model	Product Launch	Forrester, J.W. (1968). Market Growth as Influenced by Capital Investment. Industrial Management Review, 9(2), 83-105.
6	Lane & Smart (1996)	canonical situation model	Urban development	Forrester, J.W. (1969). Urban Dynamics. Cambridge, MA: MIT Press.
7	Lane & Smart (1996)	canonical situation model	Commodity production cycles	Meadows, D.L. (1970). Dynamics of Commodity Production Cycles. Boston: Wright-Allen Press.
8	Lane & Smart (1996)	canonical situation model	Ambitious product development	Graham, A. K. (1988). Generic Models as a Basis for Computer-Based Case Studies. System Dynamics Working Group Paper D-3947. Sloan School of Management, MIT, Cambridge, MA.
9	Lane & Smart (1996)	canonical situation model	Economic growth and income distributions in a developing country	Saeed, K. (1994). Development Planning and Policy Design: A System Dynamics Approach. Hong Kong: Avebury.
(1)	Forrester (2007)	generic structure	production/distribution system	none provided

(5)	El Sawah et al. (2015)	canonical situation model	urban development	Forrester, J.W. (1969). Urban Dynamics. Cambridge, MA: MIT Press.
(6)	El Sawah et al. (2015)	canonical situation model	production cycles	Meadows, D.L. (1970). Dynamics of Commodity Production Cycles. Boston: Wright-Allen Press.
10	El Sawah et al. (2015)	canonical situation model	acceptance–rejection behaviour	Ulli-Beer, S., Gassmann, F., Bosshardt, M., Wokaun, A. (2010). Generic structure to simulate acceptance dynamics. System Dynamics Review, 26(2), 89-116.
11	El Sawah et al. (2015)	canonical situation model	police arrest-domestic violence	Hovmand; P.S., Ford, D.N., Flom, I., Kyriakakis, S. (2009). Victims arrested for domestic violence: Unintended consequences of arrest policies. System Dynamics Review, 25(3), 161-181.
12	El Sawah et al. (2015)	canonical situation model	resource misallocation among social, asocial, and control parties	Saeed, K., Pavlov, O.V. (2008). Dynastic cycle: A generic structure describing resource allocation in political economies, markets and firms. Journal of the Operational Research Society, 59(10), 1289-1298.
13	El Sawah et al. (2015)	canonical situation model	cycles in airlines market	Liehr, M., Größler, A., Klein, M., Milling, P.M. (2001). Cycles in the sky: understanding and managing business cycles in the airline market. System Dynamics Review, 17(4), 311-332.

Appendix B - Interviews

Interview guide

This semi-structured questionnaire was used as an interview guide. It is annotated to make the reasoning behind the questionnaire construction and expected responses visible. Questions 1) to 20) are main questions that were posed to all interviewees. Follow-up / clarifying questions are marked as (-) and were only asked if the main question did not reveal a sufficient or clear response. In the first six interviews, the term *standard model* was used instead of *generic model*.

Part 1: Definitions, purpose and users of generic models

Objective: making mental models of the interviewee explicit, inquiring about diverse perspectives on core concepts and identifying potential consensus and disagreement between interviewees

1) (a) How would you define generic models?
   (b) (-) What makes a generic model generic?
   (c) (-) What is the difference between generic structures and generic models?
   (d) (-) Is there an agreement on this definition / are there different definitions and types?

2) (a) What is the main purpose of generic models?
   (b) (-) Is it to help managers? To help advance the field? Avoiding reinventing previous work, build on previous insights, replicability, quality increase?
   (c) (-) System dynamicists have observed that clients frequently approach consultants with a specific policy for a problem, rather than talking about the problem itself. They skip the step of analyzing the causal structure that underlies a given problematic behavior. If the development of generic models is a policy addressing a specific problem (in the field of system dynamics), what is this problem in your view? In other words, can generic models be useful to address current problems in the field? (e.g. teaching, deal with stagnating field, ...)
   (d) (-) Do you think that generic models are indeed a key to addressing the problem you just identified?

3) (a) Who would be the primary users of generic models?
   (b) (-) With which target group should they be used? That is, with which group in mind should it be developed and presented? (students, managers, scientists from other fields …)

4) (a) Forrester (35 yrs paper) claims that there is a difference between and enterprise operator (manager) and enterprise designer. What do you think of this distinction?

5) (a) Forrester envisions that enterprise designers would have to study each model with its own textbook, for a full semester and it would take at least 3 years. What do you think of this idea?

6) (a) In which context can or should they be used?
   (b) (-) For education of current/future managers; in consulting, group model building?

7) (a) Would they be used without assistance (games, case studies) or with assistance (preliminary models for consulting, training, adapted / extended in group model building)? (working with

actual model vs. gaming).
(b) (-) What would be the advantages of either form?

8) (a) Do you think currently available formats suffice to present these models?
(b) (-) Would there need to be development of other software, platforms or types of interfaces?

9) (a) A central tenet for many scholars in the field is that system dynamics models will have little impact unless they change the way people perceive a situation and that they need to communicate with prior mental models. Are generic models fit to do aid that process and if yes/no, why? (Schein: expert consulting vs. facilitation; Richmond: how do people actually learn?; Forrester: people are far more comfortable blaming their troubles on uncontrollable external causes rather than looking to their own policies as the central cause)
(b) (-) Would they hinder or enhance learning?

10) (a) Could generic models become as widely taught and used management tools as balanced scorecard, PEST(EL) tools?
(b) (-) Which steps would be needed that such a catalogue can become widely known and used?

11) (a) Who would benefit (the most) from the availability of such a catalogue?
(students, managers, modelers?

12) (a) Would such a catalogue be helpful for your own work?

13) (a) Do you already actively/frequently refer to generic models (or other generic structures) in your own modeling work / work with them with students / clients / colleagues / others?

Part 2: Identification and assessment of generic models

Objective: establishing operative approaches for the development of the framework

14) (a) Does it make sense to develop a catalogue of generic models be developed and if yes, will it be feasible?
(b) (-) Is there anything that may stand in the way of identifying generic models / agreeing on a basic set of these in the future?

15) (a) Who should develop or identify generic models / establish a catalogue of them?
(b) (-) Should it be the community or suggested by experts?
(c) (-) Should there be a focused process that is organized by some authority or should it be part of the existing academic process?

16) (a) Which operational steps would be necessary to identify and validate a generic model?
(b) (-) Is there a generally accepted research method for such structures (Paich, 1985)?
(c) (-) Would there be a different procedure from general approaches to modeling?
(Warren 4-step process; Saeed classes of factors)
(d) (-) What criteria are / should be used for identification?

(e) (-) How would you know/decide that a model can be considered as complete?
(f) (-) Can or should they build on smaller structures such as molecules (exclusively)?

17) (a) How can or should generic models be categorized?
(classic domains? Forrester: break boundaries between disciplines such as finance, marketing, production and personnel; look at what issues managers are typically faced with)

Part 3: Identification of examples and relevance of generic models

Objective: finding examples for the potential candidate list and finalizing the interview

18) (a) Following the definition and purpose that we just established, how many generic models are there in your view?
(b) (-) Forrester argues that about 20 general business models would cover more than 90 percent of situations that a manager ever encounters. Would you agree with this idea? Do you think the number of models itself is reasonable?
(c) (-) Do you think most generic models have been developed already but still need to be identified explicitly?
(d) (-) Can we have a fixed number of models or would the list have to be developed further continuously?
(e) (-) Once such a catalogue would be established, how would it become clear that it is exhaustive enough to address most management problems?
(f) (-) Would the catalogue itself have to be adjusted to new developments or should the models rather be adjusted to deal with specific situations?

19) (a) How many and which generic models have been identified already?
(b) (-) Please name generic models that you know / that you think are developed on a level that makes them generic.
(c)Why would you argue that those should be part of a catalogue of generic models, that is, given which assumptions or criteria?

20) (a) Independent of this topic, what is currently the most difficult struggle in your own work?
(see if it generic models could be relevant here)

Overview of interviewees and interviews

The following list consists only of people that responded to the researcher's request for an interview. Experts who were approached but were not available for an interview are not listed.

N*	Name		Identified by	Relevant expertise	Interview	Duration (minutes)	Terminology used **
1	Gene	Bellinger	relevant publications	archetypes	April 30, 2015	97	standard models
2	Kim	Warren	relevant publications	standard structures	May 4, 2015	70	standard models
3	Khalid	Saeed	referral	generic systems	May 6, 2015	68	standard models
4	Robert	Eberlein	relevant publications	molecules	May 11, 2015	64	standard models
5	Steve	Peterson	referral	generic system processes	May 12, 2015	73	standard models
6	George	Richardson	relevant publications	small insightful models	May 12, 2015	107	standard models
7	Eric	Wolstenholme	relevant publications	archetypes	May 15, 2015	71	generic models
8	David	Lane	relevant publications	generic structures	May 20, 2015	85	generic models
9	Jim	Hines	relevant publications	molecules	May 22, 2015	84	generic models
10	Andy	Ford	relevant publications	modeling the environment	May 26, 2015	94	generic models
11	Gary	Hirsch	relevant publications	generic models in health care	May 28, 2015	64	generic models
12	John	Morecroft	relevant publications	strategic modeling	June 2, 2015	90	generic models
13	Mark	Paich	relevant publications	generic structures	June 4, 2015	51	generic models
14	Yaman	Barlas	relevant publications	validation	June 5, 2015	22	generic models
15	David	Corben	referral	generic structures	e-mail response	0	
16	Jack	Homer	referral	generic models in health care	e-mail response	0	

* sorted according to interview date
** In the beginning, the terminology of *standard models* was used which was assumed to be a more neutral term than *generic models*. However, the researcher abandoned this approach due to critical feedback by interviewees about this term.

Overview of feedback on the framework

N	Name		Framework document	Candidate list document	Additional text*
1	Gene	Bellinger	no	no	yes
2	Kim	Warren	yes	yes	no
3	Khalid	Saeed	no	no	no
4	Bob	Eberlein	yes	no	no
5	Steve	Peterson	yes	no	yes
6	George	Richardson	no	no	no
7	Eric	Wolstenholme	yes	yes	no
8	David	Lane	no	no	no
9	Jim	Hines	no	no	no
10	Andy	Ford	no	no	yes
11	Gary	Hirsch	yes	no	yes
12	John	Morecroft	yes	no	no
13	Mark	Paich	no	no	no
14	Yaman	Barlas	yes	yes	no
15	David	Corben	no	no	no
16	Jack	Homer	yes	yes	no
			Total responses: 8	**Total responses: 4**	**Total responses: 4**

* sent by the interviewees via e-mail

Appendix C - Interview analysis

Summary of interview statements

The content of the interviews in 4.2 Interview results was summarized by indicating the diversity and ranges of expressed opinions. The different topics are described not by quantitative statistics but by general tendencies, such as *tendency to agree, tendency to disagree*, *uncertainty*, *source of confusion* and similar expressions. When several interviewees use the exact same or very close terms to describe a concept, or when several of them describe a similar concept with different words, this is expressed as *tendency to agree*. An example for very close terms is ‘applicable broadly’ and ‘widely applicable’ or ‘key insight’, ‘key policy insight’ and ‘fundamental insight’. An example for describing a similar concepts with different words is e.g. ‘improvements in area of interfaces would be good’ and ‘presentation tools need to be better’. Another example for this is the term ‘reusable’ which was understood as a concept similar to ‘structures that are repeated over and over again’. When interviewees used several distinct terms or concepts that represent an opposite or even mutually exclusive idea, this was described as *tendency to disagree* (e.g. ‘managers will only learn when seeing the actual stock and flow structure’ vs. ‘managers can learn from the use of interfaces without seeing the model’). When several interviewees stated that they were unsure or did not have an opinion on a matter this was referred to as *uncertainty.* When several interviewees used the same term but described different concepts, this was described as *source of confusion*.

The sample size did not allow for inferences based on the percentage or number of interviewees that expressed a similar idea. However, clear cut-off points were required to determine with which exact word to describe the strength of a tendency. They were defined as seen in the table below. If a statement is described without stating a tendency to agree or disagree, they were mostly just voiced by one person and are noted for comprehensiveness. If noted by two or three people, it is usually specified as *a few interviewees*. If more than that, it is noted as *some/several interviewees* and if more than half, a *tendency to agree or frequent statement* was noted. When almost everyone stated an idea, a *wide* or *broad tendency to agree* was documented. It is important to note that such frequently expressed ideas cannot be called *wide agreement* as such, but must still be described as a tendency, to ensure that misinterpretations of statements by the researcher do not lead to overstatements of a specific point. When *a majority of them* is used, this refers to a sub-set of interviewees that was defined in the previous sentence and specifies that most of this subset stated a specific idea. The cut-off points are:

Number of interviewees	1	2-4	5-7	8-10	11-14
Expression used in the summary	one interviewee	a few interviewees	some/several interviewees	tendency to agree; frequently stated	wide / broad / strong tendency to agree; most interviewees

Coding scheme

Codes were defined deductively from reviewed literature as well as inductively from recurring issues that were brought up by the interviewees. They were assigned to categories which were then assigned according to their contribution to answering specific research questions.

Deductive code categorization

Interview Part 1

Definition	Research Question		Sub-research question	Category	Code
deductively	1	Identification	1a) How can generic models be defined?	Definition	Definition
deductively	1	Identification	1a) How can generic models be defined?	Definition	Disambiguation
deductively	1	Identification	1a) How can generic models be defined?	Definition	Agreement on definition
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Purpose
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Relevance for the field
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Users	Primary users
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Users	Designer/operator
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Context of use
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Assistance
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Confidence
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Model vs. interface
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Technology / formats
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Users	Mental models
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Diffusion
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Users	Primary beneficiary

Interview Part 2

deductively	2	Assessment	2b) By which criteria can generic models be categorized and classified?	Categorization	Usefulness of catalog
deductively	2	Assessment	2b) By which criteria can generic models be categorized and classified?	Categorization	Feasibility of catalog
deductively	2	Assessment	2b) By which criteria can generic models be categorized and classified?	Categorization	Obstacles for catalog
deductively	1	Identification	1b) By which criteria can generic models be identified?	Operative steps	Identifying group
deductively	1	Identification	1b) By which criteria can generic models be identified?	Operative steps	Identification approach

deductively	1	Identification	1b) By which criteria can generic models be identified?	Operative steps	Criteria for identification
deductively	2	Assessment	2b) By which criteria can generic models be categorized and classified?	Operative steps	Criteria for assessment
deductively	2	Assessment	2b) By which criteria can generic models be categorized and classified?	Operative steps	Categorization

Interview Part 3

deductively	1	Identification	1c) Which existing models can be candidates for a list of generic models?	Models	Number of generic models
deductively	1	Identification	1b) By which criteria can generic models be identified?	Identification	Flexibility
deductively	1	Identification	1c) Which existing models can be candidates for a list of generic models?	Models	Example generic models
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Personal challenge
deductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Challenge in the field
deductively	1	Identification	1c) Which existing models can be candidates for a list of generic models?	Models	Example models

Inductive code categorization

Definition	Research Question		Sub-research question	Category	Code
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Problems with generic models
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Usefulness generic structures
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Usefulness	Combined use
inductively	2	Assessment	2b) By which criteria can generic models be categorized and classified?	Usefulness	Compatibility / connectivity
inductively	1	Identification	1c) Which existing models can be candidates for a list of generic models?	Models	Existing lists
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Challenges in consulting
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Narrative
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Familiar representations
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Case studies
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Starting point
inductively	2	Assessment	2a) For which purposes and users can generic models be useful?	Use	Improvement in interfaces

Deductive code description

Interview Part 1

Code	Description	Questions
Definition	Exact terms that interviewee explicitly used to describe generic models	1a) 1b)
Disambiguation	Differentiation between generic models and other generic structures	1c)
Agreement on definition	Perceived agreement on the definition of generic models in the field	1d)
Purpose	Suggested main purpose of generic models	2a) 2b)
Relevance for the field	Perceived relevance of generic models for the field	2c) 2d)
Primary users	Suggested primary users	3a) 3b)
Designer/operator	Usefulness of designer/operator distinction	4a) 5a)
Context of use	Suggested contexts for use	6a) 6b)
Assistance	Using generic models is possible with / without assistance of a modeler/facilitator	7a) 7b)
Confidence	Extent to which users can have confidence in generic models	7a) 7b) 8a)
Model vs. interface	Direct use of stock and flow diagram or use of interface preferred when working with managers	6a) 6b) 8a) 8b)
Technology / formats	Relevance and adequacy of available technology, software, formats for using generic models	8a) 8b)
Mental models	Extent to which generic models can interact with people's mental models	9a) 9b)
Diffusion	Probability that generic models can be widely diffused in management education	10a) 10b)
Primary beneficiary	Suggested primary beneficiaries	11 a)

Interview Part 2

Code	Description	Questions
Usefulness of catalog	Usefulness of a catalog of generic models	12a) 13a)
Feasibility of catalog	Feasibility of catalog construction	14a) 14b)
Obstacles for catalog	Possible obstacles when constructing a catalog	14b)
Identifying group	System dynamics community or experts only can or should identify structures	15a) 15b) 15c)
Identification approach	Suggested approach or steps for identification	16a) 16b) 16c)
Criteria for identification	Suggested operative criteria for identification	16d) 16e) 16f)
Criteria for assessment	Suggested operative criteria for assessment	16d) 16e) 16f)
Categorization	Suggested ways to categorize generic models	17a)

Interview Part 3

Code	Description	Questions
Number of generic models	Useful or reasonable size of the catalog; elicitation of examples	18a) 18b) 18c) 18d)
Flexibility	Catalog should be defined once and remain unchanged / be adaptive	18e) (18f)
Example generic models	Explicit suggestions for generic models	19a) 19b) 19c)
Personal challenge	Recurrent or persistent problem that interviewee encounters in their work (see if generic models can address that problem)	20a)
Challenge in the field		20a)
Example models	All example models mentioned by interviewee (not explicitly suggested as generic)	throughout interview

Inductive code description

Code	Description
Problems with generic models	Problems that were encountered or are expected when using generic models
Usefulness generic structures	Usefulness of generic models compared to other generic structures
Combined use	Possibility to use generic models together with other generic structures
Compatibility / connectivity	Possibility to combine generic models with other generic models
Existing lists	Reference to existing catalogs
Challenges in consulting	Challenges in consulting independent of generic model use
Narrative	Not format or technology, but narrative matters
Familiar representations	Show graphs, spreadsheets or equations instead of models to managers
Case studies	Use generic models as supplement to case studies
Starting point	Use generic models as starting point when working with managers
Improvement in interfaces	Improvements in interfaces are needed

Appendix D - Feedback on the developed framework

The following documents were sent to the interviewees for feedback. The document was divided into an introductory note, the conceptual and the operative framework. It consisted of short paragraphs that represented the discourse in the interviews as well as seven sections that allowed for feedback – both in form of a Likert scaled multiple choice question and in form of an open question where the interviewee could explain their reasoning in a text box. The original document is presented in the next section. Provided feedback is summarized for each item directly in this original document format. Some interviewees sent feedback in form of an e-mail, which was considered in the analysis but will not be added in full text form to the appendix due reasons of confidentiality.

Framework document

The following document contains a tentative framework subject to review and refinement by you and other experts.
Your input at this stage is of critical importance - at least as much as the interviews that were conducted in the first phase of this research!

This document is set up so that **you can read and review the framework within 20 minutes – only pages (1 – 5) are vital for review. For quick access, points of review are indicated by this arrow (➡).** The remaining pages are for your information and optional feedback only!

Your feedback can be entered directly into this document, by answering any of the seven survey questions or by using the REVIEW/Track Changes/Commenting function of your text editing software. Any feedback that you provide will **help to ensure that your perspective is sufficiently represented** in this framework and that the most important questions related to generic models are addressed adequately.

Thank you for your valuable feedback!

Note: The framework is divided into two parts. The **conceptual framework** describes the definition and general assumptions that were used for the development of the operative framework. The **operative framework** is a list of suggested steps.

The content of the framework was **derived from a literature review and interviews with 16 experts** within the field of system dynamics. Input from interviewees and literature is presented in summary and without attribution to specific people for now. This will allow for focus on the content of the framework. In the **final version** that will be used in the thesis, all contributions by interviewees and literature will naturally be **fully attributed** to sources (unless otherwise agreed on with specific contributors).

At this point this document is a draft version that is not meant to be shared with anyone else. Please do not pass it on without my consent.

Conceptual framework

Of the many questions that were discussed in the interviews, the following three were viewed as central to the research on generic models. The variety of answers to these questions are summarized here, reflecting also the amount of agreement that became apparent from the interviews.

What are generic models and why may they be relevant or useful?

Definition

There is significant overlap and agreement on the concept of generic models, although often interviewees use different terms (e.g. canonical situation models, generic systems,…). The most commonly used term in system dynamics literature is 'generic models', which was mostly used in the interviews and which will be continued to be used in this framework. Generic models are small stock and flow structures that are considered as complete models that can be simulated. These types of models

- represent a class of systems
- are small and consist of 2-4 main stocks or 2-3 loops that show main behavior
- show similar behavior patterns
- show (surprising) dynamic policy insights
- are applicable/transferable across particular cases
- are applicable/transferable across particular application domains
- are reusable structures
- have stock and flow structures and equations that remain the same when transferred/re-used
- only need changes in variable names and parameters or very small extensions or reductions when transferred
- should be well-documented to be transferable

Concluding, in the development of the framework these criteria have to be considered for identifying potential candidate models (tested in Phase 1 and Phase 3).

Please indicate your answer by inserting an 'X' or highlighting the appropriate cell:

Item #1	strongly agree	tend to agree	tend to disagree	strongly disagree
In how far do you agree or disagree with this definition?	Eric Wolstenholme	Yaman Barlas Robert Eberlein Jack Homer	Gary Hirsch Steve Peterson Kim Warren	

Why do you agree or disagree? Is there any central insight/concern that is missing?Yaman

Barlas: Agree. But there may be generic models that do not satisfy ALL items. [anything missing?]: Nothing central. But you are using 'phases' without having defined them?

Robert Eberlein: Reusable is not so important and surprising is too high a bar (provide dynamic policy insights would be better. The other thing is that the small makes sense but I would not reject something just because it has 10 stocks.

Gary Hirsch: The generic models I discussed with you could also be large ones that are not transferable across application domains, but could represent different populations or communities. The definition you have above is too limiting, from my perspective. I would apply that definition more to molecules.

Jack Homer: My one concern is that some structures that might be transferable turn out in real-world practice not to be used much if ever. A good generic model candidate is not only usable, but in fact is used!

Steve Peterson: I guess this definition is OK, but I do not think that it is particularly relevant to the work that I do. This may or may not be important, as I suppose it depends the purpose of the generic structures—why do you care about them and what do you use them for? FWIW, I think that a sweet spot in all of this is "reusable-adaptable" structures which…

- may or may not be running models
- May or may not have interesting feedback
- May or may not show policy insights
- May or may not be well documented

In some cases a simple stock/flow main chain (or even a single stock and 1 or 2 flows!) may be sufficient for a given purpose—EVEN THOUGH IT IS NOT A RUNNING MODEL!

Kim Warren: This may be true of the <u>core</u> of many models, [e.g. SIR, renewable natural resources], but any <u>real</u> model will be larger [e.g. a real SIR model would include common disease-control mechanisms, not just the core infection/recovery mechanisms. So, if you want to describe "generic models", then they are usually not small, can be quite large [a minimum model of an airline has at least 6 major stocks, some segmented and approaching 100 variables]. *This is almost certainly a minority view !!*

Eric Wolstenholme: Reasonably comprehensive

Disambiguation

There are other generic structures that must be clearly distinguished from generic models, since there is much disagreement on which of these structures may be useful. First, generic models are different from microstructures and small building blocks such as molecules. These structures are smaller, basic stock and flow formulations that do not constitute a complete model and that can be used for increasing modeling efficiency, model quality, re-usability and replicability. Second, generic models are different from abstracted system archetypes which are presented as causal loop diagrams. These archetypes are used for clear communication of central behavior and policy insights. The list provided above indicates that the complexity of generic models lies somewhere in-between microstructures and system archetypes. They may be able to either fulfill similar functions to both microstructures (e.g. re-usability) and system archetypes (e.g. communicate policy insights).

Concluding, in the development of the framework it would be useful to define possible relationships to other generic structures (Phase 2).

Item #2	strongly agree	tend to agree	tend to disagree	strongly disagree
In how far do you agree or disagree with this disambiguation?	Eric Wolstenholme	Yaman Barlas Robert Eberlein	Gary Hirsch Jack Homer Steve Peterson	Kim Warren

Why do you agree or disagree? Is there any central insight/concern that is missing?

Yaman Barlas: i- a generic model, if used in a larger model, can be called 'generic structure' (so this distinctin is not that sharp), ii- it is not always true that the complexity of generic model is less than an archetype.

Robert Eberlein: I differ with the archetypes which, following Wolstenholme, I think of as a form of generic structure. I would agree with your characterization of archetypes as Senge uses them. Also molecules and other building blocks can (but need not) be generic structures (and they can also be really big and complicated but still not complete models). - Lots of overlap in a Venn diagram.

Gary Hirsch: Again, I think generic models can represent larger structures that are limited to a single application domain, but can be applied in multiple places without structural alterations.

Jack Homer: I think it is too restrictive to distinguish generic structures from molecules. Indeed, I see molecules in real-world practice being reused much more than larger structures. The larger the structure, the less likely it is to apply to a new situation. Indeed, it seems to me larger structures are rarely reused in actual practice. My interest is much more in molecules than in larger structures. If you focus only on the reuse of larger structures, I think you'll find it's infrequent.

Steve Peterson: I do not think that complexity is the correct dimension for disambiguation. I think that in considering where "generic models" fit into the landscape, you might want to consider multiple dimensions. Is it possible to array these different types of structure along the dimensions of quantitative rigor and "self-contained-ness" where high self-contained-ness implies something that tells a dynamic story? You could use a 2x2 business school grid to do this. Then it might be possible to map purpose onto the different points in this space. This might give some insight into the topology.

Kim Warren: Following on from #1 … "common structures" are the main building blocks from which "generic models" may be built but with possibly considerable adaptation and additional elements … your terminology in these descriptions is itself ambiguous – using the same term to mean different things and different terms to mean the same thing. I think you should offer us a Glossary at the start.

Relevance and potential usefulness

The relevance and usefulness of generic models is contested by interviewees. Whereas a part of the group perceives the development or identification of generic models as necessity for the future growth and development of system dynamics as a field, another part of the group perceives the idea of generic models as unhelpful or even dangerous. The expected danger comes from the misinterpretation of generic models by possible users. It became clear that the biggest two concerns about generic models are related to ***who*** should or should not use them and to ***how*** they should be presented. Therefore, these questions are discussed in the next section.

Item #3: Is there anything you would like to add to this summary of the discourse?

Robert Eberlein: This is good - hopefully some gave examples of why dangerous and why valuable.

Gary Hirsch: No, that's a reasonable statement of the differences of opinion.

Steve Peterson: I think that both relevance and utility are to be judged in the context of purpose. So it would be hugely helpful to have some insight into how people view the purpose of these things. There is a different type of generic model: a model that is a generic representation of the specific problem space that is being addressed by the modeling team. In my experience this type of model is HUGELY as a starting point for a modeling effort. The list of generic models of this type would be generated by practitioners in specific content and industry settings, and may not have much of an intersection with your list of generic models.

Kim Warren: Of course any model can be misinterpreted – the use of generic models simply requires a health-warning "This generic model is typical of cases of this type, in this domain. It will certainly require adaptation for any specific case – additional elements, removal of elements, changing of elements – which may be extensive".

Eric Wolstenholme: SD practitioners always fall into 2 categories. The first MIT based the second non MIT based. The first are purists and will always go for bespoke solutions. The second are pragmatics who will always go for ease of use and demystification. – Political ,but perhaps my wises statement.

Who would benefit from the availability of generic models? Who should use them?

There is wide agreement that the usefulness and relevance of generic models depends on the group of users. For the given framework, the group of interest are managers (as opposed to general education, research and government applications).

Students of modeling would benefit most from the availability of generic models. There is substantial agreement on this and some say it should be the primary purpose. The availability of such models would enable students to learn modeling more effectively, to increase the quality of their work more quickly and to have a valuable point of reference throughout their studies. There is no consensus that students ***should*** use them, only that students ***can*** use them and that generic models may be most valuable in this context.

Advanced modelers would benefit from the increased efficiency and speed in model building as well. Readability and replicability of work from other modelers could be improved. There is no indication that advanced modelers ***should*** use them to make their work more accessible to others.

Managers in a variety of organizational levels and functions may benefit from the availability of generic models. This notion is contested by several interviewees for different reasons. Mostly, these reasons have to do with the setting, format and narrative with which generic models are presented. Possible problems will be discussed in the next section.

Some interviewees note that these problems do not mean that managers ***should*** not use generic models. A few responses indicated that managers should be open for the use of models and learn more about them, since traditional management tools may not suffice for dealing with ever more complex problems (e.g spreadsheets, balanced score cards,…). The question therefore remains, how to use these models with managers.

Concluding, in a catalog of generic models, the user group has to be specified carefully when identifying candidate models (Phase 2). Moreover, testing the usefulness for different users empirically has to be an integral part of the development of the catalog (Phase 4).

Item #4	strongly agree	tend to agree	tend to disagree	strongly disagree
In how far do you agree or disagree that this summary captures the essence of the discourse?	Gary Hirsch Eric Wolstenholme	Yaman Barlas Robert Eberlein Jack Homer Kim Warren		

Why do you agree or disagree? Is there any central insight/concern that is missing?

Yaman Barlas: Again 'phases'… Also the second concluding sentence is not clear enough

Robert Eberlein: There is potential for generic models as a vocabulary for policy discourse in the broad sense which means not using, but knowing about and being able to discuss the models. That is a bit different from what you have described.

Gary Hirsch: Use with managers has to be more careful since you don't want to bend their problems to fit the model.

Jack Homer: As you know, I think the idea of generic models has to be treated with care, and they are almost entirely of pedagogical value, not reuse value. If people get the idea that they are of reuse value, there is danger in people overlooking important ways in which their current situation differs from the generic model.

Steve Peterson: I don't really have an opinion on this. I think there may be a role for a set of generic models of specific industry settings in a B-school context.

Kim Warren: It is hopeless to expect students to build reliable models of common cases from first principles – though asking them to try might be a useful learning exercise. As George Richardson's SDR recent articles explain, the learning path has to include understanding, working with, and adapting well-known models. Advanced modelers *always* use common models, even if these are their own private ones. Managers are [I think] rarely offered generic models, because no-one has bothered to document them – so we don't know the possible benefits, but they could be very substantial, since they clarify for any manager the basic mechanisms of the system they are trying to steer.

Eric Wolstenholme: To me as a pragmatist opening up the field is vital and we have to accept some abuse of models. Maintaining model quality at all costs is contradictory to a basic axiom of the field. It is not a systemic perspective.

How can generic models be used?

Interviewees agree that setting, format and narrative with which generic models are used matter greatly for the usefulness of generic models. Whether the format is direct or indirect interaction with the stock and flow model, interviewees shared one concern. Modelers or facilitators have to explicitly and clearly communicate (narrative) to the client that the applied model is generic and that generic policy insights cannot necessarily be directly translated for policy design in the specific situation.

Direct interaction with the stock and flow model: Most interviewees agree that the direct interaction of managers with models does not seem useful and may even be dangerous. A first concern is that managers will rarely ever have enough time, interest or attention available to fully understand stock and flow structures. Misinterpretations of structure, behavior and misleading policy conclusions may ensue. This is true for customized models, but is feared to be even more relevant with generic models. Managers are assumed to be able to work reasonable well with a model that was customized to their situation or built jointly with the manager. When using generic models that are not tailored to the specific situation, a threat is that managers may draw direct inferences from the generic model to their own situation and that they will design policies not fit for their specific problem. It is therefore assumed that it is best not to encourage managers to use generic models directly without assistance of a modeler. Another tendency revealed in interviews is that it is best if a manager is not able to change the structure of the model himself, but to only change parameters / extend or reduce small parts of the model. Despite these views, most interviewees can imagine that generic models can be used as a starting point when building a customized stock and flow model with managers.

Indirect interaction with the stock and flow model: Some interviewees propose that it may not be necessary to let managers interact with the model directly. They claim that the structure underlying a specific behavior can also be understood without seeing the actual stock and flow structure. Examples for such applications are management games, management flight-simulators, graphical interfaces or the use of formats that managers are most familiar with, such as spreadsheets and presentation slides. In these formats, experimenting with parameter changes in high leverage variables and immediately viewing and discussing results of simulations becomes central.

Concluding, in a catalog of generic models, research about how exactly to use generic models with different user groups has to be tested thoroughly in empirical studies (Phase 4).

Item #5	strongly agree	tend to agree	tend to disagree	strongly disagree
In how far do you agree or disagree that this summary captures the essence of the discourse?	Gary Hirsch Eric Wolstenholme	Yaman Barlas Jack Homer Kim Warren	Robert Eberlein	

Why do you agree or disagree? Is there any central insight/concern that is missing?

Yaman Barlas: I do not see the point of: '…the structure underlying a specific behavior can also be understood without seeing the actual stock and flow structure'. Is there any ADVANTAGE of NOT showing the model?...

Robert Eberlein: Managers should be treated like adults - the issue is getting them to pay any attention - I don't see any big danger if they do. Generic models are more like hammers than guns - sure you can misuse them but it would be dumb to do so.

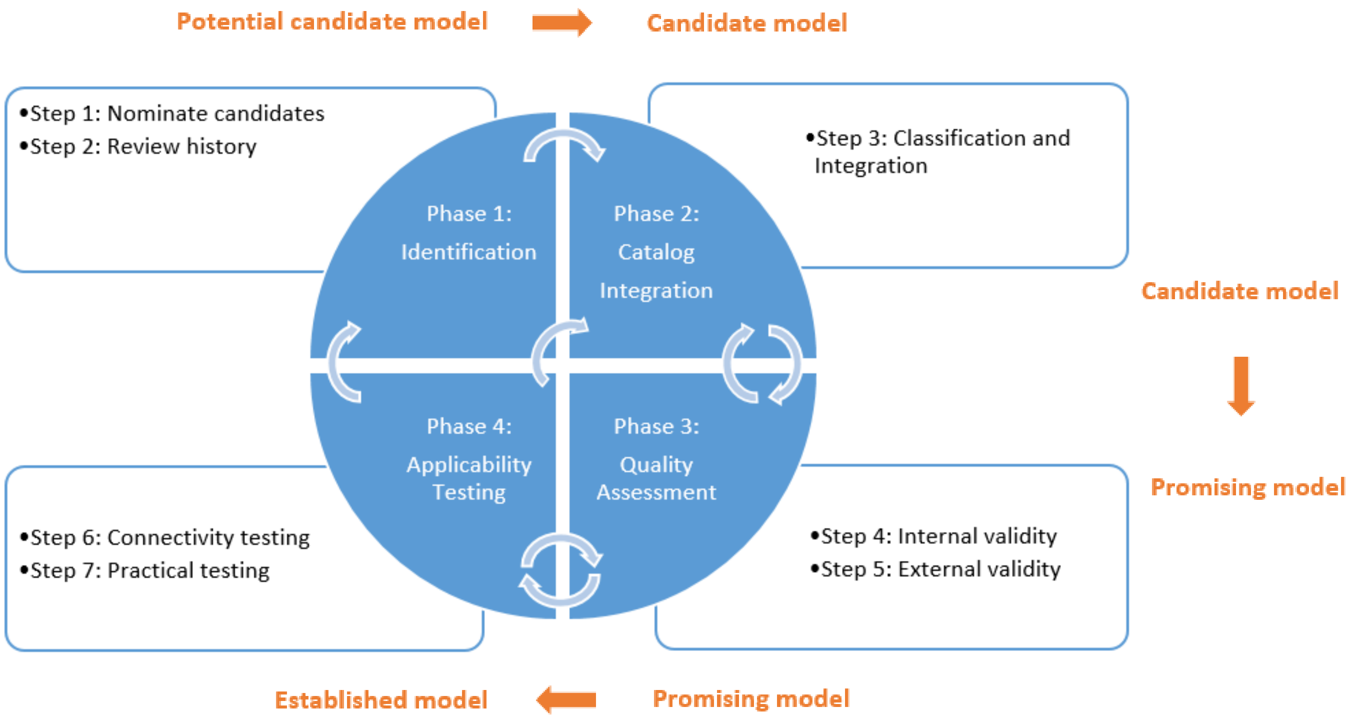
Gary Hirsch: Mangers can best use generic models as "learning labs" to understand the dynamic character of the systems they are managing. As indicated above, this might best be accomplished with management games and flight simulators. The ability to tailor a generic model by inputting data on a local situation or organization can increase the usefulness of a generic model as a learning lab, but managers and other users must always remember that the model is a tool for comparing alternative strategies and doing sensitivity analyses rather than forecasting future outcomes.

Jack Homer: The introductory explanation here is good, but you haven't explained what kinds of empirical studies you have in mind, so I can't "strongly agree". It's not obvious what the empirical work would consist of.

Steve Peterson: Not sure that I have an opinion on this. In a consulting context, the task is often one of moving the client from where they are to a more productive place. It seems to me that there are many ways that one can do this. In some cases generic models might help. In others, not so much. I wonder how much of the approach of aligning tools, processes, etc (generic models being one component) is an art form that may be derailed by empirical work that defines a "one true" pathway of usage.

Kim Warren: Agree that this summarises the discourse, but the 'indirect' school is indefensible – we know that no-one can intuitively guess the behavior of accumulating stocks, so any representation of a system that does not make them explicit must by definition fail to explain.

Operative Framework



The operative framework reflects the strong agreement of interviewees that the development of generic models has to be an iterative and continued process. In Step 1, a list of potential candidate models is established by considering a variety of sources. In Step 2, the existing history of these models is reviewed to filter out models that do not fit a basic set of criteria. When passing these criteria, the **Potential candidate model** becomes a **Candidate model** and is included in the catalog in Step 3, where it is classified and related to the other model candidates. In Step 4 and 5 the model formulation is tested thoroughly according to established standards of validity and reporting. The results of this quality assessment are continuously documented in the catalog (as indicated by blue arrows between phases in the diagram above). This way, a **Candidate model** can become a **Promising model** because it passes further criteria for being a valuable structure. In Step 6 and 7 the **Promising model** can become an **Established model**. Not only the quality of the model itself becomes validated, but the usefulness and re-usability in practical applications will be tested thoroughly.

Item #6	strongly agree	tend to agree	tend to disagree	strongly disagree
Do you agree or disagree with the overall concept of the four phase process?	Robert Eberlein Eric Wolstenholme	Yaman Barlas Steve Peterson	Jack Homer Kim Warren	
Do you agree or disagree with the steps within these four phases?	Robert Eberlein Eric Wolstenholme	Yaman Barlas Steve Peterson	Jack Homer Kim Warren	
Do you agree or disagree with the distinction of candidate model – promising model – established model?	Robert Eberlein Eric Wolstenholme	Yaman Barlas Steve Peterson	Jack Homer Kim Warren	
Do you agree or disagree with the suggested assessment frameworks/criteria as described in **Catalog and Documentation?**	Robert Eberlein Eric Wolstenholme	Yaman Barlas Steve Peterson	Jack Homer Kim Warren	

Why do you agree or disagree? Are there any important steps or criteria missing?

Yaman Barlas: There is too much here. Most of this should be attributed to the author of thesis, rather than the interviewees. (I do not recall discussing these, and I do not have the time, or expertise to do it now

Robert Eberlein: I could nitpick on terminology but I think this is really nice. What would really add to it would be examples if you got any of the evolution of some of the interviewees favorite generic models.

Jack Homer: This is all pretty unclear to me and I can't see how your described process helps us assess the usefulness of generic models. It's just a kind of filtering approach, and I would have thought you could find good candidates in just 1 or 2 steps. This 4-step process makes a fairly simple thing seem complicated and weighty, and it seems the wrong place to be putting lots of time.

Steve Peterson: A couple of observations: 1. You REALLY should use a stock-flow diagram to describe the different phases! 2. This is a really interesting process of vetting models, but I am not about the degree to which I would use the output of this process in my own work in teaching or consulting.

Kim Warren: These are not "steps" but parallel processes – if these were presented as operating simultaneously I would agree. Also, it gives the impression that generic models are hugely complicated, which is not always the case. However, this process is observable to have occurred implicitly with many common models in the field. If you go back to your startpoint definition of 'generic models' it was small structures that clearly describe key mechanisms in common issues/domains .. these are often described *very* simply and *very early* in the process .. think SIR, growth-and-underinvestment, Bass diffusion … none needed to go through this lengthy and complicated process – they were clearly right from the start.

Eric Wolstenholme: I do not think you will ever get the purists to agree on any classification. Best left to software providers to have their own set of generic models.

Catalog and Documentation

This is a possible grid for documenting the current state of research on generic models.

Title	current title of the model (drawn from past developments or new insights)
CATEGORIZATION	
Status	1: established generic model well documented regarding modeling process, structure, past applications, frequent use in the past, high confidence and evidence levels, connectivity, high consensus on relevance etc. 2: promising candidate some documentation, at least regarding modeling process and structure, intermediate use in past, intermediate confidence and evidence levels, intermediate consensus on relevance – altogether, more research is needed 3: potential candidate suggestions by small group/individual system dynamicists that only have basic documentation and require further investigation e.g.: Forrester's market growth model may have status 1 or 2 – is used widely, validated several times and referred to by several experts
Main application domain	business, education, research or governance and public policy
Application tags	assign tags of typical management problems: e.g. inventory control, staff turnover, oscillating demand, project management
Structure / behavior / feedback tags	assign tags of: molecules of structure that have been used/ can be identified in this model typical behavioral patterns / feedback types, e.g. s-shaped growth, exponential growth associated system archetypes that are representative of this model, e.g. shifting burden to the intervener
STRUCTURE	
Basic structure	number of stocks, flows, converters, loops; extensive description of each and of the behavior that they produce – not only in words but in diagrams, graphs (dimensionless, without revealing axis, just patterns)- using reporting standards that are recognized in the community
Known versions	list and links to sample structures, ideally publications or accessible online show examples for how they have been re-named and used in different contexts before
Related models	models that contain similar structures or that are often directly linked with this structure, transferability between fields

APPLICATIONS

Known uses	frequency of use overall, list and link to concrete applications (at least 3-4)
Types of use / implementation	list and link to examples of the following applications where available, describe if assisted or unassisted use, type and number of users in each case Management Games / Flight Simulators / Graphic Interfaces (e.g. ReThink Health, Storytelling interface…) Simulation supported Case Study (e.g. Beer Game, Fishbanks, People Express …) Spreadsheets, slide presentations Preliminary model (e.g. Seed Model, Overview Models are used as starting point for discussion, for model building with client)
Known users	number of users, include explicit links and if possible, contact details of users
Types of users	groups or individuals, novice vs. trained in systems thinking, modeling; facilitators or modelers

QUALITY ASSESSMENT

Internal validity	report on results from standard validation tests and reporting criteria
External validity	report on results from standard tests, e.g. have high level of generality, family member test, Perceived representativeness of models, Analytical quality of policy insights
Connectivity	show how easily it can be linked to other generic models – which exact steps, elements such as connectors are needed; compatibility: check language / terminology consistency, diagramming rules, visualization guidelines to ensure readability, re-usability, linking to other models
Applicability	report results from practice tests according to standard criteria in the field e.g. competing values approach, process effectiveness of the intervention
Known history	development of structure: e.g. major references like Author (year). Title. Source/Link.

Item #7 : Do you have any general thoughts about this documentation grid that you would like to share?

Robert Eberlein: This is hard for me to follow. I would actually be happier with just a list and some description, though I can see the value of a more standardized rubric.

Jack Homer: Again, I think it moves in the wrong direction. Let's start with the very first statement: "Forrester's market growth model may have status 1 or 2 – is used widely, validated several times and referred to by several experts." I agree that the Market Growth Model is (or used to be, anyway) TAUGHT widely, but I have never heard of it being reused in an actual consulting engagement. For example, I've never heard of heard of a single ISDC conference presentation (in my 30 years of attending ISDC) that dealt with a reuse of the Market Growth model. This alone tells me that you've gotten off on the wrong foot here, somehow. Apologies for my blunt honesty here.

Steve Peterson: Important to have a place to discuss the initial context for the generic model. Important to have a place to indicate critiques of the model.

Kim Warren: This is a nice effort to offer a means to organize the specification of a generic model – it just may be trying to do more than is possible or necessary [no need to try and define numbers of elements]. *BEWARE* the flight simulators issue. Games can easily be good examples of some principles, but very bad 'generic models' .. e.g. People Express is a great demo of growth and underinvestment, but a hopeless generic model of an airline [PEx does not apparently operate any Routes!] … not sure what generic model Rethink Health is demonstrating, but a Healthcare model that does not include Hospitals seems an unlikely candidate for a generic model. Fishbanks and Beer Game, on the other hand are strong example of generic-model illustration.

Eric Wolstenholme: No – seems pretty good

Detailed description of phases

Phase 1: Identification

Step 1 - Identifying potential candidates from different sources

Approach: List several potential candidates by review of literature, conversation with experts. Define keywords and other search criteria. Consider most frequently studied fields, models that are often re-used/ cited.

Possible Sources: major publications in business/ in System Dynamics, System Dynamics Review publication list, Case Repository, Society events, Special Interest Groups, prize winning work (e.g. Jay Forrester Award, Barry Richmond Award,…), other publically available model libraries

Step 2 – Review history

Approach: Review one model of the identified candidates more closely. Conduct extensive literature research on different versions, applications and history of the model.

Criteria: Move on to Phase 2 depending on frequency of re-use/citation, number of users, amount of versions available, amount of available literature on this or similar models.

Phase 2: Catalog Integration

Step 3 – Classification and integration

Approach: Categorize and assign tags according to available information. Frequently update according to Quality Assessment and Applicability Testing results.

Criteria: see tentative Catalog and Documentation grid

Phase 3: Quality Assessment

Step 4 - Internal validity

Review validation tests previously conducted. Apply model structure and behavior tests as described in system dynamics literature. Document approach and results of tests in catalog.

Step 5 - External validity

Approach: Assess what makes it generic, transferable, widely applicable. Documents approach and results in catalog.

Phase 4: Applicability Testing

Step 6 – Connectivity testing

Approach: Test how model is compatible, connectable and consistent with other generic models. Document results in catalog.

Step 7 - Practical testing

Approach: Test usefulness of models when working with managers. Document results in catalog. Refer back to Quality Assessment phase if unsatisfactory results, adjust model, repeat testing.