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Fragmented Knowledge and Group Model Building

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Abstract

We are conducting a study of SD group model building that is based on the following aspects:

1. *The availability (in the near future) of object-oriented components in at least one System Dynamics modeling tool.*

A component is a model piece that can be used as a building block of another component (Myrtveit, 2000).

2. *The integration of SD simulation tools in Enterprise Resource Planning systems.*

As an example we mention the integration of Powersim Constructor in the SAP Strategic Enterprise Management (SAP SEM) solution. Enterprise models tend to be large and complex. Hence, they would benefit from an object-oriented approach, i.e. decomposition into model components.

Further:

3. *The fact that the available knowledge in any enterprise is fragmented; i.e. that it exists as a sum of narrow, specialized know-how that is scattered across thousands of minds.*

Arguably, consensus-seeking group processes would not make much sense if they were to amalgamate genuine domain expertise and superficial knowledge under the declaration of «expertise.» In other words, to capture relevant knowledge and to avoid knowledge «dispersion» the expertise in a modeling group must be sufficiently focused.

We discuss the following considerations as a guide for group-modeling processes:

- *How to define model components that align with domain expertise.*
- *How to decompose the modeling group into subgroups that match the domain knowledge requirements in model components.*
- *Criteria for consistent definition of reference behavior modes for each model component separately and for the total model.*
- *Criteria for consistent validation of model components and the total model.*

Introduction

This paper deals with some aspects of a new and exciting technology, viz. object oriented extensions to System Dynamics (Myrtveit, 2000). The implementation of genuine object oriented extensions to System Dynamics, both in terms of working methodology and technology (software tool), has the potential to give SD a thrust. Genuine object oriented extensions to System Dynamics are an emerging methodology that poses many questions. In this paper we conduct a preliminary discussion on the aspects of model validation in relation to components and the associated model group building processes. Our emphasis lies in identifying and discussing (some) relevant questions, rather than attempting to provide consolidated answers (intended to be provided in our ongoing research work). Such an attempt would be premature among other things because there is no actual software tool available for the time being: While the methodology seems conceptually mature (Myrtveit, 2000), the technological implementation itself will not be released in advance of this conference.

Hence, a main purpose of this contribution is to invite critical appraisals and complementary views.

Validation of components

Quoting Myrtveit (Myrtveit, 2000): «A component is a model piece that can be used as a building block of another component… As such, the component corresponds to a class in the object oriented world… The basic SD modeling languages contain abstract building blocks (levels and non-levels) for creating models in any domain. The introduction of components makes it possible to create concrete building blocks within a specific domain. Domain specific building blocks create new and exciting opportunities for the system dynamics world, e.g. model re-use, industry specific component catalogs, quality control, standardization, and division of labor between component maker (fabrication) and component user (assembly). It can be expected that a market will develop around components, both within corporations and on the web.»

The integration of SD simulation tools in Enterprise Resource Planning systems is expected to be a primary arena for simulation components. E.g., the SAP™ Strategic Enterprise Management™ – SAP SEM™ – solution contains Powersim software in its Business Planning Simulation (BPS) system. The envisioned approach is to have libraries of generic industrial simulation components that are customized to the specific need of particular industrial clients.

The question arises: How should components be validated (and the validation results be presented) in order for the customer (the user of components) to have confidence in the product.

We argue below that this question is related to the question of how to align the content of model components with domain expertise.

Fragmentation of knowledge

The fact that human knowledge is regrettably incomplete and extremely fragmented is easily forgotten. The great economist and lawyer, Friedrich A. von Hayek, made a point of stressing this point again and again.

«Complete rationality of action … demands complete knowledge of all the relevant facts. A designer or engineer needs all the data and full power to control or manipulate them if he is to organize the material objects to produce the intended result. But the success of any action in society depends on more particular facts than anyone can possibly know. And our whole civilization in consequence rests, and must rest, on our *believing* much that we cannot *know* to be true…

What we must ask the reader to keep constantly in mind…, then, is the fact of the necessary and irremediable ignorance on everyone's part of most of the particular facts which determine the actions of all the several members of human society. This may at first seem to be a fact so obvious and incontestable as hardly to deserve mention, and still less to require proof. Yet the result of not constantly stressing it is that it is only too readily forgotten. This is so mainly because it is a very inconvenient fact which makes both our attempts to explain and our attempts to influence intelligently the processes of society very much more difficult, and which places severe limits on what we can say or do about them.» (Hayek, 1973, p. 12.)

«Another consequence of this basic fact which must be stressed here is that only in the small groups of primitive society can collaboration between the members rest largely on the circumstance that at any moment they will know more or less the same particular circumstances.…

The situation is wholly different in the Great or Open Society where millions of men interact and where civilization as we know it has developed. Economics has long stressed the 'division of *labor*' which such situation involves. But it has laid much less stress on the fragmentation of *knowledge*, on the fact that each member of society can have only a small fraction of the knowledge possessed by all, and that each is therefore ignorant of most of the facts on which the working of society rests. Yet it is the utilization of much more knowledge that anyone can possess, and therefore the fact that each moves within a coherent structure most of whose determinants are unknown to him, that constitutes the distinctive feature of all advanced civilizations.» (Hayek, 1973, p. 13-14.)

System dynamic group model building addresses the issue of knowledge fragmentation in the sense that the purpose of group processes is to capture and synthesize group knowledge. But an explicit discussion of the degree of knowledge fragmentation, the relation between the partial views and insights held by group participants, whether so-called «shared vision» is a proper absolute goal no matter how fragmented the domain knowledge might be, etc. seem to be absent from the discussion in the literature. The otherwise excellent standard treatise by Vennix (Vennix, 1996) does not take account of this issue explicitly, nor – to the best of our knowledge – does other research literature of system dynamic group model building incorporate this fact.

Arguably, an explicit recognition of fragmentation of knowledge would require a more focused selection of the domain expertise to include in a group modeling process than is traditional in practice. Consensus-seeking group processes would not make much sense if they were to amalgamate genuine domain expertise and superficial knowledge under the declaration of «expertise.» In other words, to capture relevant knowledge and to avoid knowledge «dispersion» the expertise in a modeling group must be aligned with the purpose and content of the model component.

Note that Hayek also stresses the point that human knowledge is necessarily incomplete. For the purpose of system dynamic model building one would like to believe that a well-constructed model is a result of a knowledge-advancing process (comparable to a scientific discovery process) such that the model relationships are either valid representations of some problem domain or some aggregated unknowns in the form of probability distributions (to be accounted for through risk assessment methodologies).

Defining model components that align with domain expertise

A traditional system dynamic group modeling process could be summarized as consisting of the following steps:

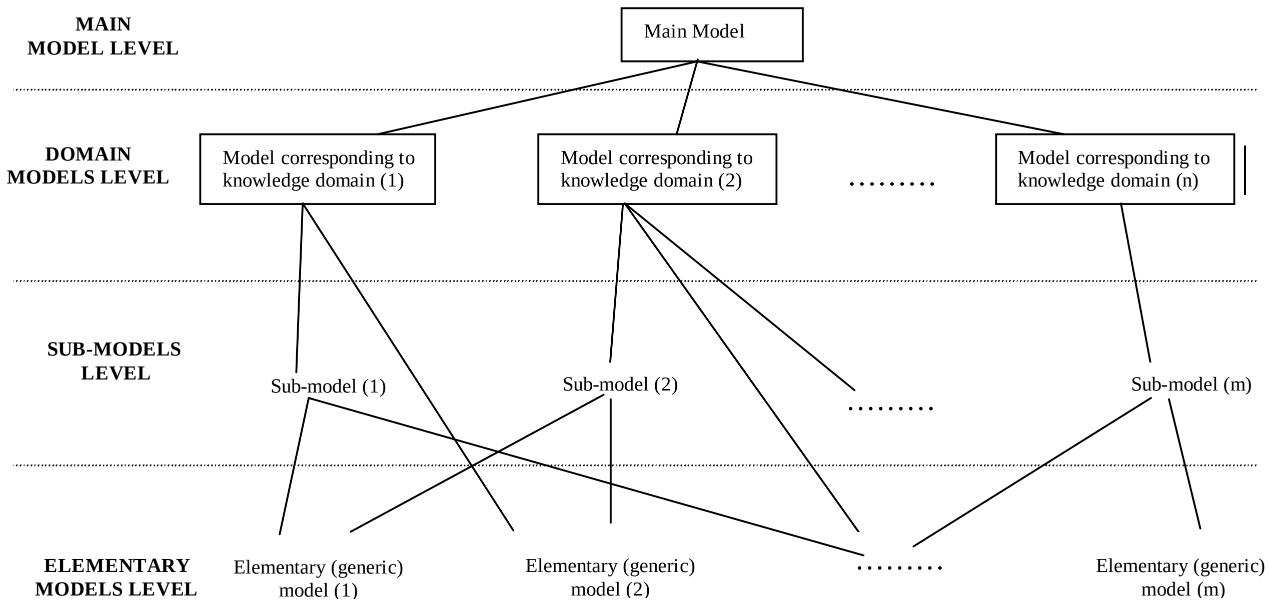
- Identify corporate issue
- Group modeling process leading to consensus as to time frame and major themes of the study, main reference modes of the problem, main variables and relationships.
- Creation of stock-and-flow model
- Verification, validation and testing of the model
- Policy analysis

With the upcoming availability of component based modeling we would like to propose a modified approach for system dynamic group modeling based on the following points:

- Identify corporate issue
- Group modeling process leading to consensus as to time frame and major themes of the study, main reference modes of the problem, decomposition of the problem into sub-problems , identification of sub-problems reference modes and higher-level connections between the sub-problems.
- Assign sub-problem to expert(s)
- Component-based stock-and-flow modeling of sub-problems
- Verification, validation and testing at component level
- Assembling components to total model
- Verification, validation and testing of the assembled model
- Policy analysis

The rationale for our proposal (which we intend to study in our ongoing research work) is that consensus about time frame and major themes of the study, main reference modes of the problem, decomposition of the problem into sub-problems accompanied by their reference modes and identification of higher-level connections between the sub-problems are high level knowledge that is normally shared in an enterprise. The decomposition of problems into sub-problems is normally an issue as to how the enterprise deals with recurring sub-tasks. Agreeing to such decomposition is tantamount to take the existing organizational structure as point of departure for the system dynamic modeling.

The following figure (Figure 1) describes elements of the proposed component based model architecture:



LEVEL	DESCRIPTION
Main Model	at this level there is a main model describing overall system
Domain Models	at this level models that are aligned with identified expertise knowledge domains are developed
Sub-models	this level contains customized constructs used in creation the Domain Models
Elementary Models	this level contains: ▪ a library of predefined basic model structures that may be reused and customized within a particular Domain Model or its Sub-model development ▪ ”designer’s” elementary models (that are not contained in the predefined elementary models library) created during particular development process

Figure 1 Component Based Model Architecture

Criteria for consistent definition of reference behavior modes for each model component separately and for the total model

Reference mode definition is a part of the very first, conceptual stage of a system dynamics model building process, i.e. problem identification and definition. This stage is considered to be one of the most difficult in the model building process: “*System conceptualization is an art.*” (Richardson and Pugh, 1981)

In the system dynamics literature two principles for appropriate reference mode definition may be found: a model purpose must be clearly defined and a focus of the study must be on a concrete problem, not on a system (Richardson and Pugh, 1981, Vennix, 1996). Additionally, the problem under study should be dynamic. Not all problems can be solved using a system dynamical approach, but only problems that are dynamically complex and can be described in terms of causal analysis and flow processes (cf. Vennix, 1996, p. 104 ff.). In general, for a problem to be considered dynamic it must result from a change that takes place over time. This change over time describes a problematic behavior. Reference modes describe this change graphically illustrating important aspects of a problematic.

Table 1 presents criteria for successful reference behavior mode definition.

Table 1. Criteria for reference mode definition

Criteria	*Question Addressed*	*Description*
1. Sufficient dynamic problem description	Does an identified set of reference modes describe sufficiently and completely the problematic behavior in question?	It is important to develop reference mode or if necessary a number of reference modes that describe fully all aspects of problematic behavior.
2. Focused dynamic problem description	Does a set of reference modes describe only issues related to the problematic behavior in question?	Care should be placed in excluding issues that are not vital to a particular problem. Defining behavior patterns related to, but not directly describing the problem will change the scope of the problem.
3. Appropriateness of used time-horizon	Is the time-horizon used for dynamic behavior pattern description appropriate?	Reference modes should correspond to time-horizon identified for the particular problem.

In case of the component-based models, the reference modes definition may be seen in general as a two-step procedure, where at first the main model's reference modes are defined, and then specific domain models' reference modes are developed (cf. Figure 1).

The main model's reference modes define a problem situation in the most general terms. The domain models' reference modes are derived to illustrate sub-problems into which the main problem was decomposed. They describe more detailed aspects of the main problem and are focused on issues related to a particular sub-problem.

The set of criteria described in Table 1 can be applied for definition of reference modes at both levels of component-based model.

The suggested approach implies that the main model is «divided» into component models. In this process, reference modes describing each of the sub-problems could play a crucial role in ensuring the whole model consistency. How to best align the reference modes of the sub-problems with a complete description of the main problem is an important issue that needs more research. E.g., should the reference modes defined for all identified sub-problems constitute a detailed and full description of the main problem and only the main problem?

Criteria for consistent validation of model components and the total model

Validity of a system dynamics model is understood as a level of confidence that is placed in the model by its target audience (Barlas, 1997, Forrester and Senge, 1980, Richardson and Pugh, 1981, Vennix, 1996). This section introduces criteria that may be applied to enhance validity of a component-based model (and any system dynamics model in general). First, we define briefly the system dynamics model's validation process. Then effects of different model building processes on validation are described. Last, we present a proposed set of criteria for models' validation.

Due to the very nature of system dynamics validity it is not possible to prescribe a set of criteria that would guarantee a model validity (Richardson and Pugh, 1981, Barlas, 1996). The validation process is a process of building confidence by the target audience in a model (Forrester and Senge, 1980). It is gradual and spread out throughout the whole model lifecycle: starting with problem definition, through the model building to implementation. The model evaluation and validation stage is usually distinguished in the model building process (see e.g. Vennix, 1996, p.49) and focuses on conduction of various validity tests. These tests allow to "formally" examine the correctness of the model. Positive results enhance the level of confidence in the model, but they may not be considered as sufficient determinant of system dynamics model's validity. This issue is thoroughly discussed by Barlas in (1996), who points out a dual nature of system dynamics model validation, proposing identification and separation of “formal” and “informal” aspects of system dynamics model validation (cf. Barlas, 1996, p. 1 ff.). Formal validation refers to model testing with application of various validity tests and is concentrated during the evaluation and verification stage of the model building process. Informal aspects of validation are concerned with subjective, individual perception of model validity and this informal validation process is distributed throughout the model building process. The more tests the model passes, the more robust it appears, and the more valid it is likely to be recognized.

The continuous and gradual nature of the validation process allows for extensive and constant questioning of the model. As postulated by refutationism, the more questioned and challenged a theory is the more corroborated it becomes. (To corroborate means «to support with evidence or authority: make more certain». In the context of this article we mean by «corroborate» to pass refutation tests.) As Bell and Senge (1980) notice, system dynamics models are likely to become highly corroborated since they incorporate causal interrelationships. Such causal relationships may be easily and frequently challenged (Bell and Senge, 1980).

Higher corroboration of models may also result from a model building process that allows more throughout model questioning and challenging. A system dynamics model may be developed in four different ways. It can be built:

1. By a system dynamicist(s) her/himself consulting and verifying the model during development with target audience’s representative
2. By a system dynamicist(s) her/himself consulting and verifying the model during development with a group of target audience’s representatives
3. By a system dynamicist(s) and a group of target audience’s representatives who co-participate in the model development process (group model building process as described by Vennix (1996))
4. By a system dynamicist(s) and multiple groups of target audience’s representatives who co-participate in the model development process (component-based model group-building process as in the new approach proposed).

The model building process chosen has a direct impact on the number of verifications that the model is subjected to. Obviously, the more people participate and the more they participate in the model building process the more the model is challenged, questioned. This enhances the model’s refutability and therefore makes it more corroborated, valid. In this context, group-model building procedures (3 and 4) seem to be most advantageous. The group model building in the component-based model development (4) introduces the possibility to allow efficient participation of even greater number of persons than it is possible in the case of the group-model building process described by Vennix (1996).

The level of target audience’s confidence in the model has impact for the model implementation and application. Component-based model building is likely to have a large potential for creating models that would be accepted throughout organizations, i.e. considered valid.

Even if the procedure does not guarantee direct participation of all the member of an organization in the model building process, it allows for a greater involvement of crucial “information agents”. Through such persons the understanding and confidence in the model can be much more efficiently dispersed throughout the organization. The importance of a good selection of participants for the effective model development is discussed by Vennix (cf. 1996, p. 111 ff.).

Additionally, the multi-level structure of the component-based model will allow not only for delivery of the high-level model. It will also facilitate a more detailed modeling of the system. This is important from the point of view of the problem owners and their confidence in the model. Campbell (2000) postulates: “Let team members get their daily work onto the table and into the model”. Detailed analysis and modeling of people’s daily work is crucial for development of their ownership and understanding of final model.

In Table 2 we present criteria that may be used during validation of any system dynamics model to enhance its validity. Criteria for formal and informal aspects of validation are presented separately. For each criterion of formal validation we suggest some known validity tests that may be applied to meet it.

The nature of component-based models validation does not differ significantly from the validation of traditional systems dynamics models. Criteria for informal validation apply throughout the component-based model building process. However, the model hierarchy introduces a possibility to vary a set of formal validation criteria applicable to a particular model component. The multiple level structure of a component-based model:

- makes it possible to skip some verification tests at certain levels of model development:
  - in case of higher level models, results of some tests carried out at lower level still hold at the higher level; e.g. there is no need to re-examine dimensional consistency of the entire model for the higher level models
  - in case of lower level models, tests of policy implications are omitted since policies are developed for the whole system (represented only by the total model)
- facilitates more detailed validation process, because some model features are examined few times at different levels of detail; e.g. in testing the model structure consistency with a real system, detailed aspects are examined for the low level sub-models, while for the Main Model only the most global elements are taken into account

Table 3 presents criteria of formal aspects of model validation as they can be applied to different level model components.

Table 2. Criteria for a system dynamics model validation

FORMAL ASPECTS OF VALIDATION		
Criteria	*Question Addressed*	*Test Applicable*
Criteria referring to model structure		
1. Model structure plausible for the model purpose	Are relationships described by a model structure sufficient and necessary to satisfy a model's purpose? Is the model aggregation appropriate?	Boundary adequacy (structure) test (Forrester and Senge, 1980).
2. Model structure consistent with a real system	Are the relationships described by the model consistent with the relationships observed in real system or the relationships described in literature? Are parameters used correct conceptually and numerically?	Structure verification test (Forrester and Senge, 1980, Barlas, 1996, Richardson and Pugh, 1981). Parameter verification test (Forrester and Senge, 1980, Barlas, 1996, Richardson and Pugh, 1981). Face validity (Richardson and Pugh, 1981).
3. Formal correctness	Is the model internally consistent and are the created relationships formally correct?	Dimensional consistency test (Forrester and Senge, 1980, Barlas, 1996, Richardson and Pugh, 1981).
Criteria referring to model simulation abilities		
4. Plausibility of results for a wide range of conditions	Does a model behave plausibly for a wide range of conditions? Is its behavior consistent with the logic and nature of real system? Does the model behavior change when equally plausible formulation is introduced?	Extreme conditions test (Forrester and Senge, 1980, Barlas, 1996). Structural sensitivity (Richardson and Pugh, 1981)

FORMAL ASPECTS OF VALIDATION		
Criteria	*Question Addressed*	*Test Applicable*
Criteria referring to model behavior pattern		
5. Model behavior agreement with real system behavior	Does the model generate some unexpected behavior that leads to discovery of previously unrecognized behavior of real system? Does the model generate some anomalous behavior that leads to discovery of flawed structure?	Surprise behavior test (Forrester and Senge, 1980). Anomaly behavior test (Forrester and Senge, 1980).
6. Model behavior match with a real system behavior	Can the model show how particular internal policies cause problematic situation to arise? Are endogenous sources of model behavior clear? Are the behavior patterns generated by the model similar to the behavior patterns expected or generated by the real system? Do behavior patterns generated by the model exhibit same characteristics as the real system behavior pattern? Can experts differentiate real and simulated behavior patterns?	Symptom-generation test (Forrester and Senge, 1980). Boundary adequacy (behavior) test (Forrester and Senge, 1980). Phase-relationship test (Forrester and Senge, 1980, Barlas, 1996). Kalman Filter (Forrester and Senge, 1980). Multi Step Behavior Validation procedure (Barlas, 1996). Qualitative Feature Analysis by Carson and Flood (Barlas, 1996). Behavior reproduction and prediction test (Forrester and Senge, 1980). Turing test (Barlas, 1996).
7. Model behavior pattern match with multiple real system modes of behavior	Can a model generate observed modes of real system behavior?	Multiple-mode test (Forrester and Senge, 1980). Family member test (Forrester and Senge, 1980) (see also Modified behavior prediction test in Barlas, 1996).

FORMAL ASPECTS OF VALIDATION		
Criteria	*Question Addressed*	*Test Applicable*
Criteria referring to model prediction ability		
8. Model ability to generate expected results	Does the model behavior pattern qualitative features match expectations? Is the model able to generate a behavior pattern consistent with some inevitable events that occur or would occur in the real system?	Pattern-prediction test (Forrester and Senge, 1980). Event-prediction test (Forrester and Senge, 1980).
Criteria referring to policy development		
9. Recommended policies robustness	Are recommended policies robust under different conditions and tests the model is subjected to? Are policies recommended by the model indeed beneficial after their implementation?	Border adequacy (policy), Changed-behavior prediction, System improvement tests (Forrester and Senge, 1980). Behavior sensitivity, extreme policy tests (Forrester and Senge, 1980, Barlas, 1996).
10. Recommended policies adequacy	Is the risk involved in implementation of recommended policies adequate and accepted?	Policy sensitivity test (Forrester and Senge, 1980).

INFORMAL ASPECTS OF VALIDATION	
Criteria	*Description*
▪ Model structure complexity	For different kind of audience different degree of complexity of the structure and/or different structure representation is required in order to understand the model's structure (Richardson and Pugh, 1981).
▪ Model ability to generate counterintuitive behavior	If a model generates a counterintuitive behavior that yet still is verifiable in real life, than this enhances the confidence in the model (Richardson and Pugh, 1981).
▪ Generation of insights	If participants of model building group gain some new insights and understanding of the system and the problem, than more confidence is placed in the model (Richardson and Pugh, 1981).
▪ Impact on performance	Development of new insights and understanding may result in the improved individual, organizational performance that may be noticed already during the model building process.
▪ Model usefulness	The more useful the model becomes the more valid it is considered to be (Richardson and Pugh, 1981, Barlas, 1996).

Table 3. Suggested criteria for formal validation of component-based model

Level	*Validation Criteria Applicable*	*Notes*
Main Model	Criteria referring to model structure 1. Model structure plausible for the model purpose 2. Model structure consistent with a real system 3. Formal correctness Criteria referring to model simulation abilities 4. Plausibility of results for a wide range of conditions Criteria referring to model behavior pattern 5. Model behavior agreement with real system behavior 6. Model behavior match with a real system behavior 7. Model behavior pattern match with multiple real system modes of behavior Criteria referring to model prediction ability 8. Model ability to generate expected results Criteria referring to policy development 9. Recommended policies robustness 10. Recommended policies adequacy	Behavior pattern generated by the complete Main Model is verified against behavior patterns identified as reference behavior modes for the main problem. A purpose defined for the whole model is used for the Main Model testing. Formal correctness of the model is carried out only with respect to connections (input & output variables) established between used component models (i.e. Domain Models). Criteria referring to policy development apply only at the Main Model level. Since the Domain Models are just parts of the greater model, the effective policy recommendation cannot be developed within their boundaries. To develop robust and adequate policies analysis of the total system model is necessary.
Domain Models	Criteria referring to model structure 1. Model structure plausible for the model purpose 2. Model structure consistent with a real system 3. Formal correctness Criteria referring to model simulation abilities 4. Plausibility of results for a wide range of conditions Criteria referring to model behavior pattern 5. Model behavior agreement with real system behavior 6. Model behavior match with a real system behavior 7. Model behavior pattern match with multiple real system modes of behavior Criteria referring to model prediction ability 8. Model ability to generate expected results	Behavior pattern generated by the domain model is verified against behavior patterns identified as a reference mode behavior for the sub-problem corresponding the particular domain. A purpose defined for the particular domain model is used for the domain model testing. Each domain model should contain only structural elements relevant to a domain in question. Formal correctness of the model is carried out only with respect to connections (input & output variables) established between used component models.

Level	*Validation Criteria Applicable*	*Notes*
Domain Sub-models	Criteria referring to model structure 1. Model structure plausible for the model purpose 2. Model structure consistent with a real system 3. Formal correctness Criteria referring to model simulation abilities 4. Plausibility of results for a wide range of conditions Criteria referring to model behavior pattern 5. Model behavior agreement with real system behavior 6. Model behavior match with a real system behavior 7. Model behavior pattern match with multiple real system modes of behavior Criteria referring to model prediction ability 8. Model ability to generate expected results	Behavior pattern generated by the sub-model is verified against behavior pattern identified as a reference mode behavior for that sub-model. A purpose defined for the particular sub-model is used for the sub-model testing. Each sub-model should contain only structural elements that describe this particular part of the domain in question. Formal correctness of the model is carried out only with respect to connections (input & output variables) established between used elementary models.
Elementary Models	Criteria referring to model structure 1. Model structure plausible for the model purpose 2. Model structure consistent with multiple real systems 3. Formal correctness Criteria referring to model simulation abilities 4. Plausibility of results for a wide range of conditions Criteria referring to model behavior pattern 5. Model behavior agreement with real system behavior 6. Model behavior match with a real system behavior 7. Model behavior pattern match with multiple real system modes of behavior Criteria referring to model prediction ability 8. Model ability to generate expected results	Behavior pattern generated by the elementary model is verified against behavior pattern identified as a general reference mode behavior for that elementary model. Any elementary model must be a generic construct that can be applied across many similar systems. Therefore it should have an universal structure that could be applied in number of situations (see change in the 2nd criterion). Formal correctness of the model is carried out thoroughly analyzing each relationship identified in the elementary model.

Concluding remarks

In this contribution we have provided the rationale for an extended approach to SD group modeling. While it is premature to draw definite conclusions we have attempted to present evidence for the following points:

- Explicit consideration of knowledge fragmentation allows for deeper analysis of knowledge aspects relevant to the problem in question.
- The new technology providing object oriented extensions to system dynamic modeling is a promising platform for component based group model development. Component based model development offers the possibility to create a high level model describing the overall problem based on improve modeling of well-identified sub-problems.
- Predefined model components libraries and re-use of model components re-use is likely to enrich the system dynamics group model building process. In a long-term view we expect this enriched approach to increase the efficiency and quality of the system dynamics model building process. However, much research is needed still.
- The approach implies that the main model is «divided» into component models. In this process, reference modes describing each of the sub-problems could play a crucial role in ensuring the whole model consistency. How to best align the reference modes of the sub-problems with a complete description of the main problem is an important issue that needs more research.
- Component based modeling is likely to improve the system dynamics models validation process. This approach should allow for a more thorough validation process, both in terms of formal and informal validation. Especially promising is the potential of component based modeling for insightful modeling of the problem, and the potential larger number of people to be involved in the model building process. This should result in more throughout model verification, and in a greater number of persons that understand the model and have confidence in it. Increased confidence in the created model throughout the organization should lead to more successful implementation of the modeling process results and use of the model.

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