

The Elements and Structure of a Group Model Building Case Study Database

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Abstract

System dynamics has been successfully used to tackle so-called messy problems. System dynamics group model building scripts describe detailed processes for involving stakeholders deeply in system dynamics modeling. Group model building scripts describe, among other things, the information required as input to each group model building process as well as information that will become the output of each group model building process. While many different input and output artifacts are described in detail, little attention has been paid to how a collection of such artifacts should be organized for optimal use. This paper describes the elements and structure of a possible system dynamics case study database.

Introduction

We are surrounded by systems. Jay Forester wrote that: “few (people) realize how pervasive are systems, how imbedded in systems we are in everything we do, and how influential are systems in creating most of the puzzling difficulties that confront us” (Forester 1991). The most troublesome social systems contain sufficient complexity that well informed system participants often articulate conflicting system descriptions. When problems arise in such systems, participants will have difficulty agreeing on a problem description, let alone the source or solution (Vennix 1999). The idea that many perspectives of the same system can coexist, invites us to investigate these perspectives in more detail in hopes that models built upon more than one informed point of view will be more useful and robust. It has been persuasively argued that involving differing stakeholders has many advantages, including a more thorough description of the mental models held by participants, better alignment and support of resulting policy changes, and an enhanced client learning process (Vennix 1996).

System dynamic group model building scripts are one example of processes that can be used to deeply involve system participants in the development of system dynamics models (Andersen and Richardson 1997). While there are many such examples of processes used to involve stakeholders, using group model building scripts as an example emphasizes the extent to which many of these processes have been well documented such as those in Scriptopedia (Hovmand et al. 2011). Script processes describe the purpose of the script, the time required to perform the script, the materials needed to perform the script, the various facilitator roles, the inputs from other scripts that are required, and the outputs from each script (among other things). The point is that performing a series of these scripts will elicit a significant amount of information from participants and generate a sizable collection of artifacts useful in the system dynamics modeling process. Typical artifacts include behavior over time graphs, causal loop diagrams, verbal descriptions of causality, stock and flow diagrams, and a listing of prioritized variables. Examples are shown in figure 1.

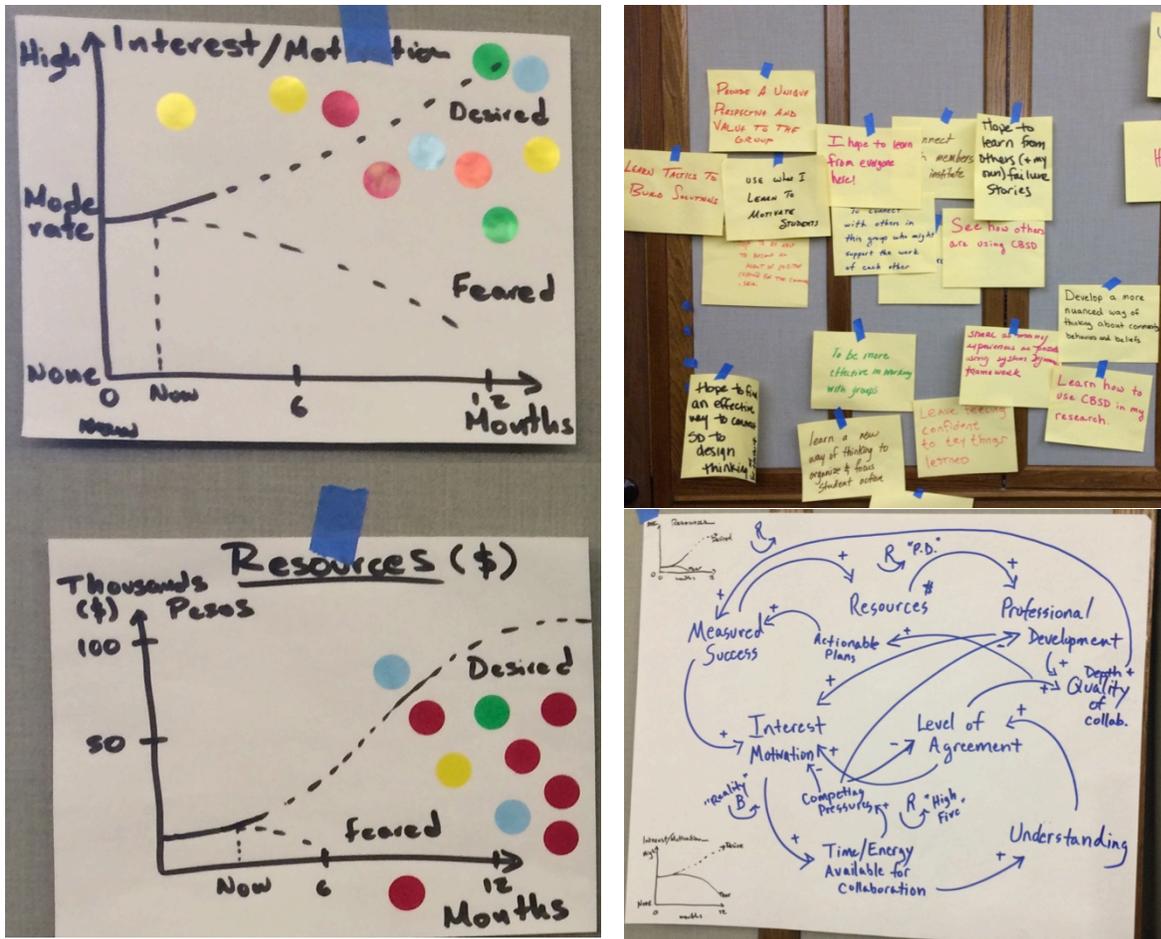


Figure 1: Example Group Model Building Artifacts

My personal experience and understanding from discussions with system dynamics practitioners who use group model building scripts is that these artifacts are carefully documented and preserved. Performing group model building scripts requires significant resources, especially if there are several sessions and/or many participants in each session. Among the valuable session outputs are artifacts. Most often the output artifacts from one process become the input artifact for a future script. It makes sense that preserving artifacts for accurate use is important to the group model building process. Complicating the preservation of artifacts is that artifacts can take many forms: a story spoken verbally, a causal loop diagram drawn on paper, a stock flow map constructed from glasses of water arranged on the table, for example. Capturing and preserving artifacts is a multi-media task often accomplished with a camera or a video or voice recorder.

While each of the artifacts produced during group model building is described in detail and carefully preserved, little attention has been paid to how such a large collection of artifacts should be organized for their most efficient and productive future use. Keeping in mind a wide variety of future uses, the structure of the proposed artifact database becomes important. Possible uses of group model building artifacts include: informing another group model building script; reporting of project progress by facilitators to participants or sponsors; recording prior beliefs upon which a new insight is based; documenting simulation models; or opening raw source data to independent confirming/refuting analysis.

Taking a step back from the details of system dynamics group model building, it is possible to describe group model building as a case study research method as described by Robert Yin (Yin 2009). According to Yin, the most important reason to use a case study method is to “explain the presumed causal links in

real-life interventions that are too complex for the survey or experimental strategies (p19)". Eliciting and documenting causal arguments is a core goal of system dynamic group model building making the case study method informative to group model building. Yin emphasizes that maximizing case study data validity and reliability requires that the researcher follow certain data collection principles including maintaining a record of: accurate raw data, multiple sources, and a chain of evidence. To accomplish this, Yin argues that the case study method requires a well-structured database be used to collect documentary evidence.

This paper assumes that there are significant advantages to storing the information generated by system dynamic group model building processes in a well-known structured database and focuses on the description of a proposed database structure. Listing and describing the advantages of a standardized data structure in detail is an important topic left for a different paper.

The Core Data Element: Artifact

At the core of the proposed data structure are the artifacts produced and used by the group model building scripts. As previously described, artifacts are the various 'tangible' products of group model building processes including informational text and hand-drawn pictures. Each artifact is initially captured in the database as it was described at the time and place it was created. While artifacts can be corrected for accuracy, any substantial artifact retelling or revision should be considered a new artifact. This will create a record of any inference chain that may occur. Artifacts have attributes used for easy categorization and recall. The table below describes the proposed attributes of artifacts.

Artifact Attribute	Examples	Attribute Description
Title	"How people move through an epidemic"	A useful name for this artifact
Type	Media Quote Publication Simulation	The primary form of the artifact. If the artifact has any multi-media such as a picture, then it is type 'Media'. If the artifact is entirely textual, then if it is from an available publication (possibly predating this project), then it is type 'Publication', otherwise it is a statement made by a participant or facilitator and type 'Quote'. Finally, the artifact could be some form of a system dynamics simulation model, type 'Simulation'.
Text Content	"The disease progresses through the population of Susceptibles by first making them Infected ..."	While Publication and Quote artifacts are defined by their text content, all artifact types may have explanatory text such as a verbal description of a causal loop diagram.
Media Content	TIFF, JPG, PDF or other formatted file	While Media and Simulation artifacts are defined by the media file content, all artifact types may have a media file to enhance their content. For example, a quote artifact could have a recording of the quote being recited in the participant's voice.
Media Type	Stock-Flow Diagram Causal Loop Diagram Behavior Over Time Graph Policy Options Variable List Iceberg Model	Associated media files have an optional type to recognize the various formats of group model building outputs and easily recall them.
Source Session	"Session #3: Describing behavior over time"	Artifacts are created by participants and facilitators during group model building meetings (Sessions). Each artifact has a Session tribute to record the Session during which it was created.
Source Publication	"Emergency Room Procedure Manual"	If the artifact type is 'Publication', then the source publication attribute provides a place to save information about the source.

Artifact Attribute	Examples	Attribute Description
Source Participant(s)	“John Smith”	Artifacts are created by participants and facilitators during group model building meetings. Each artifact has a source participant attribute to optionally record the participant(s) contributing this artifact.
Creation Date/User	“December 15, 2015 by Mary Gund”	To maintain a basic audit trail, the creation date and database user who created the database record are recorded for each artifact.
Modification Date/User	“December 17, 2015 by Kurt Welty”	To maintain a basic audit trail, the most recent modification date and database user who modified the database record are recorded for each artifact.

Table 1: The Attributes of Artifacts

The list of ‘artifact types’ was created to allow for the various artifacts produced by, and used in group model building scripts published in Scriptapedia (Hovmand et al 2011). In addition, they were chosen to conform to what Robert Yin describes as the primary types of case study documentary evidence (see note 1) (Yin 2009). It is also important to note that the ‘Media’ artifact type easily accommodates ‘boundary objects’ (see note 2). Boundary objects are thought to be a critical part of system dynamics group model building (Black 2013). Laura Black describes boundary objects as “... a crucial link between the system dynamics method and group facilitation in the social construction processes of participatory modeling”.

While the first three artifact types (Media, Quote, and Publication) are more generally applicable to the case study method, the ‘Simulation’ artifact type (e.g. a Vensim or Stella model) is more specific to system dynamics. Including system dynamic simulation models as a type of artifact allows for the inclusion of complete models, partial models, model fragments, and even ‘concept models’ (Richardson 2013). Each date-stamped simulation artifact can then be attributed to all preceding database artifacts. While not considered by Yin, simulation model artifacts are critical to the system dynamics group model building process.

Putting Artifacts into Context: Project, Session, and Participant

At its core, the proposed database structure is a collection of richly described group model building artifacts. Now we turn to the job of placing each artifact into context within a system dynamics group model building project. It is anticipated that the user of the database structure could have more than one group model building project operating in parallel. One group model building project comprises a unique vision, goal, time-line, process, and audience. The ‘Project’ database element is the container that maintains a separation between group model building engagements while allowing for possible cross-project queries within a common database. All elements of the database must be related to a project as the primary container. The table below describes the proposed attributes of group model building projects:

Project Attribute	Examples	Attribute Description
Name	“Improving Supply Line Dynamics for HVAC”	A useful title name for this project
Shared Vision	“Deeper cross functional understanding will result in a more efficient supply line.”	The core reason for doing this group model building project.
Goals and Values	“Reduce supply line costs by 10%” or “We will respect each participant in the modeling process for the experience, understanding, and wisdom that they bring.”	The anticipated outcome and or a list of values that will be used to get there.

Project Attribute	Examples	Attribute Description
Time Line	“Because our products are subject to seasonality, we will look at an historical period of five years and project forward another five years.”	One of the distinguishing features of system dynamics is the focus on describing and explaining behavior over time. It may be useful to have a documented general agreement on the time frame(s) of interest at the beginning of the project.
Process	“A series of ten group sessions are planned with the following summarized agendas ...”	A description of the anticipated steps, resources, and timeline required to complete the project.
Audience	“The funding for this project is from ...” “Management sponsors include ...”	A general description of what groups of people are involved with the project and why their involvement is critical to project success.
Creation Date/User	“March 3, 2017 by Jonathan Kasper”	To maintain a basic audit trail, the creation date and database user who created the database record are recorded for each project.
Modification Date/User	“March 4, 2017 by Matt Whitney”	To maintain a basic audit trail, the most recent modification date and database user who modified the database record are recorded for each project.

Table 2: The Attributes of Projects

At this point, it is appropriate to say a word about database security. Individual group model building projects will have different levels of required security. While securing the database is not explicitly a part of the proposed database structure described in this paper, selecting an appropriate database engine with the required data security features (e.g. unique and secured logins) is an important consideration in putting this proposed database structure to use.

Another database “container” element is the ‘Session’. A group model building Session primarily comprises a date and time, the people who participated, the artifacts that were generated during the session, and notes that are useful to the session facilitators or participants. Because sessions are date and time stamped, they serve as the primary container for when and in what context an artifact was generated. Knowing the relative order of artifact generation preserves the chain of discovery and insights that occur during a group model building project. The table below describes the proposed attributes of group model building sessions:

Session Attribute	Examples	Attribute Description
Name	“Identifying Critical Behavior Over Time”	A useful name for the session identifying its primary purpose.
Date and Time	“10/24/2016 from noon to 4p”	The date and timing of the session
Session Participants	“John Smith, Mary Gund, ...”	A list of all the people who participated in the session.
Session Artifacts	“BOTG: Infected Population” “BOTG: Susceptible Population” “Estimated Virus Infectivity”	A list of all of the artifacts that were created during the session.
Facilitator Notes	“The goal for this session is to introduce behavior over time graphs, having participants draw their current understanding of ...”	General notes useful to the facilitators of the session including the planned agenda and possible notes about any session surprises or concerns.
Participant Notes	“Participants generally agreed that thinking about population change over time was a challenging task.”	General notes useful to the session reporting process including participant thoughts on progress or next steps.

Session Attribute	Examples	Attribute Description
Creation Date/User	“November 20, 2016 by Andrea Lindstrom”	To maintain a basic audit trail, the creation date and database user who created the database record are recorded for each session.
Modification Date/User	“November 21, 2016 by Diane Pardy”	To maintain a basic audit trail, the most recent modification date and database user who modified the database record are recorded for each session.

Table 3: The Attributes of Sessions

It is anticipated that Sessions can be used somewhat liberally and creatively. For instance, if an ad-hoc discussion occurs after a planned session has ended (perhaps through email or on the phone) and important information is revealed, a new session could be created documenting the date and time of the conversation and capturing the important artifact(s). Sessions could also be used to record a facilitator post session debriefing or a facilitator pre session planning meeting. Creating a separate Session in the database in each of these examples has the benefit of memorializing any new artifacts and potentially making them available to a broader audience.

As previously mentioned, Participants are also a key database element for putting artifacts into context. Participants as a database element refers broadly to the people who participate in some way in the group model building project. This includes client participants (people generally not versed in system dynamics) as well as facilitator participants (people familiar with system dynamics group model building), as well as other people who sponsor, support, or otherwise influence the project. Making Participants a database element is important for a couple of reasons. First, associating Participants with other database elements (e.g. sessions) helps to put those elements into context. Second, maintaining separate Participant database records makes them available to form database relationships as required by a normalized relational database design (see note 2). The table below describes the proposed attributes of group model building participants:

Participant Attribute	Examples	Attribute Description
Name	“John Smith”	Person’s preferred name.
Role	“Expert” “Sponsor” “Facilitator”	The primary role that this person performs in this group model building project.
Organization	“Worcester Polytechnic Institute” “Dairyman’s Cooperative”	The name of the organization that the person represents.
Description	“Manages the central warehouse including ...” “Familiar with the Beer Game and the main sponsor of this project.”	General notes about this person that are useful to determine session participation, general perspective on the project issues, or manager/subordinate relationships.
Sessions Attended	“Identifying Critical Behavior over Time”	A list of all of the Sessions that this person has been present.
Contact Information	“Smith_John@gmail.com”	Preferred contact information for general contact and for receiving project information.
Picture	JPG file	A headshot of the person to help identify them in larger group projects.
Creation Date/User	“July 10, 2016 by Usha Thakrar”	To maintain a basic audit trail, the creation date and database user who created the database record are recorded for each participant.
Modification Date/User	“July 20, 2016 by Bob Nevins”	To maintain a basic audit trail, the most recent modification date and database user who modified the database record are recorded for each participant.

Table 4: The Attributes of Participants

It is anticipated that keeping an accurate record of a participant’s overall role will be useful for reporting purposes. As the contents of the database build, there will be opportunities to produce reports documenting project progress. Knowing the role of the report recipient will aide the report designer to include appropriate report content and format for the intended audience.

Making the Database More Useful: KeyWords (Variables)

So far, this paper has focused on defining the primary database element to be recorded, the Artifact, and the database elements used to establish the context of the artifact: Projects, Sessions, and Participants. Using the proposed database structure preserves the timeline of work and provides links to evidence for the conclusions offered in a system dynamics group model building case study. With this proposed foundation in mind, this paper will now describe a new database element that makes the database more useful.

Early in the group model building process, variable elicitation and prioritization is used to begin determining model boundaries and important stocks within the system. Once prioritized, elicited variables are used as inputs to many follow-on group model building scripts and can become the variables in a system dynamics simulation model, making Variables an important group model building element (Luna-Reyes et al 2006). In the proposed database structure, Variables will be contained in the artifacts being created during group model building sessions. For example, a ‘variable elicitation’ Session will generate a simple list of variable names as one of it’s Artifacts.

While variables can be captured within an Artifact, placing Variables into a distinct database element has several advantages. Because Variables are a key building block to simulation models, they have several additional attributes such as: type, priority, and unit of measure. These attributes and others are described in the table below:

Variable Attribute	Examples	Attribute Description
Name	“Infection Rate”	A descriptive name for the variable.
Type	“Stock” “Flow” “Converter” “Graphical Function”	The primary type of this variable as it would be used in a system dynamics simulation model.
Priority	“High”, “Medium”, “Low”	The relative priority of this variable to other variables used as an indication of where to begin the group model building investigation. Low priority variables form a “parking lot” of ideas to investigate after High priority variables are described and used in modeling.
Definition	“The number of susceptibles infected per day. It equals the number of susceptible contacts with ...”	A clear definition of this variable (word or phrase) that reflects participant understanding and uses the words of the participants.
Units	“people per day”	The unit of measure for this variable.
Parent Alias	“Becoming Infected”	When participants use multiple names for the same variable concept, the multiple names can be ‘aliased’ to a ‘parent’ variable. The ‘parent alias’ is a link to this variable’s parent alias (variable).
Linked Artifacts	“The Mechanics of Becoming Infected” “How Diseases Differ”	Links to the artifacts that contain this variable.
Creation Date/User	“August 22, 2016 by John Kasper”	To maintain a basic audit trail, the creation date and database user who created the database record are recorded for each variable.

Variable Attribute	Examples	Attribute Description
Modification Date/User	"September 3, 2016 by John Marion"	To maintain a basic audit trail, the most recent modification date and database user who modified the database record are recorded for each variable.

Table 5: The Attributes of Variables

The 'Priority' and 'Parent Alias' attributes of variables require additional explanation. Variable 'priority' is an importance ranking relative to the other variables in the database. During a 'variable elicitation' process, it may be advantageous to elicit from participants as many variables as possible. But a very long list makes it hard to know where to focus the group's time. Prioritizing variables into a small number of priority groups (e.g. "high, medium, low", or "now, soon, later") allows all variables to be added to the database while focusing the group's time on the variables considered to be most important.

Participant language is important to the group model building process. Expressing variable names carefully using preferred guidelines can aid in the model building process (Black 2016). It is reasonable to assume that group model building participants with a significantly different vantage point to the system (e.g. because of organizational structure) may have different names for the same variable. For instance, a long list of variables may contain redundancy: different names for the same variable concept. The redundant names for a variable can create a problem for group model building facilitators. It is advantageous to both preserve each (similar) variable name while choosing one in an effort to simplify the process. The proposed 'Parent Alias' Variable attribute is a way to capture all redundant names in the database while collapsing them into a single acceptable variable name called the 'Parent Alias'.

Consider two variables: "infection rate" and "becoming infected". It could be argued that these two names have exactly the same meaning (e.g. a flow, the number of people per day that become infected). In this case, they are aliases of each other. Selecting one as the 'parent alias' (and all others as 'child aliases') allows the model building process to proceed while preserving the language of all participants within the database.

Variables, as described here, have many useful attributes that may not be known at the time of variable creation. This is not a problem. Attributes such as 'type' can be filled in as the information becomes available. In fact, it could be a valuable activity to search for high priority variables that do not currently have a valid 'type' in an effort to expand participants' understanding.

Summary

While much has been written about the processes of group model building, including facilitator roles and desired outcomes, little attention has been paid to the organization or structure of collecting and storing the many group model building artifacts that result. This paper proposes a simple structure that could serve as a system dynamics group model building case study database. This structure is proposed for the purpose of creating conversation among those interested in system dynamics group model building. Enough structure has been described to begin the discussion while leaving room for modification or addition. This database structure proposed herein is not meant to be a complete and rigorous database schema for the development of such a database.

This paper assumes that the existence of a structured system dynamics case study database would create significant advantages for its users. Making the job of collecting and sense-making of information for the purpose of building a useful system dynamics model a more organized and efficient process is one example of an advantage. A convincing argument that such advantages exist has been left for another paper.

It could be argued, that the adoption of system dynamics modeling has been slower than it could otherwise have been because of a general lack of simulation model documentation. The detail of even

well documented models would likely fall short of the information that could be captured in this simple proposed database structure. Database structure is important to both capture and preserve the raw source information and to make it easily accessible to those less familiar with the model. A useful system dynamics model carefully aggregates the many participant provided details of a system. While this is a useful modeling practice, it means that the information documented by the model falls short of the rich source data. This is a problem for the field of system dynamics when it prevents others from reproducing model results, especially when a different modeling approach is appropriate.

Notes

(1) Yin describes six types of documentary evidence that were grouped into artifact types as described below:

Artifact type 'Published':

Yin's 'Documentation Records' and 'Archival Records': These forms of evidence are published and are thus (with proper permissions) available anytime for inspection. Examples include: letters, memoranda, emails, announcements, proposals, progress reports, related case studies, news clippings, etc.

Artifact type 'Media':

Yin's 'Physical Artifacts': These forms of evidence are quite literally physical or cultural artifacts (as used in anthropological work). System dynamic group model building scripts call for the creation of many physical artifacts by participants during model building sessions such as drawings of system behavior over time.

Artifact type 'Quote':

Yin's 'Interviews', 'Direct Observations' and 'Participant Observations': These forms of evidence result from interviewing one or more participants and documenting observations about the system and/or its participants. (Yin differentiates between the researcher making 'direct' observations versus the researcher as participant and making 'participant' observations.)

(2) Black defines boundary objects as being: a concrete picture, in participants' language, and accessible and changeable by group model building participants. Database Artifacts can accommodate each of these requirements.

(3) Relational database design requires that certain database elements be normalized so that they are recorded in one place and then linked to other database elements. Normalization prevents the database user from having to go back and change the same information in multiple places (e.g. change the name of a participant in all sessions that she attended). The purpose of this note is to remind the user of this paper that some database elements, such as Participants, should be normalized.

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