Process and outcomes of modeling: an attempt at formulating a conceptual framework

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Abstract

In the field's early publications, Forrester was already clear on the goals of the system dynamics approach. The purpose of constructing a system dynamics model of any real world issue of concern was to improve system functioning. The vehicle for doing so was an increased understanding of relations between structure and behavior or a change in mental models, leading stakeholders to implement conclusions of the modeling effort. In recent years much attention has been given to involving stakeholders directly in modeling, leading to various forms of group model building. Involvement in modeling was expected to increase change in mental models and thereby foster implementation of conclusions. However, only a few years ago leading authors in the field have called group model building more an art than a science, and pointed to the lack of evidence for its effectiveness. Authors in related fields have made similar comments with regard to their respective methodologies: a lack of an integrative conceptual framework linking modeling practice to modeling outcomes, makes 1. an accumulation of research results difficult and 2. leaves implicit what the crucial elements of a modeling intervention are. Thus the effectiveness of methodologies is difficult to assess and relate to relevant theories. In this article such an integrative conceptual framework is proposed, drawing on theories of persuasion (mental model change) and the influence of beliefs and evaluations on actions. Well-established theories in social psychology are used to formulate important variables and relations in the model, enabling us to draw on standard operationalizations and relate to a body of research on social interactions. The framework is used to evaluate five group model building cases in a PhD research project, of which the main results are reported here. The results indicate that group model building effectiveness can be understood in terms of the framework, leading to the identification of further research questions.

Introduction

Forrester's founding ideas of system dynamics (1958; 1961) include an integrative perspective on material and information flows and decisions, and the explanation of system behavior from the closed loops between the state of the system and stakeholders' decisions. The ultimate purpose of system dynamics interventions is then to improve the functioning of the system, and it was readily recognized that stakeholders' opinions, convictions or ideas on system functioning are crucial in accomplishing this. Stakeholders' mental models include important information on the issue of concern, part of which cannot be found in other information sources (Forrester, 1961). Mental models do not only provide information on the functioning of the system as a whole, but are also the base for an individual stakeholder's actions. Decisions within the larger system are founded on the decision maker's limited store of information and decision rules. The mental model determines which system variables are scanned for information as well the goal to be reached. It is therefore not surprising that mental models are central to modeling practice. Doyle and Ford (1998: 4) formulate this as follows:

> *'Mental models are thus the stock in trade of research and practice in system dynamics: they are the "product" that modelers take from students and clients, disassemble, reconfigure, add to, subtract from, and return with value added.'*

It seems natural that the dual need to ensure access to stakeholders' mental models and to transfer insights gained during the modeling process, would lead to involvement of stakeholders in the modeling process. Benefits of involvement have been described early on in the literature (Roberts, 1978), and are more systematically explored in publications on participative modeling formats (e.g. Randers, 1977; Richmond, 1987; Wolstenholme, 1992). Early publications focus on exploring methodological guidelines for involving stakeholders and clients in the modeling process, but from the 1980s on, evaluation studies on the effectiveness of these approaches have appeared regularly (Rouwette et al., 2002). Group model building approaches, as they are now commonly called, are widely used. The interest in the approach gave rise to a special issue of System Dynamics Review in 1997, which was devoted to methodology and research findings.

Several authors in the 1997 special issue find group model building lacking in clearly defined methodological guidelines (Vennix et al., 1997). Knowledge on constructing a system dynamics model is far better codified and structured than knowledge on eliciting information from a group or how to deal effectively with group dynamics. Group model building to a great extent seems to be the domain of gifted practitioners, who design their interventions on the basis of experience and implicit insights. A related issue is that studies on the effectiveness of the approach are scarce. The few existing studies employ different designs, focus on a wide variety of variables and sometimes find contradictory results. A research program leading to accumulation and replicability of results is missing. (Andersen et al., 1997). Part of designing a research program is theory construction: explanatory theories of why modeling goals are accomplished need to be formulated. As a starting point for such a theory,

Andersen et al. formulate seven different hypotheses on the effects of group model building, e.g. 'what matters is that top management is together with the "doers" for an extended period' or 'what matters is big chunks of insight – the details that lead up to the insights are largely means to acquire group confidence and are forgotten' (1997: 195).

The lack of insight into what the method accomplishes and why, resembles the situation in related fields. McGrath and Hollingshead (1994: 78) start their review of results of group decision support technology by pointing out that outcomes will inevitably be a joint function of contextual and intervention characteristics. After reviewing Delphi studies, Rowe and Wright (1999) stress that the question whether a technique is effective cannot be answered without knowing how it impacts decision making groups. They conclude that (1999: 373): 'We need to understand the underlying processes of techniques before we can hope to determine their contingent utilities.' Pawson and Tilley (1997) discuss this issue at a more general level and argue that a realistic comparison of evaluation studies boils down to discovering which combinations of mechanism and context lead to which outcomes. Context is used in a very wide sense here, referring to all conditions that influence the causal mechanism at work in the intervention (Pawson and Tilley, 1997: 69), e.g. social conditions, rules, norms, values and relationships between persons involved. The context of group model building is formed by the organization and the problem which is being addressed.

At present, there seems to be no agreement on the relevant variables in the context, mechanism and outcome variables of group model building interventions. The system dynamics community has been implicit in answering questions such as 'does the approach work?' and 'how does the approach work?' In the following, first the main goals of system dynamics modeling are reformulated as variables in a conceptual framework on modeling effectiveness. Next, theories of social psychology are used to describe relations between variables. This framework is then tested in five group model building applications. Operationalization of variables, research design and results are described. This article ends with conclusions for future system dynamics interventions and directions for further research.

Conceptual framework

The starting point for a conceptual framework are intended outcomes, or goals, of modeling. System improvement and mental model change are among the main goals of modeling and have been discussed above. Huz et al. (1997) propose a comprehensive framework for evaluating system dynamics modeling. On the basis of these goals and the literature analysis by Rouwette et al. (2002), the four levels of intervention goals were formulated: individual, group, organizational and methodological.

individual	positive reaction mental model refinement commitment behavioral change
group	increased quality of communication creation of a common language consensus and alignment
organization	system changes system improvement or results
method	further use efficiency

Table 1. outcomes of group model building

At the individual level four goals can be identified. Several authors stress the importance of clients' reactions to the model or other elements of the intervention, e.g. trust in the modeler (Lane, 1992). All approaches underline the importance of learning; clients are encouraged to take a broader perspective on the problem modeled. In the system dynamics literature, insight and mental model refinement are seen as closely related. Richardson et al. (1994) distinguish three elements of a mental model. A representation of prerequisites for actions is referred to by Richardson et al. (1994) as a means model. The ideas on the dynamic system are stored in a means/ends model, functioning in tandem with at least two other types of models (means models and ends models). Commitment to results and the resulting changes in behavior are also widely agreed on as an important goal of client involvement.

Discussions on common language and communication are relatively scarce in the methodological literature in system dynamics (although see Akkermans, 1995: 201 for a discussion of the central role of communication). If mentioned, they seem to be considered one of the elements affecting insight. The impact of group model building on consensus and alignment of mental models has been the central topic of a recent dissertation (Huz, 1999).

In many descriptions of the phases of modeling (e.g. Richardson and Pugh, 1981), the implementation of system changes forms the final step. However, more and more authors describe implementation as a goal pervading the complete process of model construction (e.g. Roberts, 1978; Vennix, 1996). It seems logical to expect system improvement to be a goal even higher in the hierarchy, for which commitment and implementation are a prerequisite. Behavioral change is the equivalent of implementation on the individual level.

The methodological goals in the table above are less often discussed. Further use refers to the application of system dynamics to new problems, while efficiency of (elements of) the method is concerned with the results of group model building in comparison to other methods, including unsupported decision making. Further use and efficiency almost have the role of side-effects, although one of the goals of Lane's (1992) approach to modelling is to teach participants about the techniques used.

A further question is how these goals are brought about in group model building. Why does modeling lead to insight, consensus or behavioral changes? In the system dynamics literature two crucial elements of the methodology are distinguished: facilitation and model construction. Vennix (1999) sees facilitation as a way to overcome the drawbacks of freely interacting groups. The group process is e.g. designed with an eye to separating production and evaluation of ideas, in order to minimize process losses. A facilitator enacts the behavior expected from group members and limits the need for face saving operations. Modeling also operates as a shared language, which can bridge the differences between separate functional departments (Richmond, 1997). The mainstream of publications on system dynamics methodology is however not concerned with group decision making or facilitation, but instead focuses on model content: analysis of structure and behavioral patterns, validation and testing, and policy experimentation. The system dynamics model and participants' mental models are expected to be closely related. Most system dynamicists would probably consider the development and analysis of a model as the main vehicle to produce insight. This resembles the view of models as transitional objects or items people can play with in order to refine their understanding of a particular subject (Morecroft, 1992). Lane (1992: 74) sees the function of models as making the view of participants more coherent: '…goals which seemed reasonable when only part of the system was viewed are seen as inconsistent or impossible in the context of the whole system.' This points to an impact of modeling on the ends model (Richardson et al., 1994). Vennix (1996; 1999) relates the construction of a system dynamics model to individual perception and retention processes. The human information processing capacity cannot deal adequately with complex systems, as humans are biased in their decision making and fail to see feedback processes (Sterman, 1994). A model helps participants to structure the problem and enables them to put their problem definitions to the test.

So far intended outcomes of modeling have been described, and two general features of the intervention that help in creating these outcomes: modeling and facilitation. The question then becomes how goals and intervention elements can be related to one another. In the following we focus on participants in a modeling session and the way in which their behavior is changed. This focus on the way in group model building, including the group of other participants, influences an individual participant, draws attention away from impacts at the level of organizations or the method, but allows us to draw on psychological theories to relate intervention elements and goals. Taking a closer look at the individual participant, it seems that system dynamicists assume that there is a relation between communication, cognition (in the form of mental models and consensus) and behavior. In the following we first focus on the relation between cognition and behavior, and then turn to the relation between communication and cognition.

Relation between cognition and behavior

In their review of social psychological research, Eagly and Chaiken (1993) concentrate on a particular cognitive structure whose relation to behavior has been studied extensively. They refer to attitudes, which are distinct from other cognitive structures in their emphasis on evaluation. Eagly and Chaiken (1993: 1) use the following conceptual definition of attitude: 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor.' The term evaluating is used in a broad sense and captures overt as well as covert responses, cognitive, emotional and behavioral. As a central topic in social psychology, the relation between attitudes and behaviors has generated some controversies. From the mid-1960s to the mid-1970s, the idea that attitudes were poor predictors of behavior was accepted widely. This assumption was supported by a number of studies showing no or weak relationships between the two concepts (e.g. Wicker, 1969). According to Eagly and Chaiken, the popularity of research into the impact of behavior on attitudes (e.g. Festinger, 1957) made it difficult to consider the causal link in the reverse direction. Reactions to these criticisms focused on the bias towards laboratory studies in Wicker's study, that mainly measured attitudes low in importance and involvement, on the situational barriers against expressing some behaviors (e.g. negative behavior towards minorities) and on the level of aggregation of attitudinal and behavioral measures. Fishbein and Ajzen (1975) make an important contribution in this regard when arguing for compatibility between measures in order to ensure a substantial correlation. They suggest that general attitudes with respect to organizations, institutions, groups, individuals or ideas are good predictors of general behavioral categories summed over multiple behaviors. In contrast, specific attitudes will be good predictors of specific actions. Ajzen (1991) proposes a model of the impact of attitudes on behavior which is based on influential earlier work by Fishbein (1967) and Fishbein and Ajzen (1975). The following figure shows the central variables and relations in Ajzen's model.

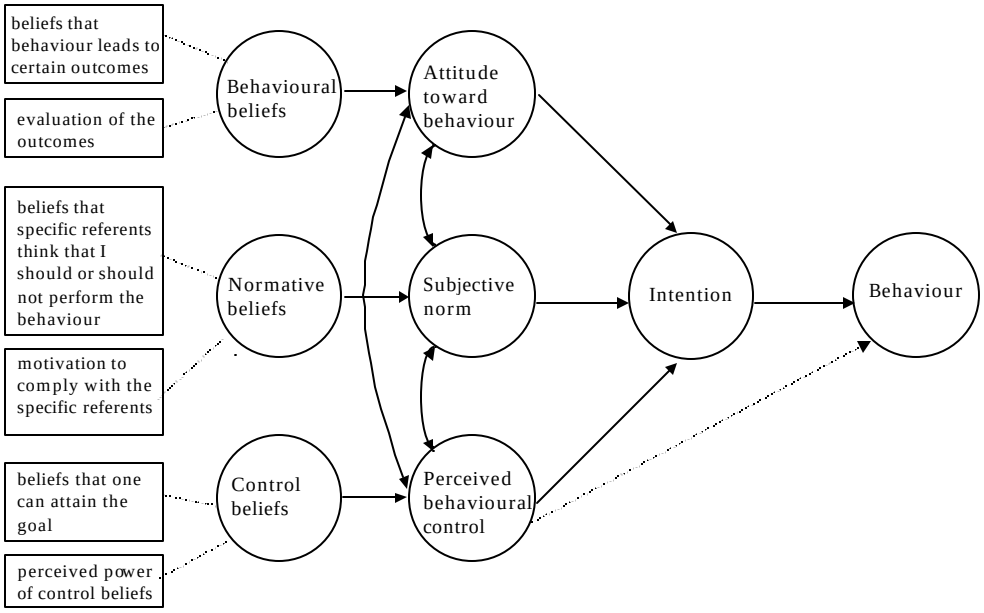

Figure 1. Theory of planned behavior (adapted from Ajzen, 1991: 182). The broken arrow at the right hand side indicates that perceived behavioral control is only predictive of behavior if it is an accurate estimation of actual control

In the model, a central role is reserved for a specific attitude called the attitude towards behavior. Attitudes towards behaviors are evaluations of the subject engaging in a single behavior or set of behaviors (Eagly and Chaiken, 1993: 164). The attitude towards a behavior is the emotion for or against this action on a scale of good versus bad (Van den Putte, 1993: 5). Fishbein and Ajzen suggest that the attitude towards behavior relates to behavior through its impact on intentions. The attitude influences intention, which forms the basis for action. Ajzen (1991: 181) describes intentions as follows:

> *'Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour.'*

In other words, intentions motivate the decision to act in a particular way. In addition to attitude toward behavior, intention is also determined by the subjective norm. The subjective norm reflects a subject's belief that significant others think he or she should engage in the behavior. Significant others are the referents whose preferences a person takes into consideration in a certain domain of behavior. Above evaluations were described as cognitive, emotional and behavioral responses to a particular entity. The description so far makes it clear that in the theory of reasoned action emotional (attitude and subjective norm) and behavioral aspects of evaluation (intention and behavior) are separated.

The theory also considers the cognitive foundation of attitudes. Attitudes are seen as a function of behavioral beliefs about consequences of an act. An example might illustrate this. Suppose an important action is recruitment of additional personnel by the HRM department of a telecommunication provider. A person's attitude towards this action is formed on the basis of two sets of beliefs. The first is the *value* placed on outcomes of this action. The second belief concerns the *expected likelihood* that the action brings about this outcome. A possible outcome is for example an increase in innovation potential of the organization. Let us suppose that a human resource manager positively values this outcome. Considering only this action (increasing recruitment), the chance that the valued outcome will be realized is the expected likelihood that recruitment leads to an increased innovation potential. If either innovation is valued more, or the relation between recruitment and innovation potential grows stronger, we expect the attitude towards recruitment to become more positive. In other words, values and expectancies combine to form evaluations. Fishbein and Ajzen (1975) propose to sum expectancy times value products over all beliefs to arrive at an indicator for behavioral beliefs.

Likewise, subjective norm is a function of normative beliefs and motivation to comply. A normative belief captures the perceived likelihood that a referent approves or disapproves of performing the behavior. This is multiplied with the motivation to comply with the specific referent, and again summed over all salient beliefs. The human resource manager might have the following normative beliefs and motivation to comply. An example of a belief that important referents are in favor of performing the behavior, is when the manager feels that the telecommunication provider's HRM department strongly favors increasing recruitment. If we also suppose that this person has a strong inclination to follow the opinion of the HRM department, his subjective norm towards increasing recruitment will be positive. Since both normative beliefs and motivation to comply are positive, we expect a positive subjective norm.

The third influence on intentions in the theory of planned behavior, is perceived behavioral control. Apart from its influence on intention, Ajzen also maintains that perception of control directly influences behavior to the extent that it reflects actual control (the broken arrow in figure 1). Only if a person's estimation of perceived behavioral control is accurate can it be used to predict the probability of actually performing the behavior.

Perceived behavioral control is again determined by control beliefs, beliefs about the likelihood that one possesses the resources and opportunities thought necessary to execute the behavior (Eagly and Chaiken, 1993: 187). First, there is the chance that a threat or opportunity will occur. In the previous example on recruitment, this could be the likelihood of a tight labor market on which few applicants can be recruited. Second, there is the degree to which the threat or opportunity is expected to influence implementation of the action. If a tight labor market prevents recruitment of employees, this lowers perceived behavioral control.

The concepts in the theory of planned behavior can be related to the goals of modeling discussed earlier. First, intention is similar to the commitment in that both capture the effort a person wants to exert in order to reach a goal (Vennix et al., 1996). The attitude toward behavior is closely related to the ends model described by Richardson et al. (1994). Huz's (1999) operationalization of the ends model resembles the cognitive foundation of attitude toward behavior in beliefs about outcomes and evaluation of outcomes. Huz asks respondents to evaluate a list of system goals by rating their importance. The subjective norm and normative beliefs closely resemble consensus. Consensus and subjective norm are similar in their emphasis on the subjective or personal definition of the important aspects of a situation. Consensus is based on concepts, properties and relations between concepts, which is cognitive in orientation (Scheper, 1991). Subjective norm is defined as an emotional evaluation, while its cognitive foundation in the theory of reasoned action is sought in beliefs about important referents. With regard to the scope of the definition, the definition of subjective norm seems to be more restrictive. Ajzen and Fishbein (1980: 76) suggest that a limited set of beliefs are considered when forming an evaluation, i.e. only those beliefs that are salient. Scheper essentially does not place any boundaries on the concepts or relationships that are considered. Consensus and subjective norm thus differ with regard to the level at which they are defined, but subjective norm can be interpreted as the individual perception of the consensus view in a group. Placing it alongside attitude towards behavior is in line with Faber's (1994) separation of cognitions on the personal and consensus view. Lastly, perceived behavioral control seems important as single participants are expected to implement behavioral changes after a group model building intervention, while a participant is not in complete control over a behavior. Similar to attitude toward behavior, a person's perception of control is an affective evaluation. The cognitive foundation in control beliefs and power of control beliefs again resembles Huz's (1999) operationalization. Huz asks respondents to evaluate a list of functions or means of the system modeled, by rating their importance.

The factors considered important for evaluation of group model building discussed above, are all included in Ajzen's theory of planned behavior. As mentioned before, outcomes at the level of the organization or method are not considered here. Nevertheless, a relation between action and system changes seems likely. If an organizational problem is modeled, it is difficult to conceive of system changes which are not implemented by an individual actor. In the remainder of this study I will refer to attitude, subjective norm and perceived control as 'evaluations' for reasons of simplicity.

Relation of communication and cognition

The intervention elements identified as important in the previous sections are modeling and facilitation. How are modeling and facilitation related to cognitions and evaluations? Eagly and Chaiken (1993) discuss two important models of evaluation formation and change, the Heuristic Systematic Model (HSM, Chaiken et al., 1989) and the Elaboration Likelihood Model (ELM, Petty and Cacioppo, 1986). Although these models concentrate on attitude change, we assume that similar

processes operate in changing subjective norm and perceived behavioral control. In the HSM and the ELM two routes are available through which evaluations can be changed. One route consists of understanding and evaluation of arguments. A persuasive message is received and understood, arguments in the message are identified, contrasted with existing knowledge and judged on their validity. This route is termed the systematic (HSM) or the central route (ELM). Following the second route, evaluations are changed on the basis of simple decision rules or heuristics (for example: 'the expert's information can be trusted'). Both the HSM and ELM refer to this as the peripheral route.

The content of both information and heuristics can be either negative or positive, leading to a change in evaluations in a negative or positive direction. For example when during modeling a new positive outcome of an action alternative is identified (a positive argument) we can expect the attitude towards that action to become more positive. According to the HSM and the ELM, the decision which route will be used depends on the person's motivation and ability to process information. If both motivation and ability are high, the central route will be more influential in changing attitudes. Motivation is high when for example the situation is high in personal ('outcome') relevance. When a person is already knowledgeable about the subject, ability to process is increased.

Contrasting these routes available for evaluation change and the practice of group modeling, it seems clear that modeling and facilitation operate to make as much use of the central or systemic route as possible. The aim of group model building is to integrate and structure available information about a problem, bypassing the heuristics used in 'traditional' decision making. The idea that modeling functions as a common language (Richmond, 1997), increasing the ability to process information, points in the same direction. Thus modeling primarily affects the ability to process. Since participants are invited to contribute to group modeling sessions based on their expertise or stake in the problem, motivation can also be expected to be high.

Two other elements of communication in decision making are influence attempts and negotiation (Eden, 1992). These elements can be placed in the HSM and the ELM as well. Participants can attempt to influence each other's opinions both by exchanging information (the central route) and by using heuristics such as their power or status (the peripheral route). To the extent that the participant group operates as a cohesive group or team, the influence of heuristics on participants' evaluations is limited because the influence of power and status differences will be limited. Vennix et al. (1996: 52) see the relation between persuasion routes and group model building as follows:

> '*We may assume that the managers in question are relatively knowledgeable about the subject. However, other factors, such as message comprehensibility and attention of the subject, have to be sufficient to enable a subject to consider all relevant information. Group model-building is generally helpful to process and integrate a large amount of information, provided that the facilitator succeeds in creating a sphere of open and supportive communication in which mental models can be shared and explored freely.* '

Influence attempts in group model building can therefore be assumed to operate largely through the central route. Before participants will change their opinions, another factor needs to be present: arguments. Exactly what makes information an argument that potentially changes a receiver's opinion, is only studied in general terms (Petty and Cacioppo, 1986). In short, information needs to be new and relevant to the receiver if it is to be effective in changing evaluations. Participants will only consider arguments if they are of sufficient quality and find their content persuasive. This highlights the role of counterintuitive insights that are sometimes gained in system dynamics interventions (Forrester, 1975). Through their impact on evaluations and intention, these insights can be expected to affect implementation. The ability to process information is influenced by the degree of support of the decision making process. The main contribution of group model building to the decision making process is to increase the ability to consider and integrate all relevant information. The second factor in the persuasion theories, motivation to process information, is an element of the context of the group model building intervention. The degree of motivation is determined by organizational and problem characteristics. If the problem is perceived as important, a high motivation to process information can be expected.

Conceptual framework

The following figure summarizes outcome, mechanism and context variables discussed so far.

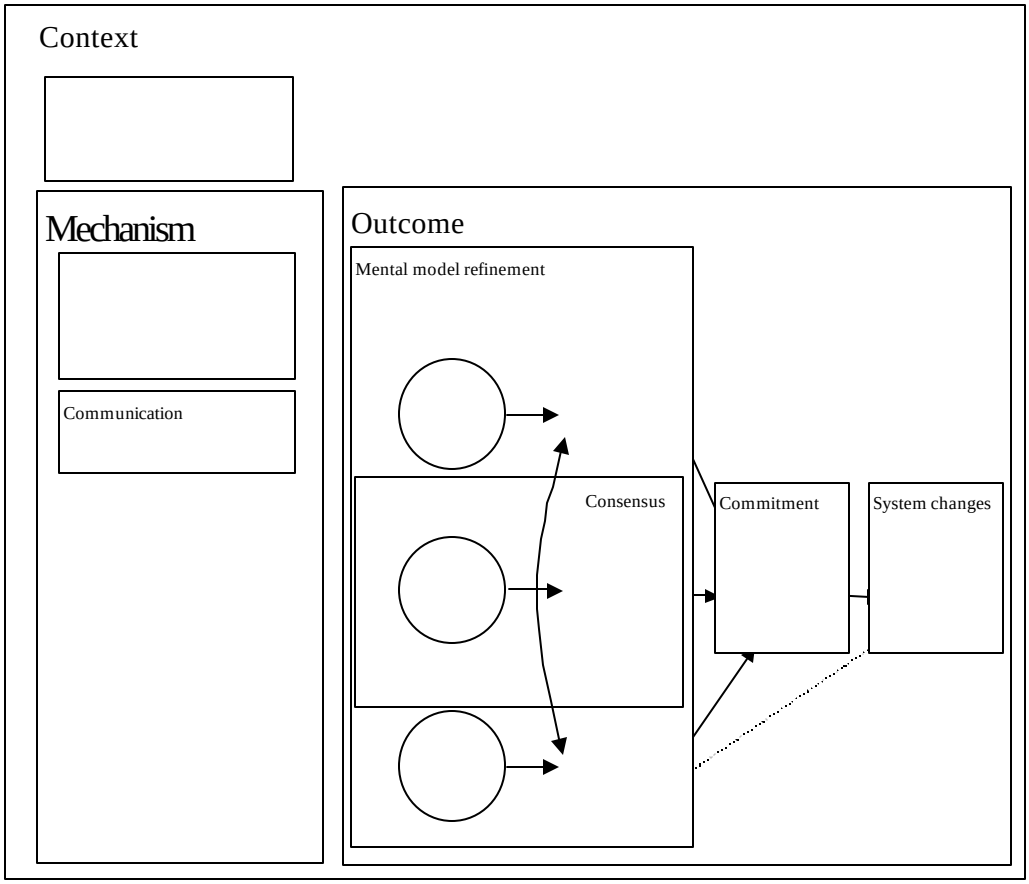

Figure 2. central variables in the conceptual model and their relation to context, mechanism and outcome elements (context, mechanism and outcome elements depicted in *italics*)

The conceptual framework includes the following context, mechanism and outcome variables. If group model building is seen through the lens of persuasion theories, problem and organization elements are important in so far as they influence the motivation to process information.

Modeling and facilitation were considered the main mechanism elements operational in group model building. Following theories on persuasion, modeling and facilitation can be said to support the ability to process information. The other important mechanism element is communication, which boils down to the exchange of arguments. Two aspects of arguments are important in this study: argument quality and persuasive content. Both can be expected to influence the direction of evaluation change.

Of the outcome variables described in the group model building literature (see table 1), positive reaction, system improvement, further use of the method and efficiency of the method cannot be related to the Ajzen model. The remaining outcome variables can be related to the concepts in the Ajzen model. Implementation of system changes is related to behavioral changes. Commitment is similar to intention. Mental models relate to all of the three evaluations and corresponding beliefs in Ajzen's model: goals models can be equated with attitudes and outcome beliefs, means models are captured by perceived behavioral control and control beliefs. Subjective norms and normative beliefs

are on one hand an element of mental models and on the other hand represent consensus. Communication, which was listed as an outcome variable, changes to a mechanism variable. Shared language is one aspect of the ability to process information. System improvement is not captured in the Ajzen model which focuses on the individual level, but must be the results of individual behavior to implement a decision. These considerations allow us to summarize the context – mechanism – outcome relations as depicted below.

Context		*Mechanism*		*Outcome*
Stakeholders in a highly complex problem who are motivated to engage in a decision making process	+	A method that increases ability to process information and identifies arguments that are either positive or negative	=	Change in beliefs and evaluations, intentions and behavior of participants

Table 2. Basic context, mechanism and outcome elements

In the following, we first address the measurement of central concepts in the framework. Next, the results with regard to five group model building cases are described.

Measurement and analysis

With regard to measurement, we will first describe the choice of research design for the present study. Next we address the operationalization of variables. With regard to the design, research on related methods (Eden, 1992 and Zigurs, 1993) leads us to the following conclusions:

- In evaluating a completed group model building intervention, a field study involving a client group working on a real problem needs to be involved. Although other groups (for example students) in a laboratory setting might prove useful for testing specific elements of the method, the complete process can only be tested in conjunction with a real and messy problem.
- In order to assess real change instead of (potentially biased) reported change, measurement at at least two points in time is needed.
- Randomization in a field test of GDSS has proven to be very difficult. Convening a control group is complicated by the impossibility of finding a matching group with respect to all important variables, e.g. problem complexity, problem urgency and stakeholder relations.
- Assessment needs to include a qualitative element to allow participants to phrase outcomes in their own language.
- Assessment also needs to go beyond participants as information sources, since their reports might be biased for a number of reasons.

Weighing the considerations above, the one group pretest posttest design (Cook and Campbell, 1979: 99) seems to be the best answer to the practical and methodological demands on evaluating group model building. In order to be able to identify differences between specific projects, multiple interventions will be evaluated. Instead of trying to convene a control group, other bases for comparisons will be used, i.e. outcomes of unsupported groups as reported in the literature and participants' subjective comparisons of supported and unsupported processes. This design can be illustrated as follows.

O_1	X	O_2

Figure 3. research design

The design consists of pretest observations of group (O1) which subsequently receives a treatment (X), after which posttest observations (O2) are made. In this study the group consists of several subgroups, each representing a single group model building intervention.

The following table shows the operationalization of context, mechanism and outcome variables. The complete research model includes a number of additional variables: ability to implement conclusions, age and years with organization (context), participant characteristics, consultant, duration, techniques employed in the intervention, model characteristics, evaluation of intervention elements (mechanism), conclusions/ dissemination and system changes (outcome).

Variable	*Data gathering method*	*Variable construction*
Context		
Client organization	Interview gatekeeper	Organisation sort, sector and size
Problem complexity	Content analysis	Qualitative: analytical and social complexity (cf. Hickson et al., 1986)
Motivation to process information	Questionnaire	Scale of two items on importance to organisation Two separate items on importance to individual
Mechanism		
Persuasive content	Content analysis Interview participant	Coding procedure Qualitative check by participants
Ability to process information	Questionnaire	Scale of six items (cf. Rouwette et al. 1997) Two separate items on dominance and time pressure Two items on overall success and efficiency
Argument quality	Questionnaire Interview participant	Scale of nine items (cf. Janis and Mann, 1977) One separate item on costs Qualitative
Outcome		
Options	By researcher/ Questionnaire	Two to four items identified by problem analysis/ Two to four items in open question pretest
Attitude towards behavior	Questionnaire	Scale of two items (cf. Madden et al., 1992)
Subjective norm	Questionnaire	One item (cf. Ajzen and Fishbein, 1980)
Perceived behavioral control	Questionnaire	Scale of two items (cf. Madden et al., 1992)
Beliefs	Questionnaire Interview participant	Scale of three to seven items Self-generated/ researcher Normative belief: open question
Intention	Questionnaire	Scale of two items (cf. Madden et al., 1992)
Behavior	Interview gatekeeper	Qualitative

Table 3. Data sources and construction of variables ("/" indicates alternative options with regard to data sources or variable construction; scales refer to final scales)

Operationalization of variables will not be described in detail in this article. The interested reader is referred to Rouwette (2003) for a detailed description of the items included in the separate scales and qualitative assessment procedures. In the following section on results, the formulation of context and mechanism variables is described in brief. With regard to the outcome variables, the following scales were used in pretest and posttest. Beliefs were measured using two scales: evaluation of the attribute (from 1: very unimportant, to 5: very important) and belief strength (or the relation between behavior and attribute, from –5: strong negative effect, to 5: strong positive effect). Please recall that attributes are the outcomes, referents and threats or opportunities related to a behavioral option. The product of belief strength and evaluation, summed over all beliefs will be used as a belief-based measure of evaluations. Since each belief reflects a separate aspect of cognitions on behavior, the scale of belief-based measures is not expected to refer to a single concept and will therefore not be tested for reliability.

Attitude towards behavior is generally measured using a semantic differential of several items (Ajzen and Fishbein, 1980: 55; Madden et al., 1992: 6). In order to limit the size of the questionnaire as much as possible, in this study attitude is measured with two items. The items are anchored by very

beneficial – very harmful and very good – very bad. The alpha reliability coefficient (or correlation between both items) for the pretest is .78 (n=76), for the posttest .93 (n=76), which is satisfactory.

Subjective norm was measured by asking subjects to respond to a single item, suggested by Ajzen and Fishbein (1980: 57): 'Most people who are important to me, think that I should implement option 1 in [time period of concern]'. This item could be scored from strongly agree to strongly disagree.

For perceived behavioral control, two items of Madden et al. (1992: 6) scale of four items were used: 'Implementing option 1 in [time period of concern] is very easy – very difficult' and 'The number of events that could keep me from implementing option 1 in [time period of concern] is very large – very small'. The alpha reliability coefficient for the pretest is .20 (n=86), for the posttest .60 (n=80). It is difficult to find an explanation for the low reliability in the pretest. The fact that the first item is phrased in a negative sense might lead some respondents to choose an answer opposite from their intended choice. However, this does not explain the increase in reliability from pretest to posttest. Although the coefficient in the pretest is low, scales will be used unchanged.

Madden et al. (1992: 6) measure behavioral intentions with three items. Again, in order to limit the size of the questionnaire as much as possible, in this study two of their items were employed: 'I intend to implement option 1 in [time period of concern] and 'I will make an effort to implement option 1 in [time period of concern]'. These items could again be answered on a scale from strongly agree to strongly disagree. The alpha reliability coefficient for the pretest is .94 (n=70), for the posttest .93 (n=67), which is satisfactory.

Behavioral options are either identified by the respondent or the researcher. The interviews provide an additional check on the interpretation of options mentioned in the questionnaire and in addition are assessed in a free format, i.e. participants are asked if any changes in working behavior occurred. These changes are compared to changes observed by the project gatekeeper and analysis of documents.

The variables above were assessed in five group model building cases and data on 34 participants were obtained. Participants filled out a pretest and posttest on two to four behavioral options, leading to about 70 measures on cognitions, evaluations and intentions which can be compared between pretest and posttest. Behavior was assessed qualitatively after the group model building sessions. Ability to process information and arguments quality were assessed in the posttest. Many separate relationships are to be considered in testing this conceptual model. Ideally path analysis would be used to estimate the strength of each relationship. However, the low number of measurements and the fact that we are interested in establishing relationships between variables at multiple levels, prevent this. Instead variables are related to one another in a stepwise procedure. The main focus of this study is the influence of treatment (positive versus negative arguments) on outcome variables. In order to test this relationship, outcome variables will be regressed on treatment, other mechanism variables, and context variables. Since the Ajzen model (1991) assumes that causation flows from beliefs to evaluations, to

intentions and finally to actions, this order is followed here as well. The next section discusses the impact of mechanism variables on outcomes.

Results with regard to five group model building cases

The conceptual model described above was used to evaluate results of five group model building cases. Below we focus on the main elements of the conceptual framework: motivation to process information (context), ability to process information and argument quality (mechanism) and the variables in the Ajzen model (outcome).

Context: motivation to process information

Motivation to process information is measured with two items on problem importance. Problem importance scores from 3.90 to 5.00 (on a scale from 1: very unimportant to 5: very important). Problem importance is high and does not show large differences between cases. The degree to which participants find the problem important to their organisation was taken as a measure of motivation to process information. Motivation to process information is high (mean score=4.40, sd=.52). Motivation is significantly higher than neutral (t=15.492, significance=.00), which means that the expectation that participants are motivated to process information is confirmed.

Mechanism: ability to process information

For the quantitative measurement of ability to process information, a scale was developed consisting of six Likert items measured from 1: strongly disagree to 5: strongly agree. The overall score on this scale is 3.85 (n=34, min=2.83, max=5.00, sd=.50) This score is significantly higher than neutral (t=10.006, one-sided significance=.000). The following table shows the results for the separate aspects of ability to process information.

Aspect	n	min	max	mean	sd
open communication	34	2.00	5.00	4.06	.69
clear and understandable communication	33	2.00	5.00	3.82	.73
everybody had a chance to voice their opinion	33	3.00	5.00	4.03	.53
ample opportunity to raise issues about which opinions diverged	33	2.00	5.00	3.64	.86
a focussed approach	33	2.00	5.00	3.70	.85
attention to each others' ideas	33	2.00	5.00	3.85	.62

Table 4. Participants' opinions on aspects of ability to process information

The mean score of each of the process aspects is above neutral. Two additional questions deal with overall success and efficiency of group model building. On average, participants feel the modelling project was successful (mean score 3.69, n=32, min=2.00, max=5.00, sd=.69). Efficiency scores are

satisfactory as well (mean score 3.76, n=29, min=2.00, max=5.00, sd=.83). Again this means that our expectation is confirmed: participants are able to process information.

Mechanism: argument quality

Argument quality is measured using a scale of nine Likert items, which could be scored from 1 (strongly disagree) to 5 (strongly agree). An example is 'In the meetings all relevant risks were discussed'. The item on costs does not correlate to the total scale. The item on costs scores below neutral (mean=2.61, n=31, min=1.00, max=4.00, sd=1.02). The overall score on this scale is 3.24 (n=33, min=2.00, max=4.22, sd=.51) This score is significantly higher than neutral (t=2.662, one-sided significance .01). The following table shows the results for the separate dimensions of outcome quality.

Dimension	n	min	max	mean	sd
all relevant options	32	2.00	5.00	3.44	1.05
all relevant goals	32	2.00	5.00	3.50	.88
all relevant values	31	2.00	5.00	3.55	.85
all relevant risks	33	1.00	5.00	2.76	1.00
all relevant information for weighing options	31	2.00	4.00	3.06	.81
all relevant information is integrated	30	2.00	5.00	3.60	.81
all positive and negative consequences	27	2.00	4.00	3.26	.66
all relevant conditions	31	1.00	4.00	3.16	.86
all relevant contingencies	27	1.00	4.00	2.85	.82

Table 5. Participants' opinions on dimensions of argument quality

As we can see from the table, participants in general agree that all goals, values and consequences have been discussed, and that all information is integrated. They do not feel that all risks and contingencies have been dealt with. Other elements (options, information for weighing options, conditions) score around neutral. Only four out of 86 actions do not correspond to a model variable or recommendation. It seems that most of the actions that participants (in the posttest) list as relevant to the problem are addressed in the sessions, but the question whether all relevant actions are addressed scores around neutral (3.44 in the table above). In the interviews several respondents state that the most relevant actions have indeed been identified, but that a comprehensive treatment of all possible actions would be impossible. In general the questionnaire data indicate a positive evaluation of arguments exchanged in the sessions, confirming expectations.

Outcome: Ajzen variables

In order to assess the impact on the Ajzen variables, a multilevel regression analysis using MlWin was performed. Outcomes were regressed on context variables, mechanism variables and related outcomes. The analysis is best explained with regard to a concrete example. For analysing the relation of context and mechanism variables to changes in attitudes, the following steps will be taken. First posttest attitude is regressed on all independent factors:

- correlated error on the level of the individual respondent;
- pretest attitude score;
- treatment (positive versus negative arguments);
- case effects;
- related outcome variables, with regard to attitudes these are behavioural beliefs, subjective norm and perceived behavioural control;
- context variables: ability to implement conclusions and motivation;
- mechanism variables other than treatment: ability to process information and argument quality;
- interaction of motivation, ability to process information and argument quality.

The last term is added to the regression equation because the theories on persuasion propose that people will consider information to the extent that they are able and motivated to do so.

The outcomes of the separate regression analyses will not be reported in detail. The interested reader is again referred to Rouwette (2003) for a full description of outcomes. Basically what is expected, is that positive information changes outcomes in a positive direction, while negative information changes outcomes in a negative direction. The null hypothesis is therefore that no change will occur, H1 is that outcomes will change in the direction of conclusions of the sessions. The impact of treatment (positive versus negative information) is tested controlling for the variables described above. The table below lists the expectations with regard to outcome variables and related results.

Outcomes		
Group model building leads to…		
Beliefs		
1.	Change in behavioural beliefs:	rejected
2.	Change in normative beliefs:	rejected
3.	Change in control beliefs:	not rejected
Evaluations		
4.	Change in attitude towards behaviour:	not rejected, direct effect
5.	Change in subjective norm: through normative beliefs	not rejected, direct effect and indirect effect
6.	Change in perceived behavioural control:	rejected
Intention and behaviour		
7.	Change in intention: attitude and subjective norm	not rejected, indirect effect through changes in
8.	Change in behaviour:	not rejected, under the conditions that 1. the model and behavioural options were at the same level of generality and 2. support for implementation was adequate

Table 6. Results with regard to outcome variables

Conclusions

This aim of this study was to develop a conceptual model relating the main outcomes, mechanism and context variables in group model building interventions. Theories from social psychology, on persuasion and the impact of attitudes on behavior, were used to this end. The resulting conceptual model was then used to evaluate five group model building cases. The results are encouraging: the conditions for mental model change proposed by the model are shown to be present. Participants indicate that they are motivated and able to process information exchanged in the sessions, and that information contained persuasive arguments. These arguments influence participants' cognitions and evaluations, leading to changes in intentions and behavior. Two results with regard to outcomes are surprising: the lack of impact on beliefs and perceived behavioral control. Results of similar studies in an organizational context point to possible improvements in the measurement method with regard to the first issue. However, the lack of impact on perceived behavioral control in organizational settings is also found in other studies, which means that the conceptual model might be refined with regard to this point (Rouwette, 2001). On the basis of the conceptual model and empirical results, a number of suggestions for improvements and areas for future research can be formulated.

Four areas for improvements in future modeling projects stand out:

1. ensure that the problem is important to participants;
2. relate modeling conclusions to participants' insights;
3. support behavioral change by means other than insights alone;
4. tailor group model building to specific problem and organizational contexts.

Avenues for future research include the following. The first goal for future studies might be to find commonalities between group model building approaches. Which elements are necessary to produce insight or consensus? With regard to modeling, the impact of facilitation can for example be assessed by comparing a modeling intervention supervised by a chairman (who participates actively in the discussions) to an intervention supervised by a facilitator (who remains neutral with regard to content). In this way it might be possible to disentangle the intervention from organizational surroundings, and identify more specific context – mechanism – outcome configurations.

A second aim that seems promising is to research the impact on beliefs constellations in more detail. Triangulation of methodologies can provide further insights into the influence of modeling on mental models, including evaluations. This can be done by researching the impact on cognitive maps in more restricted interventions (cf. Vennix, 1990). Alternatively, subjective interpretations can be studied by using paired comparisons (Thurstone, 1927) as is done in a modeling context by Frost-Kumpf et al. (2001). The approach advocated by Scheper (1991; Scheper and Faber, 1994) probes the meaning of constructs in a mental model and thereby provides additional information on mental model content.

There seems to be a place for more qualitative research into group model building using a grounded theory approach (Glaser and Strauss, 1967). Burt (2000) uses this approach to investigate the impact of scenario development on organizational change.

Third, future studies might incorporate group and organizational factors in addition to individual variables (also mentioned by Vennix, 1990). As shown by the study of Hickson et al. (1986), organizational variables have an influence on decision making processes of management teams. More insight into the effect of group and organizational variables allow us to better group model building interventions to contextual conditions.

Fourth, this study and the proposed directions for future studies mentioned above, involve a multitude of interrelated variables. It is likely that further development and testing of theories can benefit from formal modeling (cf. Hanneman, 1988). In addition to empirical research, formal modeling might shed further light on the complex interactions of variables in group decision making.

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