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Group Model Building: A Systematic Review of the Literature

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Abstract

System dynamics is a method for the model building of complex socioeconomic phenomena. One of the important sources of information is the mental model. Group model building was devised to extract mental models. Since this modeling method was proposed for the first time, it has been applied by many researchers, and a lot of research has been conducted about how to practice it, its instructions, and their evaluation. This paper seeks to make a comprehensive review of the literature associated with this method. To achieve this goal, a systematic review is made of 156 articles published until 2017 on group model building, the findings of those studies are summed up, and their orientation pattern is determined through identifying the focuses of attention of researchers. Finally, the existing research gaps are identified and explained, and some suggestions are given for future research in the field of group model building.
Keywords: System Dynamics Approach, Mental Model, Group Model Building, Systematic Review of the Literature.

Introduction

System dynamics is a method for understanding the behavior of complex systems over time. In this regard, model building of complex socioeconomic phenomena was introduced by Forrester at MIT in the 1950s (Château *et al.*, 2012). The approach is rooted in the control theory and nonlinear dynamics (Sterman, 2000) and is a combination of the systems theory, cybernetics, servomechanism, information theory, decision theory, and computer simulation (Chen *et al.*, 2014). At first, this approach aimed to help managers understand industrial processes but,

nowadays, it involves a range of social sciences, economic, cultural and natural disciplines, and areas from decision-making in business to medical and biological model building, as well as from environmental systems to public policy-making (Antunes *et al*., 2006). Since the approach was designed, different tools, software programs, processes, and information resources have provided for model building system dynamics (Ackermann and Vennix, 1996). One of the important sources of information is the stakeholder mental model that has been emphasized since the very beginning of this approach so as for Forrester to consider it important to involve customers in system dynamics model building (Forrester, 1961). Doyle and Ford (1997) state that "A mental model of a system dynamics is a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing or projected) whose structure is analogous to the perceived structure of that system"(Doyle and Ford, 1997).
In order to extract mental models, various methods such as using individual interviews (individual model building), participatory model building, and group model building have been created.
Group model building is a participatory method to extract knowledge from experts of the studied problem through official activities and facilitated discussions, which has applications from problem definition to simulation in system dynamics (Hernantes *et al*., 2013). In other words, in group model building sessions, experts provide their individual perspectives on the problem, its structure, the resulting dynamic model, as well as the results and solutions. These views are improved by knowledge sharing of people, discussions, and group analysis. In case of a consensus on the final model, the group reaches an effective solution to resolve the problem, and the commitment of people to execute their tasks is increased.

Group model building is a powerful tool for extracting and eliciting stakeholder mental models and combining them in a system dynamics model. On the other hand, the model building of system dynamics helps participants in group model building to define, clarify, and organize their ideas into a shared view (Château *et al*., 2012).

Winz and Gary (2007) state that stakeholders' participation in system dynamics is not a new phenomenon. However, involvement of stakeholders in all the steps has grown within the last 20 years with the aim of improving learning and supporting the implementation and use of the model in the form of group model building (Vennix *et al*., 1997).

Since its emergence, the group model building method has been rapidly expanding (Antunes *et al*., 2006; Olabisi, 2013) such that it is practically applied in many researches (Antunes *et al*., 2006; Elias, 2008a). Also, many studies have been conducted about the method, its modeling process, instructions, and evaluation (Groesser, 2006). This can be of benefit to sum up the findings and the major tenets of these separately done studies.

The first empirical study was conducted in 1988 by reviewing the corresponding pieces of research that had been done during the past 13 years (Scott, Cavana and Cameron, 2016). Then, Rouwette, Vennix, and Mullekom (1999) reviewed studies on the evaluation of group model building through a systematic and empirical research. They reviewed articles related to group model building and other techniques such as the reference group approach, strategic forums, participatory policy model building, model building as learning, soft systems methodology, and cognitive maps. These items were presented in the System Dynamics Conference from 1981 through 1997, the Journal of System dynamics review from 1985 through 1997, and other publications. In their study, a total of 75 papers involving 81 model building cases were examined in five categories including background characteristics, client organization, problem to be modeled, type of intervention, and evaluation of modeling impacts (Rouwette, Vennix, and Mullekom, 1999). They also extended their study in 2002 and reviewed the group model building literature by examining 107 articles during 1987-2000. Based on their review, only three articles

were published before 1970, four articles during the 1970s, 16 during the 1980s, and 62 papers were published in the 1990s. In their papers, they reviewed aspects such as the source of data (e.g. modeling team, participants), the type of data collected, how the data were collected (e.g. interviews, questionnaires, (in)formal observations), when data were collected (i.e. pre, post, during intervention), and how they were found (Rouwette, Vennix, and Mullekom, 2002).

By reviewing the genealogy of group model building, Zagonel (2002) found that it has stemmed from two schools of thought. The first school is the system dynamics approach which is rooted in the thread of policies. The second school or mode of thinking is the thread of decisions which forms the decision conferencing framework. By purposeful sampling of the literature, they identified five categories including classic system dynamics, direct system dynamics modeling with clients, decision conferencing, system dynamics modeling used in decision conferences, and group model building. It is suggested that, with those two different routes in the genealogy of group model building, there are two approaches to consider. In the first approach, model building is as a representation of reality or the micro world which is based on the thread of decisions. In the second approach, model building is as a tool for discussion or negotiation in a social order or on a boundary object that is based on the thread of policies. Then, Zagonel (2004) did some review of the group model building literature to examine the tension between model as a micro world (representing reality) and model as a boundary object (a tool for discussion in a social order).

Also, Scott, Cavana and Cameron (2016) have sought to extract published quantitative evidence on group model building by reviewing 100 articles, taking into account three questions including 'what does it achieve?', 'when should it be applied?', and 'how should it be applied or improved?'. They generally argue that, as the evidence indicates, group model building is improving and helps to improve communication and consensus among the participants in group decision-making processes. They also suggest that future research related to group model building should represent three shifts: from single cases to multiple cases, from controlled settings to applied settings, and toward augmenting surveys with more objective measures (Scott, Cavana and Cameron, 2016).

Considering the necessity of reviewing previous studies on group model building, both in aspects that have not been reviewed yet and in greater time periods, this paper aims at a comprehensive review of the literature related to group model building. In this study, through the systematic review of 156 articles published until 2017 on group model building, we have summed up the pieces of research and determined their orientation patterns through identifying the focuses of attention of the researchers.

In the following, the research method used in this paper is explained. Then, based on the analysis of the studies on group model building, we will provide findings of the literature review.

Methodology

In this paper, using a library method and through a systematic review of the literature, we review the studies on group model building.

Compared with traditional or narrative literature review methods, the method of Systematic Review of the Literature deals with literature review in one specialized field with a more precise and well-defined approach (Ryan, 2010). In this method, based on a specific issue or question, the conducted studies are reviewed and then, beside assessing and evaluating their relevance, evidence is extracted and summarized in relation to that issue or question. (Khan *et al*., 2003; Ryan, 2010). This approach causes a decline of biases and leads to acquisition of accurate information of the phenomenon in consistence with the literature, identification of factors

affecting the phenomenon, and creation of a model of the phenomenon using the literature (Zurynski, 2014)

In the present study, the studied subject is group model building that is mentioned in the full texts of all the articles in the first two rounds of the research conference on system dynamics in 1976 and 1981 as well as 33 rounds of system dynamics conference from 1983 to 2015. Also, articles of scientific databases of Elsevier, Wiley Online Library published until 2017 have mentioned the terms "Group Model Building" and "GMB" in their titles, abstracts or keywords. It should be noted that this article only focuses on group model building and does not involve studies related to other similar methods such as reference group approach, strategic forum, participatory policy model building, model building as learning, soft systems methodology, and map cognitive. It also focuses on journals and conference papers while other documents are not investigated. The survey was conducted until 2017, and only English language documents were studied. Accordingly, a number of 195 primary articles were identified some of which, in more in-depth studies, were eliminated due to lack of complete focus on the subject. Ultimately, a total of 156 fully related papers were analyzed.

According to Scott, Cavana and Cameron (2016), article search results may be biased due to the following three reasons:

1) It is possible that studies on group model building exist in other sources that have not been studied.

2) It is possible that some articles have been removed due to human error.

3) It is possible that all the research and studies in the field of group model building are not published for various reasons such as doubt, commercial sensitivity, and avoidance of releasing unsuccessful cases.

The analysis of previous research

After collecting the relevant articles, each article was reviewed and summarized within 12 areas. The following diagram shows the number of articles whose main focus is on group model building. As it can be seen, there exist a total of 156 articles. The first article dates back to 1988, and there are about 32 papers until 2000. The first article published in a scholarly journal belongs to 1996.

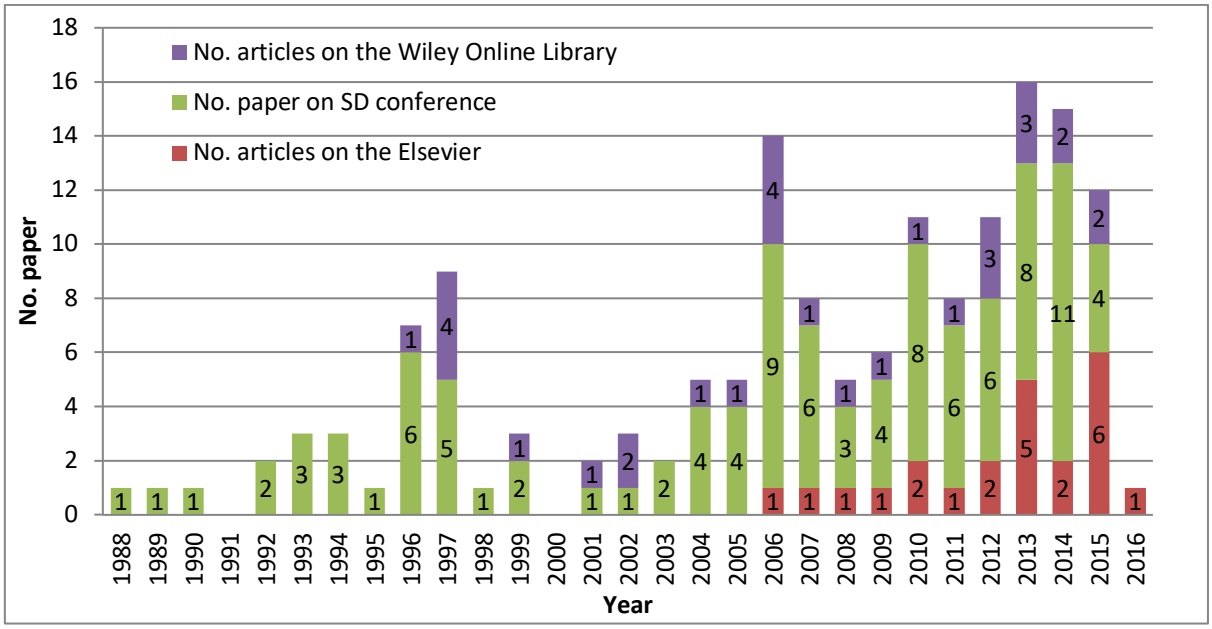

Figure 1. Diagram of the number of articles related to group model building

In the following, the results of a full investigation of 156 articles related to group model building are provided within the context of the itemized areas: Definitions of group model building, The type of suitable problems, Outputs of group model building, Group model building processes, Different roles in group model building, Advantages and disadvantages of group model building , Findings in terms of the research methodology, Findings in terms of the modeling type, Findings in terms of the application or modeling area, Findings in terms of the number of participants in group sessions, Findings in terms of the geographical regions, Findings in terms of the relevant journals.

Definitions of group model building

In this section, we provide definitions of group model building according to various specialists. Ackermann (1995) introduces participative business modeling (PBM) as "a synergistic blend of system dynamics and group knowledge elicitation techniques". Vennix (1996) and Vugteveen *et al*. (2015) suggest that group model building (GMB) is defined as "a method involving facilitators (usually a modeling team) and a group of stakeholders that co-build a model to solve problems within a complex system". Some researchers have defined group model building from the perspective of participatory model building. For example, Renger, Kolfschoten and de Vreede (2008) consider participatory model building as a term to describe model building approaches that deal with creation of a model with the participation of end users, stakeholders, experts and analysts. Anderson *et al*. (2007) argue that Participatory Model Building (PMB) refers to resource management forms rooted in integration of stakeholder input to conduct the process and results. In participatory model, stakeholders have a large control on model building, intervention, the proposed policy solutions, and testing and applying them (Butler and Adamowski, 2015). In this type of model building, the level of participation is dependent on different selected methods. Group model building (GMB) is a subset of Participatory Model Building (PMB) where stakeholders are engaged in developing, testing and applying models as a group. Stakeholder, in a broad sense, means anyone who can affect or be affected by a system under study (Garrod *et al*., 2013).

Elias (2008b) views group model building as "a process in which team members exchange the perceptions of a problem and explore such questions as What exactly is the problem we face? How did the problematic situation originate? What might be its underlying causes? How can the problem be effectively tackled?".

Group model building has repeatedly been used to extract knowledge from a group of experts familiar with the subject matter (Vennix *et al*., 1990; Vennix, 1999). Rich individualistic knowledge is used in group model building (Goh *et al*., 2012). In other words, in group model building, the individual-level dimensions including the reaction, insight into the problem and other assumptions, commitment and behavior, and group-level dimensions including communication, shared language and consensus are taken into consideration (Brömmelstroet, 2013).

Hovelynck *et al*. (2010) suggest that group model building is one of the approaches to the integration of knowledge and is based on a participatory method that, in turn, depends on a system dynamics approach. It is rooted in simulation modeling by face-to-face sessions with clients (Hovelynck *et al*., 2014)

Finally, it can be said that group model building is a specific case of problem structuring method (PSM) and, as Anderson *et al*. (2007) have described it, "a bundle of techniques used to construct system dynamics models working directly with client groups on key strategic decisions". The method is specifically designed for the development of SD models (Esensoy and Carter, 2015).

Type of problems

According to the literature, group model building is more concerned with ill-defined strategic issues, messy problems, wicked problems and unstructured problems (Vennix *et al*., 1988; Vennix, 1999; Carter *et al*., 2013; Halbe *et al*., 2015; Vugteveen *et al*., 2015). Messy and wicked problems are those with features such as high complexity and multi-causality, difficulty of defining, analyzing and solving (Rettel and Webber, 1973; Groesser, 2006; Smagt, 2006; Wagner *et al*., 2010; Butler and Adamowski, 2015). Problem complexity consists of technical complexity (e.g. high number of variables and nonlinear relationships between them) and organizational complexity (e.g. existence of individuals with opposed opinions and preferences). Its difficulty is due to imperfect information (Qian and Gonzalez, 2006). The other factors in this case are unknown feedback loops, qualitative data, heterogeneity of stakeholders which is also due to the presence of various stakeholders with opposed views and divergent opinions in defining the problem and solutions, different interests and lack of trust, involvement of too many institutions, overlapping jurisdictions and spheres of influence, multiple users with different records, expressions and knowledge, as well as different ways to intervene in problem (Roos, 1997; Groesser, 2006; Pahl-Wostl, 2007; Château *et al*., 2012; Hernantes *et al*., 2013; Pagani and Otto, 2013; Halbe *et al*., 2015; Vugteveen *et al*., 2015, Flynn, 2015). Apart from the complexity of these issues, there are adverse effects of managers' measures that lead to delays (Sterman, 2000; Goh *et al*., 2010 a, b), causing border challenges and distance of causes from effects either in time dimension or in place dimension (Pahl-Wostl, 2007). In other words, dynamic, nonlinear messy problems with multiple and inconsistent boundaries are not limited to political or geographical areas of the problem; but rather, they include different laws and regulations, awareness, language and culture (Ford and Sterman, 1997; Hernantes *et al*., 2013). These problems are usually transdisciplinary (Ford and Sterman, 1997) and require the use of various sciences, combining transdisciplinary sciences and intersectoral actions (Beall and Ford, 2007). In this regard, group model building involves different stakeholders, including scientific experts in different fields, policy-making experts, program managers, front-line workers, communities, and end users (clients) to draw the model (Munar *et al*., 2015).

Antunes *et al*. (2006) argue that, when our problems are in a post-normal science paradigm, in other words, when the data are highly uncertain, when the values and quantities are controversial and high risks and urgent decisions are needed, and when the studied issues have a dynamic complexity and require an integrated perspective (Chen *et al*., 2014), ordinary scientific approaches do not work; in such cases, policy debates need to be held with the participation and involvement of all walks of life (Funtowicz and Ravetz, 1994). So, in such issues, group model building is needed (Antunes *et al*., 2006). This is because an important feature of this method is that the fact is separated from values, the main focus is on descriptive and diagnostic perspectives (Elias, 2008 b), and the goal is to create consensus (Vennix, 1996).

McCardle-Keurentjes, Rouwette and Vennix (2008) state that group model building is formidable in discovering hidden profiles in strategic decision-making processes. Hidden profile exist when 1) the information related to a decision is distributed among the members of the decision-making group and each member has a unique part of this information, and 2) it is required to integrate these pieces of information so that the alternative of a superior decision can be chosen (McCardle-Keurentjes, Rouwette and Vennix, 2008).

In response to the question 'What time should group model building be used?' Scott, Cavana and Cameron (2016) express that the method is useful in various fields such as policy-making, developing and implementing strategies, and within-organizational and inter-organizational agreements. They argue that, although group model building does not work in certain different fields, a great bulk of literature has remained silent on this point. However, the literature indicates that group model building is effective in complex pluralist situations (Scott, Cavana and Cameron, 2016). When there is a need for recognizing the complexities of a system, integration of stakeholders' knowledge and desirability of communication and learning among stakeholders may give potentials to the group model building (Vugteveen *et al*., 2015)

Finally, it can be said that, in this model building method, development of a system dynamics model takes place through knowledge extraction from one or more experts. The extraction of knowledge from experts is because this knowledge about the system does not exist in the literature (Vennix *et al*., 1988).

Model building outputs

One of the important elements in group model building is to determine the modeling output (Andersen and Richardson, 1994). Regarding the output of group model building sessions, we have created three categories in this paper based on the review of different papers. The first category includes:

1) System dynamics simulation models/ stock and flow diagrams (SFD)/ quantitative models (Andersen and Richardson, 1994; 1997; Ackermann, 1995; Zagonel, 2004; Groesser, 2006).

2) Conceptual models/ casual loop diagrams (CLD)/ qualitative models (Ackermann, 1995; Checkland and Scholes, 1999; Rouwette *et al*., 2004; Zagonel, 2004; Groesser, 2006). In group model building, it is mostly qualitative (conceptual) model building that takes place (Vennix, 1994; Rouwette, Vennix, and Mullekom, 1999).

3) Scripts and guidelines for group model building and management of sessions (Andersen and Richardson, 1997; 2010; Luna-Reyes *et al*., 2005; 2006; Anderson *et al*., 2007; 2009a; 2009b; 2013; Calhoun *et al*., 2010; Ackermann *et al*., 2010; 2011; Homand *et al*., 2011; 2012; Homand and Rouwette, 2013; 2014; 2015).

Of the determinants of the model building approach and output, one can refer to the availability of quantitative data, the purpose of the study, and the research approach (Coyle, 1999). If

quantitative data are not available, or the purpose of the study is to extract variables and models from different divergent perspectives, or the research is exploratory, a qualitative approach is more appropriate (Goh *et al*., 2012). In other words, in subjects where data are limited and the majority are qualitative, engaging stakeholders directly is appropriate, and both deductive and inductive logic can be used to detect mental models qualitatively (Richards *et al*., 2013; Pagani and Otto, 2013).

The second category regarding the output of group model building sessions includes:

1) Model as a micro world (Zagonel, 2002; 2004) or as a representative object (Bayer *et al*., 2010) or a virtual world (Sterman, 2000) which is a presentation of the reality of a foreign policy-making environment. In other words, micro world models are used as the actual representation of a decision-making position for testing the results of policy choices (Zagonel, 2002; 2004; Eden and Ackermann, 2006; Martinez-Moyano *et al*., 2007; Bayer *et al*., 2010; Timothy *et al*., 2011; Esensoy and Carter, 2015; Scott, Cavana and Cameron, 2016).

2) Model as a boundary object, a transitional object or a socially constructed artifact which is a tool for discussion, confidence building, shared understanding, and agreement (Zagonel, 2002; 2004; Eden and Ackermann, 2006; Martinez-Moyano *et al*., 2007; Bayer *et al*., 2010; Timothy *et al*., 2011; Black and Anderson, 2012; Black, 2013; Esensoy and Carter, 2015; Com, 2015; Scott, Cavana and Cameron, 2014; 2016).

It is important to note that, in some cases, the distinction between the two (namely micro world and boundary object) is not clear (Zagonel, 2002), and, in some other cases, the output is a combination of the two (Scott, Cavana and Cameron, 2014; 2016). In addition, the model, whether as a boundary object or as a micro world, can be an epistemic or technical object. Epistemic objects help to create new knowledge and are fluid while technical objects are static and serve as a means of making the existing knowledge available (Bayer *et al*., 2010).

Finally, it should be said that there is a difference between a model building process and its output. In a group model building process, attempt is always made to discover mental models, structures and data and to clarify them, while the output of model building may be the learning that results from the model building process or a problem-describing model (Laurenti *et al*., 2014; Vugteveen *et al*., 2015). In other words, given the framework of Location-Form Continuum proposed by Kim (2007), group model building is located between the output continuum (the same model) and the process (Kim, 2007). It can also be said that engaging users is important for knowledge acquisition and diffusion (Vennix *et al*., 1988).

The third category regarding the output of group model building sessions based on the objective includes:

1) Solution to the problem (practical approach): It is mainly group model building by involving managers to solve a specific problem (Luna-Reyes, 2004; Zagonel, 2004). For example, Siemer and Otto (2005) used group model building to make decisions in the field of wildlife management (Siemer and Otto, 2005).

2) New theory (academic approach): In some studies, group model building is used for theory building (Zagonel, 2004; Luna-Reyes *et al*., 2006; 2013; Kuhlberg, 2015), such as dynamic social theory about the complexity of inter-organizational information integration (Luna-Reyes, 2004). In their article, Luna-Reyes *et al*. (2005) used group model building for theorizing in IT innovation (Luna-Reyes *et al*., 2005). Luna-Reyes *et al*. (2013) developed a theory of the impacts of governance principles on the adoption of a large-scale inter-organizational system to increase supply chain transparency (I-Choose information system) (Luna-Reyes *et al*., 2013).

Model building process

So far, many experts have done a lot of research in the field of group model building. Designing a model building process is usually done through scripts. In this regard, Anderson and Richardson (1994, 1997) developed a series of small-group semi-structured processes on the basis of before-workshop scripts. These scripts contain tasks related to individuals, small groups, and whole groups that attend workshops. Also Ackermann *et al*. (2011) have provided a script map which is a framework for a combination of successive activities, products, and deliverables in a formal network to enable facilitators to plan and conduct group model building workshops. In this script, two methods of system dynamics and journey taking are combined. Different authors have also developed different procedures and approaches for participatory model building. As an example, Ackermann (2001) provides the Renga approach which involves individual, group, and general interviews.

A group model building process has three general phases (Anderson, Richardson and Vennix, 1997; Winz and Gary, 2007) in each of which different activities are carried out. Of course, these general phases and their corresponding steps may be not done depending on each case and according to circumstance; rather, they may be realized in other ways. Another important point is that the phases and steps are repeated and reciprocating (Groesser, 2006; Butler and Adamowski, 2015).

The phase before group model building workshops (i.e. planning phase):

In this phase, firstly, a model building team including a group of system dynamics researchers and a group of client representatives, who undertake the management of a group model building project in various roles, is formed. The roles players include facilitators, moderators, modellers, process coaches and gatekeepers (Esensoy and Carter, 2015). Then, the problem is defined or its overall subject is reviewed and agreed on by the client and the modeling team (Ackermann, 1995; Zagonel *et al*., 1997). Then, the modeling team starts its initial studies including the literature review and client documentation (Halbe and Adamowski, 2011). Since recognizing the problem participants and audience is a vital step (Richardson *et al*., 1989) and it is needed to engage them deeply (De Gooyert *et al*., 2013), context and content analysis and problem's stakeholder analysis based on the literature, brainstorming with or without the support of the snowball method and institutional analysis (Elias, Cavana and Jackson, 2004; Elias, 2006; Antunes *et al*., 2006; Groesser, 2006; Elias, 2008b; Cavana and Adams, 2010; Halbe and Adamowski, 2011; Inam *et al*., 2015), the use of various means of mass communication such as newspapers and websites for public notice, and request for participation of individuals and groups (Glicken, 2000) are taken into account. Also, based on such criteria as legitimacy, power, and urgency (Mitchell *et al*., 1997), existence of expelled individuals and communities (Pierce Colfer and Dudley, 2011; Butler and Adamowski, 2015), individuals' interest levels, influence of the process, the level of project support (Sarriegi *et al*., 2006; Reed *et al*., 2009; Ormazabal, Rich and Sarriegi, 2012), and use of different methods such as stakeholders analysis, card-sorting, strategic perspectives analysis, Q methodology, and constructivist method (Reed *et al*., 2009; Richardson and Anderson, 2010), stakeholders are prioritized and selected to be invited to participate in the group model building. So, selecting people is purposeful (Yuliani and Tasrif, 2006). In some cases, contributors are members of the intended community. So, this method is referred to as 'community-driven participatory modeling method (Yadama *et al*., 2010; Homand *et al*., 2010). Prior to holding a workshop, the arrangements for it should be made and its activities should be planned. They include goal setting, procurement, timing or developing a precise time table for the workshop day, determining a convenient location and required facilities (including whiteboard, white wall, video projector, computer equipped with modeling software, proper arrangement of seats and appliances), and

taking decisions about the use of work books (Anderson and Richardson, 1994; Tsuey-Ping *et al*., 1998; Luna-Reyes *et al*., 2005; Groesser, 2006; Hernantes *et al*., 2013; Butler and Adamowski, 2015).

In some cases, pre-workshop interviews with stakeholders to get their initial perspectives on structuring the problem (Berard, 2010) or even primary causal modeling as well as modeling the training may take place (Ford and Sterman, 1997; Butler and Adamowski, 2015).

Phase of modeling workshops (i.e. execution phase):

In group model building workshops, a facilitator who is usually a neutral person **(**Pieters, Franx and Akkermans, 2007; Vugteveen *et al*., 2015) guides a group of participants to make a model or a decision (Vennix, Thijssen and Rouwette, 1997, Papamichail *et al*., 2007; Franco and Montibeller, 2010). The workshop begins with a brief introduction of researchers and purposes of the study (Goh *et al*., 2012). Also, at first, the rules and procedures of modeling, such as conflict resolution and model implementation, should be explained (Vennix, 1999). Then, the workshop continues using the initial model or conceptual models to start a discussion followed by training of system dynamics modeling (Vennix, 1996; Groesser, 2006; Richardson, 2006; 2013).

Workshops usually evolve from individually-based activities into small groups and full groups (Anderson and Richardson, 1994; 1997). The purpose of the individual activities is mainly individual interviews or individual modeling. The purpose of small groups, namely small professionally heterogeneous groups with 2 to 3 members, is to work on details and run exact discussions on the problem and the model. Eventually, these individuals in small groups merge in full groups or plenary sessions where all the members are present for providing their achievements and debates on different perspectives, seeking to achieve convergence that leads to completed models (Vennix *et al*., 1990; Vennix, Thijssen and Rouwette, 1997; Ackermann *et al*., 2011; Hernantes *et al*., 2012; 2013). In many cases, large groups in workshops are broken down into small groups with specialized knowledge domains (Vennix *et al*., 1988; Akkermans and Bosker, 1994; Rich *et al*., 2009; Carter *et al*., 2013). Bartolomei and Miller (2001) and Olafsdottir *et al*., (2014) argue that 5-6 member teams are appropriate (Olafsdottir *et al*., 2014) and, if more members are required, it is better to perform modeling in the form of 3-4 member subgroups (Bartolomei and Miller, 2001).

In the workshops, attempts are made to integrate the tasks for running discussions and getting feedbacks about the causes, consequences and solutions (Halbe and Adamowski, 2011). Also, dialogues are held with various stakeholders to promote social learning and consensus (Pahl-Wostl *et al*., 2011).

In the second phase, depending on the modeling goal, the participants go through the steps of problem definition, creation of hexagons, making quantitative and qualitative diagrams (e.g. causal loop diagrams and stock and flow diagrams), formulation, simulation and testing, implementation of various policies on the model, and finally drawing conclusions (Antunes *et al*., 2006; Cavana and Clifford, 2006; Elias, 2008b). The important point often neglected is model validation in group model building, where tests should be conducted with regard to the data and logic, individual and group mental models, and interactions between them in a system dynamics model (Happach *et al*., 2012; Bachurina, 2013).

Usually, in early steps, qualitative approaches and divergent thinking are used to extract information, but, in final steps, the focus is on quantitative approaches and convergent thinking (Richardson *et al*., 1989; Château *et al*., 2012).

Practical implications for group model building sessions include the need for enough time and resources to hold modeling sessions until completion of the project because a suitable model

possibly cannot be built in a few days. Also, clients and participants should have motivation to spend sufficient time and attention in the sessions (Pagani and Otto, 2013).

The phase after the group model building workshops or the final phase:

After testing the model and selecting the proposed solutions, the results are presented to the client to implement them (Butler and Adamowski, 2015).

Finally, as Otto and Struben (2003) have stated, some researchers such as Vennix emphasize structured processes and precise approaches while some others such as Hines emphasize being heuristic.

Different roles in group model building

As noted, the modeling team undertakes the management of a group model building project by playing various roles (Haslett, Barton, Sarah, 1999). These roles include facilitating, moderating/recording, content coaching/modeling, process coaching, and gatekeeping (Luna-Reyes *et al*., 2005; Yahril *et al*., 2006; Anderson and Richardson, 2010; Esensoy and Carter, 2015). In other words, different roles are required to be played because group model building involves various tasks such as extracting information about the structure and behavior of problems, compiling information on the model, providing and explaining the model to the members, getting feedbacks, and modifying the model (Richardson *et al*., 1992). The role players are defined as follows:

A facilitator is someone who undertakes the task of knowledge extraction and facilitating the affairs in the group. Among his duties are continuous attention to the group process, the role of individuals in the group, and extracting knowledge and insights from the group. It is the most visible role working with the group.

A content coach/modeler does not focus on the whole process but mainly works on the model to be established clearly by the facilitator and the group. He helps both the facilitator and the group. This person thinks and draws ideas in the form of a model, reflects the information to the group, then reconstructs formulas and codifications, and expresses undeclared assumptions that need to be clarified. In general, the person is a catalyst of various aspects of the model structure and behavior.

The important point about both of the above roles is that the person concerned must be experienced in system dynamics modeling.

A process coach is a person who does not focus on the content but on individual and subgroup dynamics in the group. He is not a system dynamics modeler but mostly helps the facilitator.

A Recorder tries to write and draw important behavioral and expressive parts of the group. His writings, along with notes of the facilitator and the content coach, should cause reconstruction of group thinking. This person should have enough modeling knowledge as well as awareness of what things should be written.

A Gatekeeper is a person within or related to the clients' group who is responsible for the project with regard to the clients, usually starts the project, helps to define the problem and identify the right people, works with the modeling team to structure sessions, and participates as a member of the group. He is the supporters of both sides; within the organization, he talks about the modeling process and, within the modeling team, he talks about the client group and their problems. The gatekeeper is, indeed, someone rising from the organization with communicating tasks (Anderson and Richardson, 1994; Luna-Reyes *et al*., 2005).

An important point about these five roles is that they can be combined and allocated among different individuals from the consultant to the members of the modeling team and clients. For example, Richardson *et al*., (1992) and Ackermann, Vennix and Rouwette (1993) allocated these five roles to three persons. However, according to the results of their research, for large groups, it is better that each role be played by one person (Richardson *et al*., 1992).

Finally, it must be noted that, typically, three distinct sets have roles to play in group model building. The first set is the core modeling group or the modeling team which deals with the project management, collection and analysis of data, simulations, etc. The second set includes clients and problem stakeholders serving as institutions or departments that have a significant responsibility in the desired problems. Finally, the third set consists of experts that are people with good knowledge about the problem (Richardson *et al*., 1992; Anderson and Richardson, 1994).

Advantages and disadvantages of group model building

According to various articles that have directly (17 articles) or indirectly expressed the results and features of group model building, there are many advantages to this method. Involvement and participation of stakeholders in modeling has various benefits such as extracting the correct information, organizing deep discussions, making more qualified decisions (Winz and Gary, 2007), giving a greater understanding of the problem and the structure that creates it, providing a more relevant useful model with the integration of stakeholder perspectives (Quade, 1982; Meadows and Robinson; 1985; Ackermann and Vennix, 1996; Vennix, 1996; Rouwette and Vennix, 1996; Chen *et al*., 2014), improving the policy solutions and efficiency of responses and measures (Ackermann, 1992; Pahl-Wostl and Hare, 2004), creating a positive insight for cooperation, strengthening mutual understanding, providing equal opportunity for all the groups, making a consensus on the model and solutions, increasing the sense of ownership and commitment to the model implementation (Vennix *et al*., 1990; Lane, 1993; Vennix and Scheper, 1993; Vennix, 1994, 1999; Ackermann and Vennix, 1996; Vennix *et al*., 1996; Rouwette and Vennix, 1996; 2010; Ford and Sterman, 1997; Zagonel, 2002; Otto and Simon, 2005; Kljajic Borstnar *et al*., 2006; Antunes *et al*., 2006; Qian and Gonzalez, 2006; Visser, 2006; Martinez-Moyano *et al*.,2007; Rouwette and Hoppenbrouwers, 2008; McCardle-Keurentjes, Rouwette and Vennix, 2009; Château *et al*., 2012; Pagani and Otto, 2013; Vugteveen *et al*., 2015; Scott, Cavana and Cameron, 2016), creating more innovative and equitable solutions, individuals, and groups, bringing about organizational and social learning (Winz and Gary, 2007; Carhart and Yearworth, 2010; Mikulskiene and Pitrenaite, 2012), sharing experiences, making mental models of stakeholders, achieving a shared vision (De Geus, 1988; Lin, 1992; Morecroft, 1988; 1992; Senge, 1990; Ackermann, 1992; Gary and Charyk, 1996; Vennix *et al*., 1996; Vennix, Thijssen and Rouwette, 1997; Haslett, Barton, Sarah, 1999; Ruud and Bakken, 2003; Stave and Dwyer, 2005; Groesser, 2006; Yahril *et al*., 2006; Voinov and Bousquet, 2010), improving communication and discussion among members (Eskinasi, Rouwette and Vennix, 2009; Schlyter *et al*., 2012), increasing reliance on model and its results (Pahl-Wostl and Hare, 2004; Olafsdottir *et al*., 2014; Vugteveen *et al*., 2015; Flynn, 2015), reducing bound rationality (Zimmermann *et al*., 2015), seeking a system by extracting and integrating the different perspectives of stakeholders and identification of feedback mechanisms, studying multifactor and multilevel relationships among system elements through simulation of an experimental learning environment, reaching a shared language, understanding and consensus (Lin, 1993; Vennix, 1996; Elias, 2008b; Schmitt Olabisi, 2010; Alexiev, 2011; Carter *et al*., 2013), and identifying and evaluating possible policy options (Munar *et al*., 2015; Butler and Adamowski, 2015; Hernantes *et al*., 2013).

Group model building increases learning through two ways of clarifying the content related to a complex issue (i.e. reducing the technical complexity) and strengthening client commitment via a participatory approach (in relation to organizational complexity) (Roos, 1997).

In a research that Ackermann, Vennix and Rouwette (1993) conducted through direct questionnaires about knowledge, insight, knowledge sharing and commitment among participants before and after group model building, it was found that most participants would consider group model building successful in the strengthening of these four measures.

Vennix and Scheper (1993) evaluated the group model building method in four case studies. They suggest that, although various researchers have expressed important functions of models and group model building, no systematic review of this method has been much conducted yet. Via questionnaires, they investigated four aspects including 1) insights created in relation to the problem (learning), 2) facilitation of sharing mental models and communicating with the problem (communication), 3) creating shared understanding of the problem (shared understanding), and 4) strengthening of commitment (commitment). A Likert-type questionnaire was formulated for each of the four aspects consisting of 4 to 7 questions. In their study, it was found that all the participants in the group model building acknowledged its usefulness and importance, and most of them considered this method effective (Vennix and Scheper, 1993).

In his article, Vennix (1994) argues that group model building has been successful in integration of conflicting views, strengthening of consensus, and making a commitment. He states that, in this respect, there exist three effective factors including system thinking, improvement of the quality of communication, and the role of facilitator.

By reviewing the literature on group model building, Vennix, Ackermann and Rouwette (1996), Ackermann and Vennix (1997) and Rouwette *et al*., (2002) found that participants believe group model building leads to an improvement in the quality of communication, insight, consensus and commitment to results.

Comparing two methods of problem solving including group model building system dynamics and traditional group process, Dwyer and Stave (2008) found that system dynamics provides a better foundation for structural discussions, extracting mental models and making the correct decisions. According to their findings, group model building has a better performance both in the process and in the output variable but is slightly poor in the input variable.

Rouwette, Bleijenbergh and Vennix (2014) argue that, in relation to messy problems in a general multi-organizational field, group model building is filled with ambiguity and contradiction, which leads to open communication as well as changes in insight and quality of the results. According to the findings of a review of literature by Rouwette *et al*. (2011, 2012), the efficiency of group model building can be discussed at four levels including individual, group, organizational and method levels at the individual level, one is concerned with cognitive changes such as positive reaction, purification mental model, insight, commitment to decisions, and behavior changes. The group level involves group behavior, such as increasing the quality of commitment, developing a shared language, and coming to a consensus. At the organizational level, the significance is given to changes in the system and improvement of the system or its results. The method/efficiency level refers to the more efficient use of time and resources for acquisition of individual and group effects (Rouwette *et al*., 2009). It is argued that group model building possibly cannot have organizational effects, because it is not mentioned in the literature (Scott, Cavana and Cameron, 2016). Apart from this finding about the 4-level efficiency proposed by Rouwette *et al*., (2012), Scott, Cavana and Cameron, (2016) have achieved some other new results regarding persuasion, decision quality, power leveling, and group cohesion. They have indicated that persuasion is created both in the outcome and in the mechanism of group model

building. Decision quality is measurable on the basis of the participants, the number of variables considered, and the elaboration of problem topics to solutions. Power leveling analyzes the interaction between individuals, where people with less power can participate in group model building and discussions (Nistelrooij *et al*., 2012). Their study shows that consensus, commitment, power leveling and persuasion are more of a concern in group model building than in traditional sessions. In addition, compared to traditional methods, tacit, or hidden, knowledge sharing is of more significance in group model building, but sharing understanding and communication or commitment plays a better role in some studies than in others. They also argue that, according to their findings, the output of group model building can be improved better and faster than that of traditional sessions.

In a previous study, Scott, Cavana and Cameron (2014) had investigated the results of group model building. Also, further back, Scott *et al*. (2012) had administered questionnaires to 52 participants within four modeling workshops to find that the quality of communication, insight, consensus and commitment would increase, and modeling outputs might be achieved faster and better than in conventional workshops. These results are consistent with Herrera (2014). It was also found that open communication and model ownership are critical components the group model building in terms of respondents. In other studies, Scott, Cavana and Cameron (2013a, 2013b) found continuous changes in mental models and the resulting insights.

Hovelynck *et al*. (2010) suggest that extraction of knowledge in transdisciplinary fields through group model building overcomes three dualities of simplicity versus complexity, constraining versus containing, and defining versus refining.

In the assessment of group model building, Fokkinga, Bleijenbergh and Vennix (2009) state that building a model in a group increases the knowledge of participants in relation to the number of effective variables, leading to an increase of learning. However, learning about feedback processes in a group is not much more than learning achieved through written studying and modeling. According to those researchers, this may be because, in causal loop modeling, the communication is through images rather than words, knowledge about feedback is not increased immediately after drawing it, and mental model does not change as soon.

Vugteveen *et al*. (2015) state that group model building has advantages such as method flexibility, transparency, capability of integrating quantitative and qualitative information, ability to integrate a wide range of parameters in a meaningful way (demonstrating the inherent interactions and feedbacks), explicit recognition of the multiple forms of uncertainty, serving as a tool to involve stakeholders, knowledge sharing, and exchange of individual perspectives. According to them, this method has limitations as well. As an example, the answer is in the room. In other words, the input in this method is participants' understanding and their mental model, but there is not an opportunity to check them with actual data and statements or various data sources.

Finally, in their review studies of group model building, Rouwette, Vennix and Mullekom (1999; 2002) indicated that group model building improves insight, commitment, quality of communication, consensus, behavioral changes and changes in the systems but does not support shared language.

However, the participation of stakeholders in the whole process has some disadvantages, including the need to spend more time, resources, and efforts (Winz and Gary, 2007; Hovmand *et al*., 2010; Butler and Adamowski, 2015). Wagle (2014) proposed rapid participatory system dynamics modeling (RPSDM) approach to meet the challenge of limitations of time and resources and provide expertise which is based on combining individual and group model building methods in three rounds. Also, in group sessions, in case of dominance of a particular individual

or group, there may be no correct discussion to present or no chance for the model to be taken with a consensus (Hernantes *et al*., 2013). In such cases, the sessions fail to benefit from collective or group thinking (Hovmand *et al*., 2010).

Findings in terms of methodology

The summary results of previous papers in terms of methodology are provided in Table 1. According to the table, as many as 87 papers are in the form of case studies, seeking to solve or recognize a problem. Papers with empirical methods are in the next place, mainly seeking to assess the results of these methods. Conceptual expansion of group model building through descriptive methods and viewpoints of the experts of these methods are in the third place.

Table 1. Summary findings from the review of previous studies in terms of methodology

Research Method	No. of articles in Elsevier	No. of papers in SD Conference	No. of articles in Wiley	Total
Exploratory empirical study	2		1	3
comparative analysis		2		2
Systematic Review	1	6	2	9
Technical report	1	6	1	8
Viewpoint, Editorial, NOTES AND INSIGHTS	1	1	6	8
Case study	15	56	16	87
Survey		5	3	8
Experimental	1	11	1	13
Action Research	2	5	2	9
Grounded theory	1	1		2
conceptual work		2		2
Description		9	1	10
Total	**24**	**104**	**33**	**161**

Findings in terms of modeling type and model output (artifact)

The summary results of previous papers in terms of modeling type are given in Table 2. According to the table, most such studies have been conducted with no modeling. In other words, their focus has been more on theorizing and improving group model building.

Table 2. Summary findings from the review of previous studies in terms of modeling type

Modeling type	No. of articles in Elsevier	No. of papers in SD Conference	No. of articles in Wiley	Total
Quantitative	6	25	9	**40**

Qualitative	11	24	2	**37**
No modeling	6	54	19	**79**
Total	**23**	**103**	**30**	**156**

In a review article about the steps of involving stakeholders in group model building, Rouwette, Vennix and Mullekom (1999; 2002) express that most acts of modeling come to an end in the conceptualization step, but, in all or a part of the steps, studies have used client involvement. In other words, the majority of articles are qualitative. However, in our research, as the graph below shows, the percentage of articles written on qualitative modeling and quantitative modeling is equal.

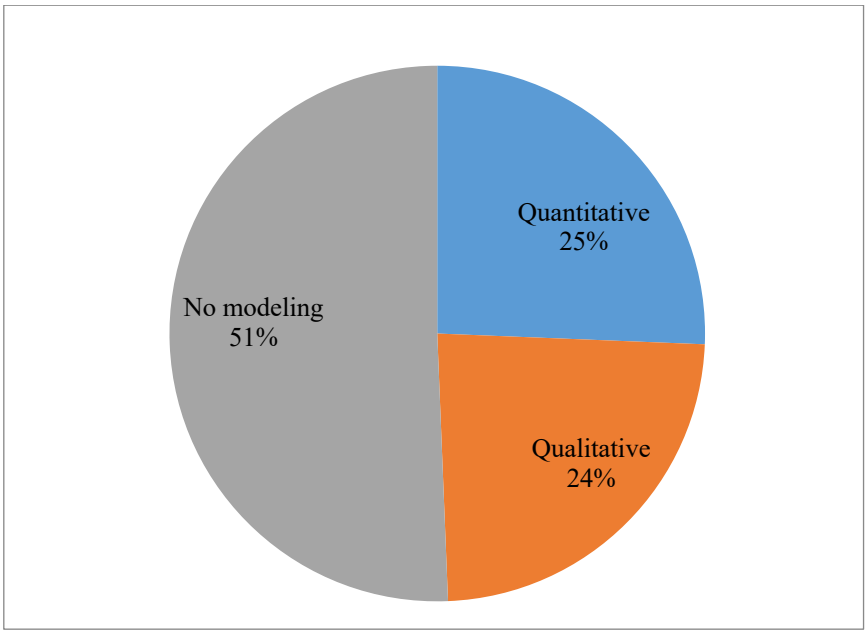

Figure 2. Percentage of articles by the type of modeling

The table below shows the output of the modeling, or the article artifacts. As the case is, most of the articles did not have any specific output in terms of artifacts, and this is consistent with previous findings based on the focus of articles on theorizing and improving the group model building method.

Table 3. Summary findings from the review of previous studies in terms of output (artifact)

Row	Output (artifact)	No. of articles
1	Improvement suggestions for participation	1
2	Stock and Flow diagram (simulation model)	41
3	Causal loop diagram (conceptual model)	35
4	Scripts Map / scriptpedia	6
5	Provide methods to quantify variables	1
6	Confirm findings related to the effectiveness of group model building	2
7	The initial structure for simulation on the Web	1

8	Introduction to Groupware Technology	1
9	No specific output	68
	Total	156

The great thing about their articles and their output is that, out of 156 desired articles, around 17 have examined the effectiveness of group model building, suggesting that this area is one of the key areas to study more.

Survey works in terms of application or modeling area

To review the articles from the viewpoint of the fields of application of group model building, they may be divided into 5 categories of organization and business, group model building, environment, health care, and public sector. In the figure below, the share of each of these areas has been identified. About 72 percent of the papers have sought to solve a problem, which is consistent with the statement of Rouwette, Vennix and Mullekom (1999) in that about 75 percent of studies aim at applied solutions.

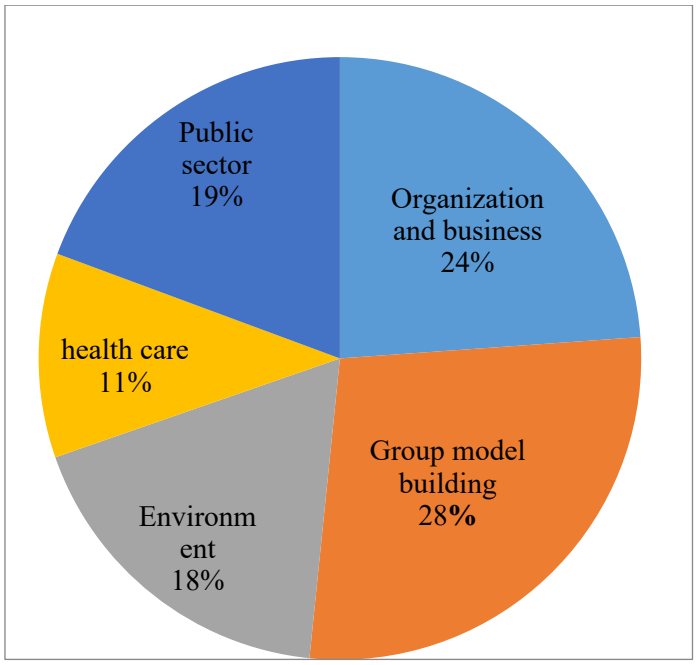

Figure 3. Percentage of article breakdown in terms of application field

In Tables 4 through 8, these areas and subareas are presented separately for a number of articles. As it can be seen in Table 4, in the field of business, the greatest contribution is related to organizational strategic planning.

Table 4. Summary findings from the review of previous studies on group model building in terms of business area

organization and business		
Row	**Subareas of application**	**No. article**

1	Life Cycle Assessment	1
2	Organizational strategic planning	11
3	Management and organizational structure	5
4	Planning and information systems	5
5	Decision-making and education	3
6	Production and Operations Management	5
7	Police human resource management	1
8	Various industries (fisheries, banking, nuclear, military, tourism, etc.)	6
	Total	**37**

According to Table 5, in connection with the articles that have explained and developed group model building in terms of methodology and its various aspects, most of the articles are related to the scripts and assessment of group model building.

Table 5. Summary findings from the review of previous studies on group model building in terms of group model building

Group model building (GMB)		
Row	**Subareas of application**	**No. article**
1	GMB methodology and scripts	24
2	GMB Assessment	10
3	Validation in GMB	2
4	System Dynamics Training	2
5	Stakeholder analysis in GMB	1
6	Mental models in GMB	2
7	GMB and combination with other methods	1
8	GMB and visual display tools	1
9	Communication theory and Facilitation in GMB	1
	Total	**44**

Table 6. Summary findings from the review of previous studies on group model building in terms of environment area

Environment		
Row	**Subareas of application**	**No. article**

1	Environmental management and natural resources	10
2	Energy	4
3	Adaptive management in natural resources and climate	2
4	water resource management	6
5	Management of forest resources	3
6	Support decisions in wildlife management	2
7	Transport and environment issues	1
	Total	**28**

Table 7. Summary findings from the review of previous studies on group model building in terms of health care

Health care		
Row	**Subareas of application**	**No. article**
1	Health care systems policymaking	11
2	Culture management and safety in Health	1
3	World's infant mortality problems	1
4	Insurance and health care system	1
5	The paradox in primary care	1
6	Health system and hospital management	1
7	Justice in oral health for the elderly	1
	Total	17

Tables 6, 7, and 8, present the articles related to the field of environment, health care, and policymaking in the public sector. Since there are other aspects of significance in the field of group model building, a lot of articles have also analyzed and solved problems in such areas as stakeholders, high complexity, and long-term effects,

Table 8. Summary findings from the review of previous studies on group model building in terms of public area

Public area		
Row	**Subareas of application**	**No. article**
1	Criminal and Justice issues	3
2	Social Welfare	4
3	Sustainable Development	2
4	Transportation Management and municipalization	5
5	Policymaking and public strategy	7
6	IT in the public sector	2
7	Crisis management and critical infrastructure	2
8	Social issues	5

	Total	30

Findings in terms of the number of participants in group sessions

In a review paper on group model building, Rouwette, Vennix and Mullekom (1999, 2002) refer to time and the number of people involved in modeling sessions. As they state, in most articles, participation in face-to-face interactions is reported to be with 5 to 12 and maximally 22 people, which is a very small number. However, more people, 30 to 70, are reported to participate in subgroups. As for the time of participation, it is reported to be from two full days to five years, but two to four workshops are found to last from one full day to two or three hours.

As it is clear from Fig. 4, the number of participants ranges from four to 66 while most articles have reported four to 12 participants, which is consistent with the results of Rouwette, Vennix and Mullekom (1999, 2002).

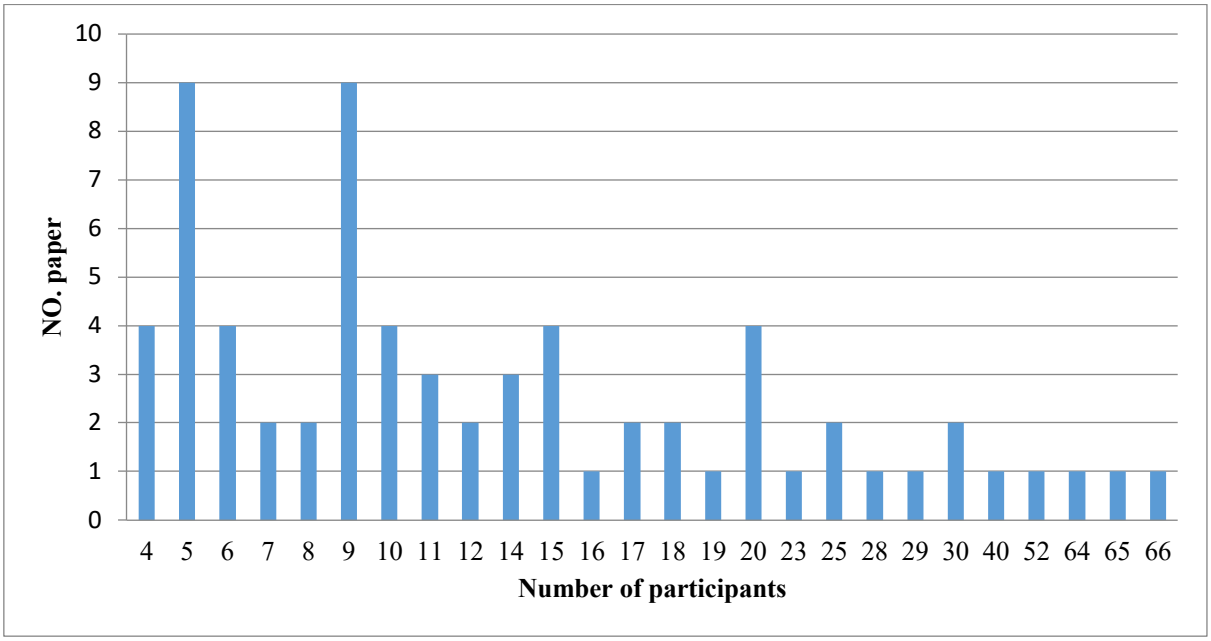

Figure 4. Summary findings from the review of previous studies on group model building in terms of the number of participants

In the table below, three categories are provided in terms of the number of participants in modeling sessions. As it can be seen, the greatest number of articles is related to small groups (0 to 12 people). The average number of participants in these groups is eight. These categories also show that a full group (i.e. a large group with more than 25 participants) has been used in a few articles.

Table 9. The average number of participants in small, medium and full groups

	Range (participants)	**Average participants**	**No. of articles**
Small group	0 - 12	8	39
Medium group	12 - 25	18	20

Full group	more than 25	45	9

Findings in terms of geographical regions

The summary findings from the review of previous studies in terms of geographical regions are provided in Table 10 and Fig. 5. As suggested, about 50 percent of the studies on group model building (i.e. 78 papers) are conducted in Europe.

Table 10. Summary findings from the review of previous studies in terms of geographical regions

Geographical region	No. of articles in Elsevier	No. of papers in SD Conference	No. of articles in Wiley	Total
Europe	13	49	16	78
Asia and others	6	19	3	28
Canada and America	4	35	11	50
Total	**23**	**103**	**30**	**156**

By examining the regional distribution, it is clear that more than 58 percent of the studies have been conducted in the Netherlands. This is attributed to the specific activities of Delft and Radboud Universities as well as the European program of system dynamics in which several universities are engaged for teaching and research in the field.

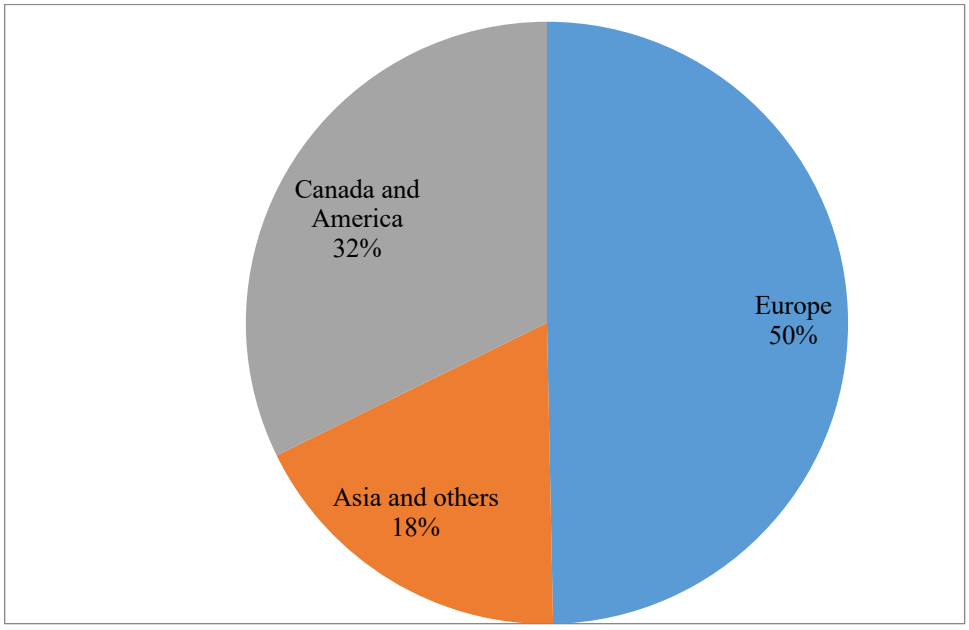

Figure 5. Graphic view of the summary findings from the review of previous studies in terms of geographical regions

According to the table below, in Australia as well as in some Asian countries such as New Zealand and India, good work has been done in the field. Also, in terms of the number of papers, the USA and the Netherlands are in the first two places, implying that these two countries are the cradles of the approach.

Table 11. Summary findings from the review of previous studies in terms of regional and national geographical distribution

Geographical region	No. of articles	Frequency (%)
Asia and others	**28**	**100%**
Australia	9	32%
Taiwan	2	7%
New Zealand	8	29%
Philippines	1	4%
India	5	18%
Indonesia	2	7%
Japan	1	4%
Canada and America	**50**	**100%**
America (USA)	46	92%
Canada	2	4%
Mexico	2	4%
Europe	**78**	**100%**
Spain	3	4%
Germany	6	8%
England	8	10%
Italy	1	1%
Belgium	1	1%
Portugal	1	1%
Sweden	2	3%
Norway	4	5%
Netherlands	45	58%
Slovenia	1	1%
Swiss	3	4%
Iceland	1	1%
Russia	2	3%

Findings in terms of the relevant journals

Table 12 reports the summary findings from the review of previous studies in terms of the number of papers published in each of the relevant journals. In this regard, the two journals of System Dynamics Review (with 22 articles) and Systems Research and Behavioral Science (with 7 articles) have published the highest number of articles.

Table 12. Summary findings from the review of previous studies in terms of the relevant journals

Journal	No. of articles
Accident Analysis and Prevention	1
Computers, Environment and Urban Systems	1

Energy Policy	1
Environmental Modelling & Software	2
Environmental Science & Policy	2
European Journal of Operational Research	1
Expert Systems with Applications	1
International Conference of the System Dynamics Society	103
International Journal of Critical Infrastructure Protection	1
Journal of Business Research	1
Journal of Cleaner Production	2
Journal of Environmental Management	2
Knowledge and Process Management	1
Land Use Policy	1
Ocean & Coastal Management	1
Omega	1
Operations Research for Health Care	1
Procedia Computer Science	1
Science of The Total Environment	1
SEMINARSIN PERINATOLOGY	1
System Dynamics Review	22
Systems Research and Behavioral Science	7
Technological Forecasting and Social Change	1
Total	**155**

The table below presents the types of papers published in the field. As it can be seen, System Dynamics Conference accounts for the highest number of articles.

Table 13. Summary findings from the review of previous studies in terms of article type

Paper Type	**No. of articles**
Conference paper	95
Conference paper-abstract	9
Journal paper	49
Editorial	3
Total	**156**

Conclusion

Since the designing of the system dynamics approach by Forrester in the 1950s, different methods, tools, software programs, processes, and information resources have been provided for system dynamics modeling. From the beginning of the emergence of this approach, Forrester has emphasized the importance of involving clients in system dynamics modeling. In this regard,

various methods are developed, such as individual interviews (individual modeling), collaborative model building, and group model building.

Group model building is a participatory method to extract knowledge from clients, stakeholders and the studied problem experts through face-to-face and official meetings. This may involve tasks ranging from problem definition to model simulation and offering solutions.

Since it emerged, the group model building method has been rapidly expanding, such that it is practically applied by many researchers. Considering the necessity of reviewing the studies ever done on group model building from the viewpoints of both its tenets and instructions and of other aspects that have not been studied yet, this paper aims at a comprehensive review of the literature related to the group model building method. In this study, through a systematic review of 156 articles published until 2017 on group model building, we summed up the studies conducted on this issue by identifying the focuses of attention of researchers represented in definitions of the group model building method, the type of problems suitable for this method, outputs of group model building, group model building processes, different roles in group model building, advantages and disadvantages of group model building, survey works in terms of methodology, survey works in terms of modeling types, survey works in terms of application or modeling areas, survey works in terms of the number of participants in group sessions, survey works in terms of geographical regions, and survey works in terms of the related journals.

Based on the literature review, it was found that implementation of this approach requires certain conditions, and, thus, it is not suitable for every problem. However, transdisciplinary messy problems with dynamic complex pluralist situations are suitable for this approach. Depending on the type of the problem and the goal of modeling, the output of this approach may be classified into three categories. According to the conducted study, most articles have not had a specific output in terms of artifacts, implying a focus of those papers on theorizing and improving the group model building method and providing new scripts to improve the modeling process. It was also found that articles with quantitative outputs are of the same percentage as those with qualitative outputs and causal diagrams.

According to the review of the papers, it was found that three distinct sets of people are generally involved in group model building including the core modeling group or the modeling team, clients and stakeholders, and experts. These individuals typically play different roles in group model building sessions.

Many articles have pointed to the benefits of this approach. Most articles have listed some benefits such as better understanding of problems, individual and group learning, open communication and involvement of people with different power levels, providing better solutions with consensus, and greater commitment to implement those solutions. However, in some of the reviewed articles, certain disadvantages have been expressed such as the need to spend a lot of time and money and group thinking challenges.

It was also found that the major bulk of research is in the form of case studies with 87 papers seeking to solve or recognize a problem. In addition, about 17 papers have examined the effectiveness of group model building. In terms of the application areas of group model building, we can classify the papers into five categories of organization and business, group model building, environment, health care, and public sector. The highest share in the articles belongs to strategic fields and development of methodology for group model building. In terms of the number of participants in modeling sessions, three categories of small, medium, and full group were created. The highest number of articles is related to small groups (0 to 12 people). In these groups, the average number of participants is 8. This classification also indicates that full groups (i.e. large groups with more than 25 participants) have been used in a few articles.

Finally, it is obvious that the use of group model building is expanding due to the complex nature of problems in the world today.

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