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Bachelor Thesis

Formalizing Group Model Building

The next step in supporting Group Decision Making

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"Managers are not confronted with separate problems but with situations that consist of complex systems of strongly interacting problems. I call such situations messes."

Russell L. Ackoff

RADBOUD UNIVERSITY

Abstract

Faculty of Science
Institute for Computing and Information Sciences

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Formalizing Group Model Building

The next step in supporting Group Decision Making

by M.J. (Mats) Ouborg

Creating consensus when solving problems is one of the most difficult things for organizations, as individual views of the problem can be biased. Group Model Building has been created by Jac A.M. Vennix, to help solving these so called Messy Problems by mediated sessions. Although very useful in a lot of organizations, this technique is too restricted in large multinational organizations, because all the participants must be in the same room together. This thesis presents a solution in resolving this restriction by creating a computerized approach, which enables participation via the Internet. This is realized by formalizing the processes and data into models. These models form the architecture for a system supporting distant Group Model Building.

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Chapter 1

Introduction

1.1 About this thesis

This thesis is about the next step in supporting group decision making, namely Formalizing Group Model Building, and is submitted in fulfillment of the requirements for the degree of Bachelor of Science in the Information Sciences on the Radboud University Nijmegen. The subject is inspired by the book "Group Model Building; Facilitating Team Learning Using System Dynamics" (Vennix, 1996). This book explicates the management technique enhanced by Vennix (1996), namely Group Model Building, which is a technique to create consensus in a group which are not clear on what the problem they encounter exactly is, known as "messy problems" (Ackoff, 1974, 1979).

Although the book by Vennix (1996) is not completely clear on which exact steps a manager has to take to create consensus in his group, later researchers like Rouwette and Franco (2014) have created some sort of framework with explicit steps for the manager to simplify the use of the group model building technique. This framework is used in the course "Intervention Methodology" taught to 3rd year business students at the Radboud University, Nijmegen. The work by Vennix (1996) and Rouwette and Franco (2014) forms the basis for this thesis, as it is being examined to create a formal framework of the group model building technique.

Not only a formal framework is being created, also some enhancements to the use of group model building will be presented. In this way the author hopes this thesis will help modernize and promote the use of group model building in not only small groups but also in large multinational companies. To further introduce this approach, first, an example of a messy problem is given, second, the value of this thesis is being amplified, third, the process of research is being explained, and last, the structure of this thesis is being clarified.

1.2 Not uncommon situation in a random multinational

Imagine, you are working as head of the marketing department in a multinational company, and due to the multinational nature of this company, every department is established in a different country. Your marketing department is settled in The Netherlands, the company's headquarters is settled in the US, and the company's financial office is settled in the UK. Due to declining profits, the head of the company asked every head of every department to think about a way to increase profits to save the company from going down. The CEO organizes a meeting at the headquarters in New York, where all the department bosses can establish a new strategy to prevent the company from going down.

As head of the marketing department, you prepare yourself by asking within your department if anybody can name a cause for the declining profits. As marketers, you immediately think that the declining profits is due to the lack of interesting products your company sells. Accompanied with some great new product ideas you fly to New York. You arrive just in time for your meeting. You are accompanied by the CEO, the head of the financial department, and the head of human resources. The meeting starts and the CEO asks who has come up with some ideas. You start by saying that a new product, which enthuses potential buyers, could create some new profits, which in its case will improve overall company performance.

Not long after that you find yourself in a big debate with the head of the financial department who find your idea insufficient, because a new product means extra development costs, thus lower profits. The head of the financial department thinks a great way of lowering costs is to cut on salaries, which offended the head of the human resource department. In his turn he thinks that the attraction of some clever new minds would create some fresh air, which makes you angry because of the fact that your marketing department has some of the brightest minds of the company.

Quickly the meeting transforms in to one big fight, in which is debated what should be the best solution for this problem. Mutual respect is hard to find and the CEO decides to intervene. He says that he thinks these are all great ideas to create new profit, but he does not know if we anticipate the problem well enough. The discussion goes on and on and people make a lot of fuss about each other's findings about what the problem exactly is. In the end, the discussion is cut off by the CEO to prevent that more damage is being done due to the extreme fighting discussions.

Meanwhile some months and meetings later, the profits of the company are still declining. You are still fighting with the other department heads about what causes this decline. You all think you should act fast, because the company's cash reserves are getting smaller and smaller. Still, as marketer, you do not want to get overruled by some new bright mind which would be hired by the human resource department. The financial department is not attending meetings anymore, because they think nobody listens to them. Eventually everybody thinks their idea vanishes, and your company is in a governmental crisis.

1.3 Supporting group decision making

Although maybe a bit exaggerated, the situation as described in the section above should sound quite familiar to a lot of business man and woman. For a lot of boards, commissions, and management, it is quite hard to create consensus between people who have unequal interests. Their view about the situation is most of the time biased by their own working conditions and by their lack of interest in other departments. A chief financial officer is interested in money and in how not to spend too much money, but is most of the time not interested in how this is being achieved. The same situation applies to other departments as well.

For central management it is thus hard to get an unbiased overview of the situation, and for that matter, a lot of management techniques have been developed to overcome these biased views. Group Model Building (Vennix, 1996) is a technique to overcome bias in situations in which it is not clear what the problem exactly is, known as ”messy problems” (Ackoff, 1974, 1979). In the situation above, everybody ascertains that profits are going down, but no one is a hundred percent sure what causes this decline, and thus how to solve it. Group Model Building tries to overcome a messy problem like this by step wise building a ”system dynamics model”[1] in group sessions, by disconnecting the idea generation from the idea discussions.

Like in the situation above, most brainstorm sessions are going wrong due to the fact that a radical idea is immediately questioned. Instead of using all the time left to generate more radical ideas, all the time is being spent to discuss the initial radical idea. Structuring the conversation (Rouwette and Franco, 2014) by splitting idea generation from idea discussion, solves this problem and overcomes biased images of reality.

Even though group model building has been successfully used in practice (Rouwette, Vennix, and Van Mullekom, 2002), there is still a practical problem. To participate in a group model building sessions, all the participants[2] must be in the same room with a mediator and a recorder. This makes this technique quite costly in the situation of a multinational company, as getting people together would then be a quite demanding task. All the department heads should fly around the world to participate in a session of an hour, and this could be the reason that large companies do not use this technique more often.

1.4 The value of this thesis

Given the fact that the internet has become a standard element of the working environment, it seems quite obvious that it must be part of the solution to the practical problem described above. Instead of flying to a group model building session, one can sit in a lazy chair at his or her PC and participate in a meeting. Unfortunately it is hard for a mediator to control such distant meetings because of the lack of body language, emotions, etc. Also, one can imagine that an internet conversation, say via Skype, is very difficult to follow when more than two or three people are participating, due to the delay in the connection.

The solution would be to create a computer program that follows some exact predefined activities, therefore (despite the delay and lack of body language, emotions etc.) controls the communication between participants, and thus create an environment in which a group model building session can be held, without the necessity that people must be together in the same room. Unfortunately, the informal nature of management literature causes a problem here. A computer operates through exact stated rules and conditions, whilst the management literature trusts on people’s interpretation skills. Therefore the solution would be to translate group model building into a set of formal rules.

[1] Which will be explained in chapter 2.

[2] In the situation of section 1.2 this would be the CEO and the heads of the departments.

This thesis would be the first step in formalizing group model building. With the delivery of the pre- and post-conditions for the group model building processes, this thesis creates a field for other researchers to expand the formalization of group model building. Besides, the modeling of the data creates an extra support for regular group model building meetings (that are held in a single room), because it creates the possibility to produce formal meeting reports. Usually, the group model building sessions are realized by more than one meeting (because of doubt or time to do some research). Therefore, when you want to start with meeting two, and you have a formal report of meeting one, you can immediately derive where to pick up the group model building process, and thus start meeting two without losing valuable time (because of the possible overlap of the sessions).

1.5 The formalization process

As said before, this thesis will formalize group model building by creating pre- and post-conditions for the group model building processes. To accomplish this, there are a few steps to undertake. First the process flow of group model building has to be mapped into models. Next, the data that flows through these processes must be mapped into models as well. For instance, when it is clear that the process will be, say "first A happens, then B happens", the data that is in between process A and B will be mapped. In what fashion the process and the data will be modeled, is explained in the next two sections.

1.5.1 Modeling the processes

To model the processes of group model building, a language called BPMN[3] will be used. To be more specific, the "Business Process Diagrams" of the "BPMN 2.0" standard will be used. The reason for choosing BPMN, is the fact that (once familiar) it makes it easy to visually understand the process without it being accompanied with some commentary. For those who are unfamiliar with these diagrams, a few examples are given:

Case: sequential process

When we look at figure 1.1, we will see a process with three activities connected by a XOR-port. This means that the process will start at the left circle, then A is active, then B or C is active (but not together), and then this process is finished (due to the fact that it is arrived at the right circle).

Case: parallel process

When we look at figure 1.2, we will see a process with three activities connected by a parallel-port. This means that the process will start at the left circle, then A is active, then both B and C are active, and then this process is finished (due to the fact that it is arrived at the right circle).

[3]Stands for "Business Process Model and Notation".

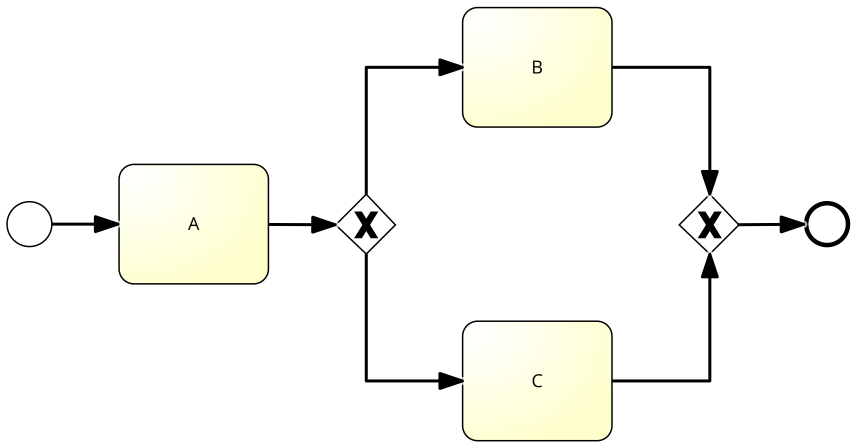

FIGURE 1.1: An example of a sequential process in BMPN.

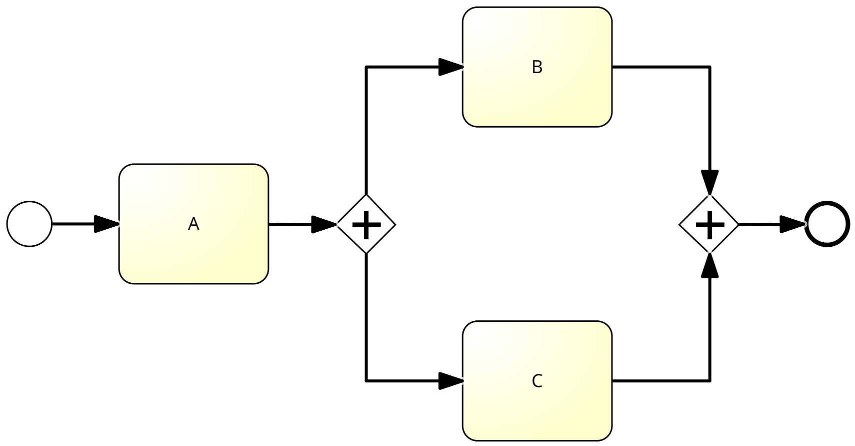

FIGURE 1.2: An example of a parallel process in BMPN.

1.5.2 Modeling the data

After the processes are modeled and the process flow of group model building is mapped, the data that flows through the processes will be modeled. When you look at figure 1.2, you can imagine that just before process B is active there has to flow some data (coming from A) into it. Than B does something with this data (like for instance, processing it) and a stream of data will leave B. One can image that the data that is coming from A into B must be different from the data that is produced by B. This automatically creates a precondition for B (the data that is coming from A), namely, only when this data is from a specific form, B can be made active. Also this automatically will generate a post condition for B, which logically is the data that is produced by B.

When the data that flows through the processes are known and the pre- and post-conditions are derived, a structure to produce formal reports can be made. For instance, when you have a report that contains the same data as the precondition of A, but not the as the precondition of B. You simply know that you cannot start at activity B, but you must do activity A first. This principal creates a framework to automatically check at which point the session can resume.

To model the data, a language called ORM[4] (Paulussen and Van der Weide, 2007) is being used. ORM maps data by modeling the data objects and the relations between those objects. The choice for ORM lays in the fact that, just like BPMN, it is easy to visually understand the diagrams without commentary. For those not familiar with ORM, an example is given.

Example of ORM

If you look at figure 1.3, you will see three data objects (called object types). The object type "Company" and "Employee" are being identified by "Name" (which is called label type). The object "Salary" is identified by the label type "amount"[5].

All these object and labels types are connected by a so called fact type. For instance, a "Company" "has" an "Employee". The dot in that relationship denotes that every company must have an Employee. If you read the relationship the other way around (Employee of Company), you will see a little line above the relationship. This means that every employee can only be of one unique company. The relationship tells you that every employee (if it is of a specified company)[6] can only have one specified company.

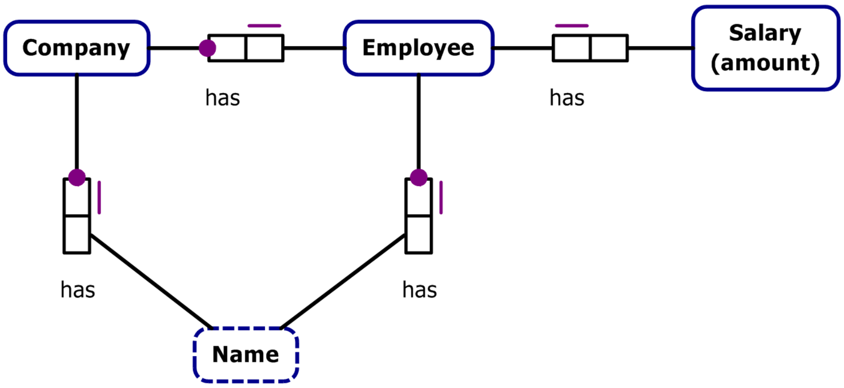

FIGURE 1.3: An example of a data model in ORM.

1.6 The structure of this thesis

This thesis is can be seen as a concatenation of three parts. Chapter 2 will examine some literature and history of group decision making and the birth of group model building.[7] This creates a fundamental understanding of the group model building procedure and it creates a further understanding of the advantages of the group model building technique. Chapter 4 and 5 will guide the reader through the modeling process by following the structure of a group model building session. Here the pre- and post-condition are being

[4]Stands for "Object Role Modeling".

[5]Due to readability, one can choose to use implicit label types. These are presented between "(" ")" beneath the title of the object type they identify.

[6]This is due to the missing dot in that relation.

[7]Chapter 2 is partly inspired by the literature research of Rouwette and Franco (2014).

developed and presented, as are the formal reports that can be derived from these conditions. Thee last part, which consists of chapter 6 and 7, will contain some suggestions for further research and will conclude what has been achieved with this thesis.

Chapter 2

Literature

2.1 The history of group decision making

Organizations have changed over time. Not only did they change in where they operate, also the way they organize themselves has changed. This means the way decisions are being made have changed as well. Over the years, more and more people got involved in answering what would be the best way to solve problems in organizations. Due to the need for more group decision making (as groups within organizations getting larger), the need for *Group Decision Support Systems* (of which group model building is a part of) have grown over the years. To fully understand this development, the changes of the organization structure is being explained, as well as the early and basic forms of group decision support systems.

2.1.1 The need for group decision support systems

In the early days,[1] organizations where mostly organized in a hierarchical and bureaucratic fashion (Weber, 1946). This meant that every worker had a strict set of tasks that he or she had to perform every day. This set of tasks also meant that the worker did not had much to say about his own work, as there was no room for debate. Every worker had some sort of boss or manager who checked if they were working following the stated tasks. These bosses or managers did not made much important strategic decisions as well, because they only (if necessary) adjusted the way people worked and reported this to the director of the organization (Robbins and Barnwell, 2006).

At that time, the director was the only one who made the decisions that steered the organization. Due to the highly structured tasks and thus the enormous ability to overview the tasks, it was easy to make the right decisions. If something went wrong on the floor, due to structural organization issues, it was easy to know which tasks did not work all that well and the director just had to adjust that task. Also, if the director had the feeling that the organization should do business in another sector, he just had to define some different tasks. In the end the director was the person who could make or break the organizations performance.

[1] Roughly before the 1960s.

For a long time the hierarchical model (as described above) worked very well, because markets did not changed very fast. But when markets grew and the speed at which technologies arose, the hierarchical model start lacking flexibility. From then on, not structure and hierarchy, but creativity and flexibility became important in the organization (Robbins and Barnwell, 2006). This meant that the director himself was not always able the quickly come with the best solution possible, due to lack of skill or information. He had to find the creative minds from inside the company. Therefore companies started to decentralize decision making by creating divisions, which could make decisions on their own within a predefined range. Any decision that could not be made by the divisions, was still being made by the director.

The division model worked for a long time, but as problems became more complex, it was not clear which department should be responsible for making the decision. Sometimes the problem had effect on more than one department. Therefore, the director began to organize meetings with heads of every department, in which they thought about solutions for these problems (Robbins and Barnwell, 2006). This was the first form of a *group decision support system*, in which they start using brainstorming (see section 2.1.3) as the mean technique. Although this was a way to quickly come up with ideas, there were some drawbacks. This form of idea creation disregards the effect of politics within a company. When sensitive subjects are being discussed, it is more likely that the outcome of the idea creation (like with brainstorming) will be biased.

From then on, and still in modern organizations, the need to overcome such biased outcomes resulted in the need for better group decision support systems (Rouwette and Franco, 2014). Given that the organization has to deal with fast changing markets, international operations with different cultures, and many people internally, who all have great ideas, but may have differences in each other's ideas, results in that the organization has to deal with very complex problems, of which it even may not be clear what the problem exactly is. These so called *messy problems* (Ackoff, 1974, 1979), are one of the biggest challenges of today's organizations. This means there is a great need for *group decision support systems* who can cope with these messy problems. The characteristics and detail of messy problems will be discussed next.

2.1.2 Messy problems

The not uncommon situation (as described in section 1.2) is a so called *messy problem*, which was first discussed by Ackoff (1974, 1979). He claims that *"managers are not confronted with separate problems but with situations that consist of complex systems of strongly interacting problems"* (Ackoff, 1994), and he calls these problems *messes*. Later research has defined some typical characteristics of these messy problems (Rouwette and Franco, 2014):

- Messy problems will have interconnectedness between different aspects of the situations (its systemic nature).
- Messy problems will exhibit high levels of uncertainty.
- Local solutions to a particular problem only generate other or new problems.

If we look at the situation of the multinational described earlier we can see these characteristics emerge. The interconnectedness between the different aspects of the situation, shows up in the different departments who have all different solutions and interests. Also the high uncertainty manifests itself, because the CEO is not able to form an unbiased overview of the situation, and therefore decides in uncertainty. Also the local solutions, namely those of each department, results in new problems, because other departments will obstruct those, due to political and functional reasons.

According to Rouwette and Franco (2014), messy problems come with challenges in two ways: when trying to be solved individually and when trying to be solved in a group. The challenge with individuals is that *"even for important problems, individuals find it difficult to articulate which information should be taken into account"* (Bond, Carlson, and Keeney, 2008). The uncertainty that follows result in that individuals search for *"satisficing"* solutions (Simon, 1985). So, trying to find solutions individually will most of the time not work optimally. This has been accepted due to the fact that organizations (as described above) do not organized themselves via a hierarchical model anymore.[2]

The other way is to tackle messy problems with a group, where stakeholders *"get together to produce a joint response"* (Rouwette and Franco, 2014). Even the effect of working in a group when trying to find solutions, has not always been optimal (Lu, Yuan, and McLeod, 2012). The sharing of information, or to be more specific, the sharing of *all* the information seems to be the biggest problem here, because the amount of groups where all information has been shared, is about twenty percent (Stasser and Titus, 1985).

So not only the characteristics of the messy problem itself forms an issue when solving them, the amount of sharing of all the information necessary to solve the problem is probably not high enough. Nijstad and De Dreu (2012) claimed that if you want to solve a complex problem, it is essential to process all the information (Rouwette and Franco, 2014). In trying to solve this, research has exposed that *"groups that are accountable for their decisions, have appropriate time available, do not work under undue pressure and whose members have different preferences, are more likely to process information in depth"* (Rouwette and Franco, 2014).

It thus seems that it is important to create an atmosphere where it is easy to share information. This means, as stated by Rouwette and Franco (2014), De Dreu, Nijstad, and Van Knippenberg (2008), Poole and Roth (1989), that *"deep processing of information needs to be supported by behaviors,"* because this means that the group relations are being maintained. Therefore, the group decision support system, that must tackle a messy problem, must not only create an environment that creates the maximum amount of information sharing, but must also create an environment that is friendly in the long run. Only then consensus between the participants, and therefore the will to solve, can be achieved.

Another (more detailed) view on messy problems, is that of Rittel and Webber (1973). They did not call the situations messy but *"wicked"*, and defined ten characteristics of a *"Wicked Problem"* (Rittel and Webber, 1973). To create a bigger understanding of messy problems, the characteristics of wicked problems are being given, as they form a more detailed view of a messy problem.

[2]So there is no single boss who makes all the decisions anymore.

Characteristics of *"wicked problems"* (Rittel and Webber, 1973):

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The social planner has no right to be wrong (i.e., planners are liable for the consequences of the actions they generate).

To summarize, not only is being explained what a messy problem is, it is also being discussed how to tackle them, namely by controlling group behavior in such a way, that information sharing is being maximized and the motivation to solve the problem is increased. This means that if a group decision support system (like group model building) is going to handle a messy problem, it needs to attain these goals. Next, examples are being given of early forms of group decision support systems, namely: *brainstorming* and *nominal group technique*. Although these two are used in modern organizations, they differ in how they can handle messy problems.

2.1.3 Brainstorming

To create solutions to problems, ideas must not only be generated, but also be shared with the rest of the organization. One of the most common techniques to generate and share ideas is *brainstorming* (Osborn, 1953, 1957, 1963). In brainstorming, you meet with some creative colleges, sit around the same table, someone states the problem, and participants then can call their ideas. When an idea is being called by a participant and the group finds this idea useful in solving the stated problem, it is written down (e.g. on a piece of paper or on a whiteboard). For a lot of organizations who work in small teams, this way of idea generation and idea sharing has proved itself very useful, due to the possibility to quickly plan a meeting, and therefore the fast nature of solution generation.

Brainstorming is a great technique for a lot of situations in which there is the need to quickly generate some new ideas. But, the effectiveness of brainstorming has been questioned over the years (Stroebe, Nijstad, and Rietzschel, 2010). Although brainstorming most of the time leads to the generation of some ideas, Stroebe et al. (2010) claim that it does not always lead to *creative* ideas. They claim this is due to three things: *"free riding or social loafing"*, *"social inhibition"*, and *"production blocking"*. These three findings where supported by some other research. Collaros and Anderson (1969) stated that if participant thought other group members had better ideas than theirs, they did not shared their ideas with the group, and thus create a free riding or social loafing atmosphere. Diehl and Stroebe (1987) found prove that participants would censor their ideas if they thought it would create *"an undesirable or even embarrassing aspect of themselves (e.g. lack of knowledge, ideological biases)"* (Diehl and Stroebe, 1987). You can imagine that ideas that are extreme or political incorrect are being censored by the person itself, and thus creates social inhibition. About the last, production blocking, Stroebe et al. (2010) claimed that when someone else in the group is sharing an idea, you either would not listen to them because you are too busy with your own ideas, or you can not generate ideas because of the fact that you must listen to what the other has to say.

It must be clear that with the disadvantages claimed by Stroebe et al. (2010), brainstorming is not suitable to find solutions to messy problems. The possible "political sensitive" nature and the "unclear" nature of messy problems can respectively cause *social inhibition* and *free riding or social loafing* when solutions are found with brainstorming. Also with the "possibility of debate", brainstorming can cause *production blocking* when used to find answers to messy problems. To prevent free riding or social loafing, social inhibition, and production blocking, Stroebe et al. (2010) suggest that groups should create ideas in a nominal fashion, and later share them as a group. The *nominal group technique* (Delbecq, Van de Ven, and Gustafson, 1975) is an answer to the disadvantages of brainstorming and is being used in the *group model building technique* to generate variables. The nominal group technique will be explained next.

2.1.4 Nominal group technique

The *nominal group technique* (Delbecq et al., 1975) was suggested by Stroebe et al. (2010) as an alternative to *brainstorming* (Osborn, 1953, 1957, 1963), because it overcomes the disadvantages of brainstorming, namely free riding or social loafing, social inhibition, and production blocking. Delbecq et al. (1975) states that the basic principle of nominal group technique is as follows: *"The term 'nominal' was adopted by earlier researchers to refer to processes which bring individuals together but do not allow the individuals to communicate verbally."* In other words, participants create ideas, but while creating them, they are not allowed to share these ideas with each other.

The splicing of the idea generation phase and the idea sharing phase, creates a creative atmosphere where free riding or social loafing, social inhibition, and production blocking, are being minimized. With the nominal group technique, one can be assured that the mental model of the participant is being shared as much as possible (Stroebe et al., 2010), and thus, is ideal to use with messy problems. Therefore, it is being used in the group model building process. To understand how this type of idea generation and idea sharing is being achieved, the nominal group technique as described by Delbecq et al. (1975), will now be explained in more detail.

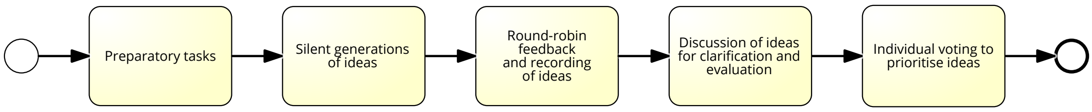

FIGURE 2.1: The basic flow of the nominal group technique (Delbecq et al., 1975).

The steps of the *nominal group technique* (Delbecq et al., 1975)

To completely understand what the benefits of the nominal group technique are, we will explain briefly how it works. A nominal group technique sessions is a type of meeting where there are participants and a mediator. The mediator, who fully understands the process of nominal group technique, guides the meeting. The participants are sitting in a U-shape around a whiteboard where the mediator stands, so he can see all the participants. The basic steps of this technique, modeled in BPMN,[3] can be found in figure 2.1.

- *Preparatory tasks*: In this step the mediator makes sure that the meeting room is set in the previously mentioned U-shape setting. He or she also checks if there is a piece of paper and a pen for every participant. Then he or she welcomes the participants and thanks them for participating in this idea generation meeting. The mediator writes down the problem variable for which some possible solutions must be generated. He or she asks the participants if they understand the problem variable.
- *Silent generations of ideas*: Here, the mediator explains that participants now will write down some ideas they are having. He makes absolutely clear that it is forbidden to talk to each other for five minutes, while they write down some ideas individually. The mediator also states that every idea is welcome and should be written down on the paper in front of the participants in a brief manner. Catchwords or tiny phrases are preferred. The mediator asks if everybody is ready and then starts the five minutes of silent idea generation.
- *Round-robin feedback and recording of ideas*: After the five minutes the mediator asks the participants to lay down their pens. Talking to each other is still not allowed. The mediator now tells the participants that he or she will ask every participant to read one idea he has come up with, and when shared, the mediator will write down the idea on the whiteboard. This will happen in a round robin fashion until all the ideas have been shared.
- *Discussion of ideas for clarification and evaluation*: After all the ideas have been shared and written down on the whiteboard, the mediator will tell the participants they can asks questions if they want clarification or explanation about the ideas that are written down. The mediator then ask the group to clarify.
- *Individual voting to prioritize ideas*: When everything is clear the participants are asked to write down on their piece of paper a top 10 of most important ideas. This is used as a voting system to create a top many of the beast ideas to priorities them. Other prioritization methods are possible.[4] When this is all done, the mediator

[3]For an explanation about how to read this type of diagrams, see section 1.5.1.
[4]Like clustering in two or more groups. Because voting is not part of the nominal group technique within group model building, further explanation of possible prioritization methods is left out.

promises he will make a report and sends it to the participants. He then thanks them and closes the session.

One can imagine that the role of the mediator is most important within the whole session. He has to make sure that everybody is following the nominal group technique rules perfectly, or else the end result of the session can be biased. But one can see that due to the rules of silent idea generation and sharing, and only then the permission to a form of discussion, will minimize the heat that can be caused by the creation of political sensitive ideas and also will force all the participants to listen to each other instead of stating just their own ideas. This makes it an ideal method to control a messy problem a group has to cope with, and thus forms a solid basis for group model building.

2.2 Why does group model building work?

This section discusses the group decision support system that is the main subject of this thesis, namely *Group Model Building* (Vennix, 1996) (Rouwette and Franco, 2014). Because there are a lot of group decision support systems, the advantages of group model building will be explained. There is a lot of scientific basis for the framework of group model building, some has been explained in the section above, but some group model building specific (which has not been discussed) will be explained next. At the end of this section the process of group model building will be discussed. This process forms the basis of the modeling process (or formalization) used in this thesis.

2.2.1 Structure drives behavior when using system dynamics

Imagine you want to tell someone in which direction he or she has to walk. You can explain this by talking to them and tell them step wise how they should go, but you can also explain this to them by drawing them a few roads on a piece of paper. When you draw them a small map you will sense they understand faster and better, and you will see that they are more confident in finding the correct route. This map can be seen as a model: *"A simplified description, especially a mathematical one, of a system or process, to assist calculations and predictions"* (Oxford dictionary). In helping explain what we mean, and therefore help others understand our mental model better, we use these models more often than we probably are aware of. According to Rouwette and Franco (2014), models have a number of advantages:

- "Models may be used to represent theories, both in the sense of theories that can be found in academic texts as well as 'local theories' on what is happening in a certain situation."
- "As a group, it is much easier to construct a model together than to write a text."
- "In a model, the relations of a particular element to other elements is clearly visible."
- Models use one term to describe an element, while texts may use more.

Rouwette and Franco (2014) conclude that when models are being made with a group, the *"clarity on what is meant with a concept and why it is related to other concepts"* will increase, and this *"makes it easier to identify the essential differences of opinion."* Therefore we can say that building models can increase consensus within a group and create a shared understanding among participants, thus models can help overcome messy problems.[5]

In group model building a specific type of models are being build, namely *system dynamics* (Forrester, 1975). These type of models, map variables and their relations into a web of interdependent variables. These models form a great solution to map messy problems as they take the whole framework of the problem into account and not just a single effect of the problem. Forrester (1961), who formally called it *industrial dynamics*, explains these type of models as follows: *"Industrial dynamics is a way of studying the behaviour of industrial systems to show how policies, decisions, structure, and delays are interrelated to influence growth and stability. It integrates the separate functional areas of management – marketing, investment, research, personnel, production, and accounting."*

Rouwette and Franco (2014) concludes: *"A basic premise of system dynamics is therefore that the characteristics of the whole are more important than the characteristics of individual parts."* Vennix (1996) is more specific, as he states basic assumptions that system dynamics is based on:

- social systems are information-feedback systems
- structure drives behaviour
- mathematical models are necessary to trace dynamic behaviour of a complex problem

About the first, Rouwette and Franco (2014) states that *"actors use the information about the structure as input to their decisions, and by implementing their decisions influence system behaviour"* this creates the feedback loop structure of the information-feedback systems. Within group model building, the search for feedback loops is central, because these are probably the cause of the elusiveness of the problem, therefore the solution can most of the time also be found within that feedback loop. Rouwette and Franco (2014) adds that *"many feedback loops are closed because actors in the system use information on system elements in their decisions. Thus, decisions of actors within the system have an important influence on the system's behaviour."* The second is based on the premise that *"system dynamics attaches more importance to factors internal to the system than to external influences"* (Rouwette and Franco, 2014), which is also supported in research by Richardson and Pugh (1981).

The last is the biggest advantage of system dynamics when trying to solve messy problems. As said before, messy problems tend to get very complex with a big network of concepts and relations (Rouwette and Franco, 2014) (Ackoff, 1974, 1979). Therefore, it gets very difficult to create an understanding of the mutual influence each concept has. When you use mathematics to create simulations based on quantitative measurements of these relations, one can create a bigger understanding what will happen if one of the concepts changes. As this thesis is more focused on the process of group model building

[5] See section 2.1.2 for details about messy problems.

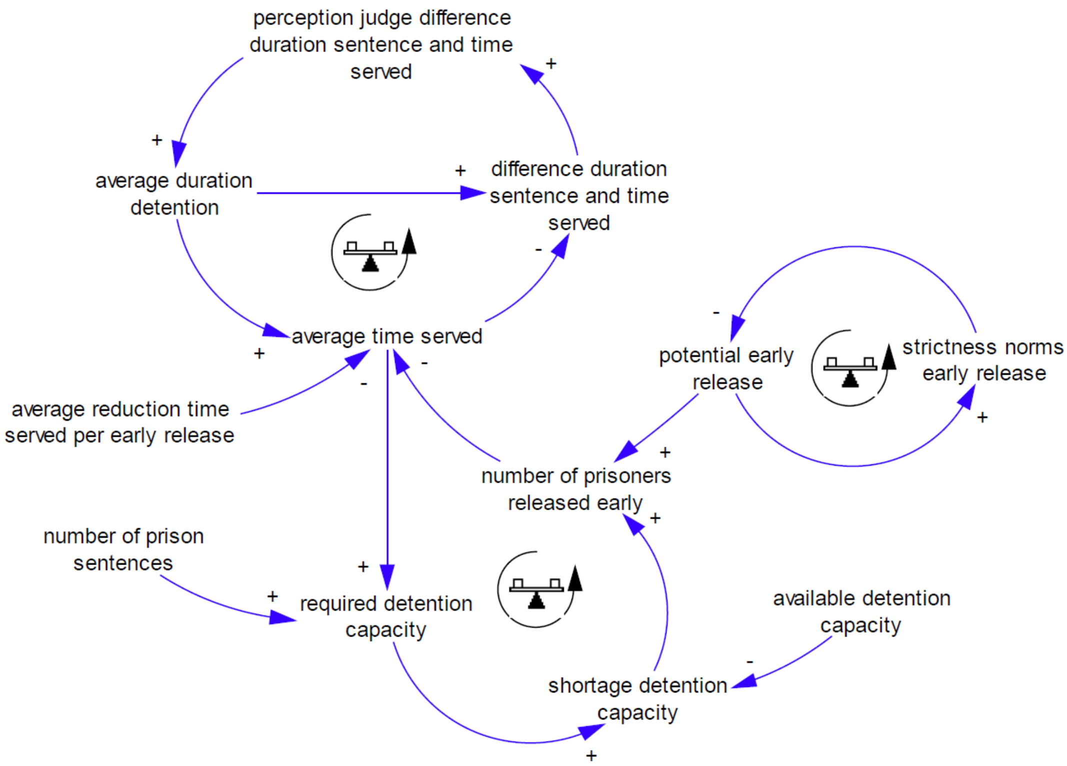

Figure 2.2: Example causal loop diagram (system dynamics) on early release policy (Rouwette and Vennix, 2007).

and not on the final calculations, the research on quantitative analysis of concepts is left out.

To give a better understanding about system dynamics, a small example is given. In figure 2.2 (Rouwette and Vennix, 2007) one can see a small system dynamics structure mapped by a causal loop diagram which was created by a group model building session. There are concepts which are connected by arrows, which form the relationships (positive "+", or negative "-"). The image of the seesaw denotes that there is a loop which is balanced, so an increase of a concept will later on in the loop be balanced by a decrease.

To summarize, group model building (Vennix, 1996) distinguishes itself by the combination of creating consensus with a shared understanding and creating a framework to solve a messy problem. Next, the basic steps of group model building (according to (Vennix, 1996, Rouwette and Franco, 2014)) will be explained.

2.2.2 Group Model Building by Vennix and Rouwette

Now that we discussed the scientific background of group model building, the procedure will be explained. Group model building (Vennix, 1996, Rouwette and Franco, 2014) is a technique which combines the benefits of nominal group technique (Delbecq et al., 1975) for creating and sharing information with benefits of group wise building a system dynamics model (Forrester, 1975). Therefore we will see that the process of group model building is a contamination of these techniques.

As stated earlier, although Vennix (1996) created the framework of group model building, Rouwette and Franco (2014) created a simplified road-map of how to perform group model building with a group. The participants are being seated in a U shape in front of a whiteboard, as is with nominal group technique (Delbecq et al., 1975). Then the group will follow a few steps (Rouwette and Franco, 2014):

1. *identify reference mode of behavior*: Here the process is explained to the participants and some social rules are being carried out. Also the reason for this sessions is being clarified.

2. *note down problem variable*: In this phase, the problem variable is being stated. In the example of section 1.2 this would be: "What can cause our profits to decline?"

3. *nominal group technique on variables*: Now, the participants are thinking of answers in a nominal group technique fashion, and then the answers will be shared (still in a nominal group technique fashion).

4. *identify causal relations*: This step is all about creating the relations between the variables, and the identification of the type of each relation (e.g. positive, negative etc.).

5. *check feedback loops*: Here, the feedback loops are being identified. In this step, it is important that all the participants understand the model, and thus, understand why the loops can be identified as feedback loops.

6. *identify control and target variables*: This last step is all about the creation of a possible solution to the messy problem. First, there is being identified which variables can be controlled by the organizations (control variables). Then, the variables that must change, but cannot be controlled by the organization, are being identified (target variables). The next step would be to create a simulation of the control and target variables, but since this is quantitative analysis, and therefore not the focus of this theses, a detailed explanation is left out.

These processes form the basis for the formalization process of this thesis. The next chapter will explain how these processes are being interpreted, and on which part of the group model building processes is being focused.

Chapter 3

Translating the literature into goals for this thesis

Now we discussed what group model building is and what background it has, it is time to transfer the literature into goals for this thesis. The main goal of this thesis is to formalize group model building. This means that the literature is being made formal by translating it into models. These models then form the basis to generate so called pre- and post-conditions, which will be forming a basis to create the computer program, which in turn, makes it possible to participate in a group model building session from your lazy chair at home.

As said in the introduction of this thesis, the downside of group model building is that every participant must be in the same room at the same time.[1] The possibility to create an environment (e.g. a computer program) that makes it possible to participate from your lazy chair at home, will be the progression in creating cheaper and more modern forms of group decision support systems. This thesis will therefore form the first step in doing so.

The formalization process has been divided into a few steps. First, the main process of group model building[2] was modeled in BPMN,[3] and then the data that flows through these processes was being modeled in ORM.[4] These ORM data models formed the basic pre- and post-conditions of these processes. The results of this formalization process are presented in chapter 4.

Next, the processes where zoomed into to formalize in more detail. This has been done one process at the time, and also, has been modeled in BPMN and ORM. This is being presented (one process at a time) in chapter 5. Here, with the data models not only pre- and post-conditions were being developed, also the ability to generate formal reports where being developed and presented in list-form. These reports support the ability to pause the group model building session and continue later on. Such reports can be used to check what already has been discussed and at which step the group model building session can continue.

[1]Remember this is considered a downside, due to high organizational costs.

[2]The processes are freely interpreted and inspired by the processes as described in section 2.2.2.

[3]See section 1.5.1 for an explanation of BPMN.

[4]See section 1.5.2 for an explanation of ORM.

Due to the large amount of work, a complete formalization of the group model building session would be too much for a bachelor thesis. Therefore, there is being focused on the basic process flow and the data that flows through these processes. This means that the detailed actions of the individual participants, the recorder, and the mediator are being left out. Chapter 6 will make a short suggestion about how this can be done in later research. When something is left out or not being focused on, it will be denoted in the specific sections of the following chapters. Also the reason for doing so will be clarified in more detail.

Chapter 4

The main process of group model building

This chapter will present the formalization results of the main process of group model building by step wise guiding the reader through this process. Figure 4.1 shows the main process, and here it can be seen that the main process is a chain containing five actions, which is a different amount than Vennix (1996) and Rouwette and Franco (2014) presents (see section 2.2.2). Within the interpretation of this thesis, the last two actions *check feedback loops* and *identify control and target variables* are joined together to one action, namely *Calculate and define end result*.

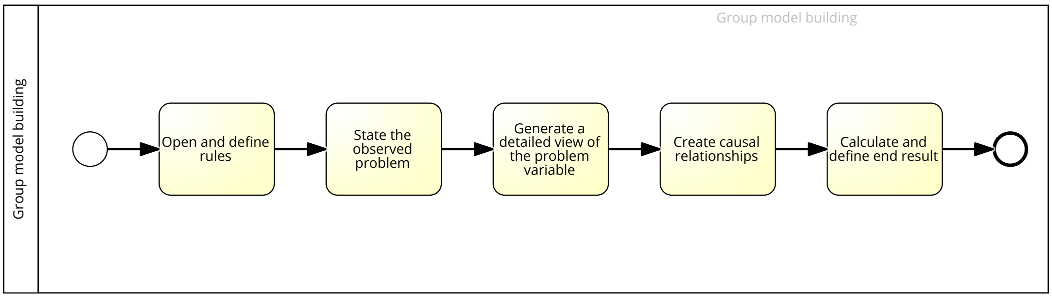

FIGURE 4.1: The main process of group model building.

The reason for this joint is that both *check feedback loops* and *identify control and target variables* (from the original description), work with the same feedback loops. This means the data models would not change that often, and this would create a situation where the pre- and post-conditions do not differ that much from each other. As the data models are the focus of this thesis (as these define formalization), readable data models were more important than the exactness of the actions itself.

The interpretation and the joining of the last two main actions, resulted in the following actions: *Open and define rules*, *State the observed problem*, *Generate a detailed view of the problem variable*, *Create causal relationships*, and *Calculate and define end result*. These actions will be explained gradually. Each section will look at the process and defines the post-condition of that process and the precondition for the next. Figure 4.2 shows the position, denoted with an arrow that will be explained first.

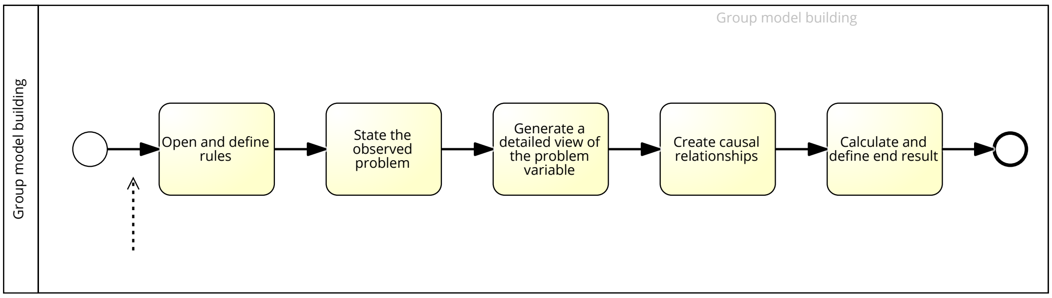

Figure 4.2: The main process of group model building: 1st data position.

When a group model building session begins, some specifics are already known (as is shown in figure 4.3. For instance, it is know which participants (identified by a name) will participate in the group model building session and what their function within the company is (e.g. CEO, sales manager, head of the marketing department etc.). It is required that a participant represents some department, and therefore, the function is a basic requirement to participate in a session.

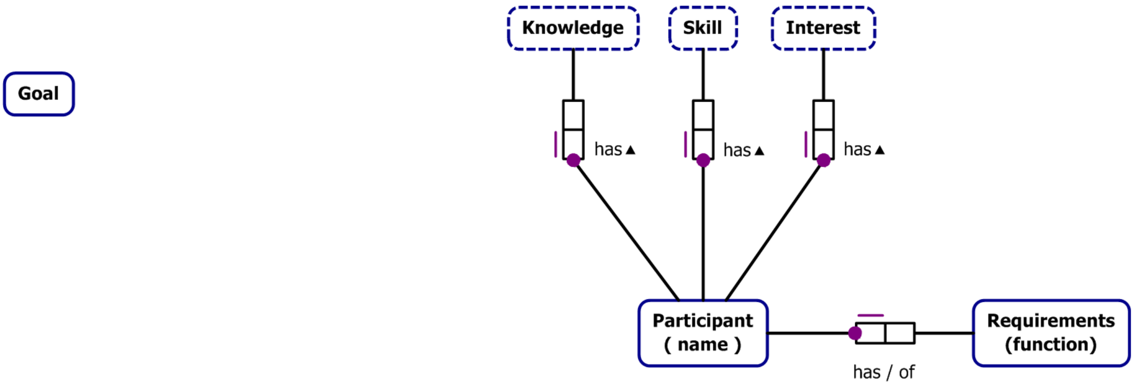

Figure 4.3: The main process of group model building: data on the 1st position.

Every participant has some knowledge of the company. For instance, an IT employee has specific knowledge about the way the IT-system works, while the financial employee has specific knowledge about the profits and growth that are being generated by the company. Also, a participant has some specific skill, like programming for the IT employee or book keeping for the financial employee.

Last, a participant has some specific interest within the company. The not uncommon situation (as described in section 1.2) showed that the head of the marketing department did not want that the HR department would bring in some bright minded people, as he felt the marketers where the most bright minded people within the company, and therefore, did not want to step down in the ladder of respect when it comes to intelligence. One can imagine that *interest* can be of great influence to the decisions being made within the group model building session.

Whenever a group model building session starts, not only the participants with their information are known, also the goal of the session is known. This goal is the reason a group model building session is being picked up. When we look at the situation of the introduction (section 1.2), the declining profits where the reason to start a group model building session.

An important thing to note here is that a goal is not the same as the interest of a participant. A goal is a given which is widely supported in solving it. Everyone wants to solve the declining profits, therefore this is the goal. Whenever there is talked about the details of the solution, the interests of the individuals comes forward.

When we are at this point in the process (as shown in figure 4.2), we can only start with the first step of group model building, when the data is known as shown in figure 4.3. Therefore, we can conclude that figure 4.3 represents the precondition of the action *Open and define rules*. This creates also a formal report which is given below.

Precondition for *Open and define rules*:

- Goal
- Participant with
  - name
  - function
  - knowledge
  - skill
  - interest

To conclude, only when the list above is being met, the action *Open and define* may start.

4.1 Open and define rules

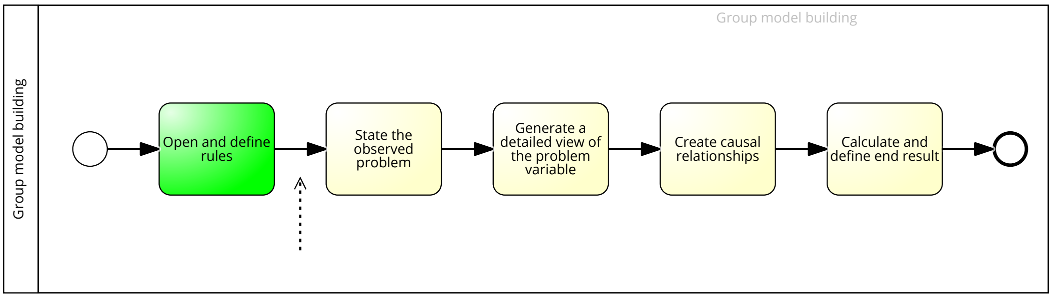

FIGURE 4.4: The main process of group model building: 2nd data position.

Figure 4.4 shows us where we are now in the main process of group model building. The step *Open and define rules* welcomes the participants to the session and introduces them to the group model building technique. As this is a very trivial part of group model building, it is not being explained in more detail in the following chapters. Within *Open and define rules*, it is also being explained in which way people can talk to each other and to what extend an overall discussion is allowed.[1] Last, the steps of group model building are presented to the group, as they then have a feeling of what is expected of them.

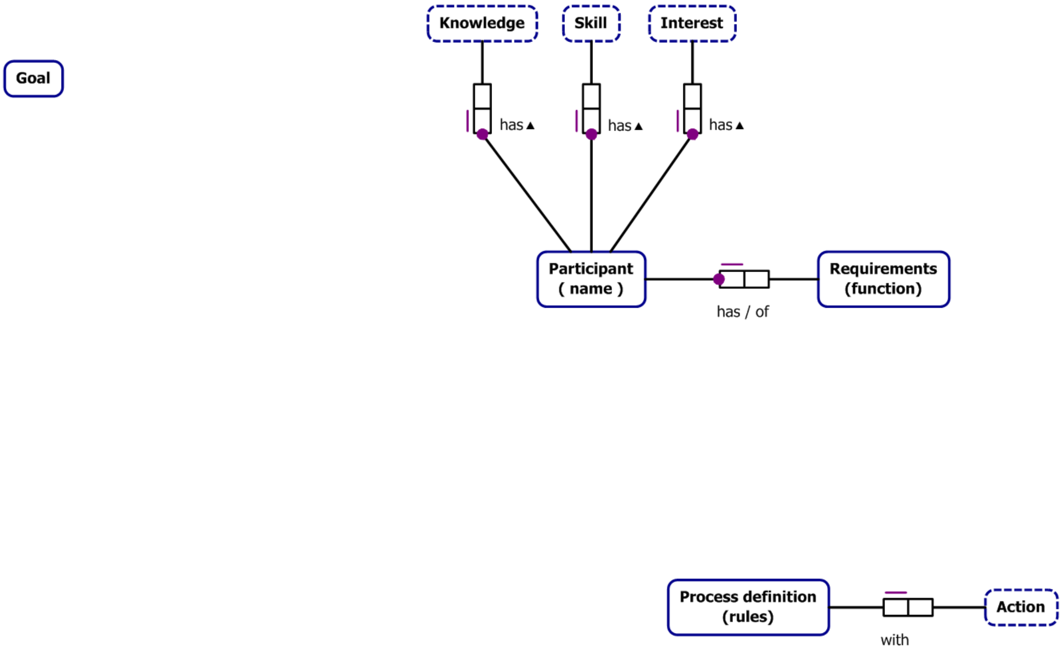

FIGURE 4.5: The main process of group model building: data on the 2nd position.

This means there is a *process definition* which is defined by *rules*. Also, this process definition can contain some actions, these actions can for instance be the explanation to the participants about the group model building steps. Also these actions can define

[1] Vennix (1996) and Rouwette and Franco (2014) called this *reference mode of behavior*.

some instruction for the participants.[2] Figure 4.5 shows us the construction of this data. One can imagine that the knowledge of the participant has been enriched with processes of group model building as well as with the basic rules of engaging other participants.

The post-condition for *Open and define rules* has now been modeled with figure 4.5. But, this model is also the precondition for the next step, namely *State the observed problem*. Therefore we can conclude that the list (and thus the formal report) of the data that is known at this place in the process, is as shown below. To conclude, this thus means that the step *State the observed problem* can only start when these data requirements are met.

Post-condition for *Open and define rules* and precondition for *State the observed problem*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
  - skill
  - interest
- Process definition defined by rules, and actions

[2] Due to the way the main process is divided, there are not much actions defined in between. When the processes are being looked in greater detail in chapter 5, the function of this concept will be clearer.

4.2 State the observed problem

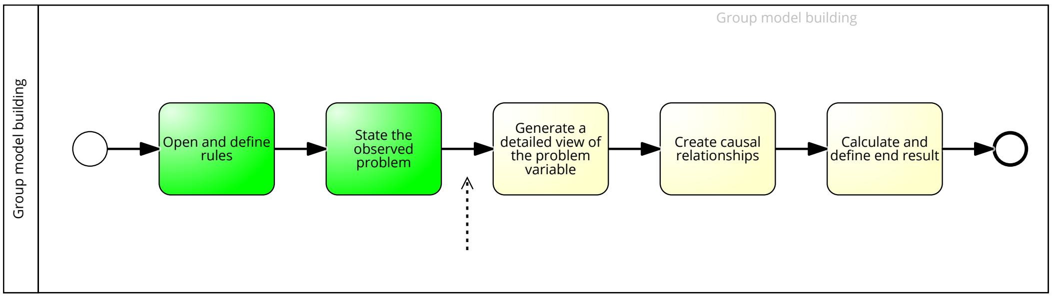

FIGURE 4.6: The main process of group model building: 3rd data position.

After the step *State the observed problem*[3] is finished (as is shown in figure 4.6), we can now define what has been created in this step, and therefore, what is necessary to start the next step, namely *Generate a detailed view of the problem variable.*

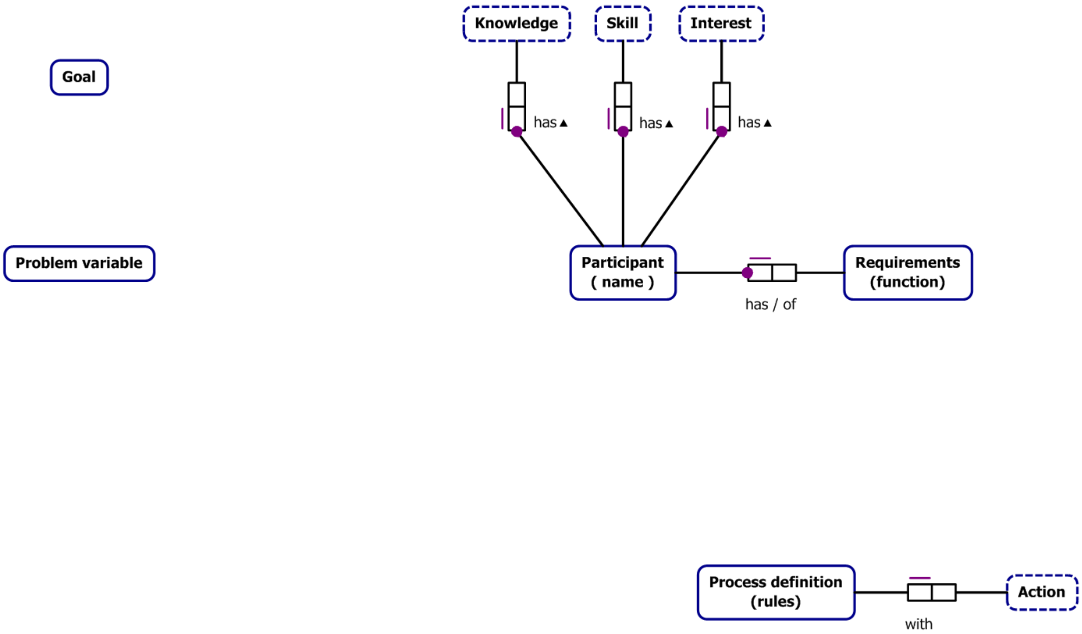

FIGURE 4.7: The main process of group model building: data on the 3rd position.

The step *State the observed problem* defines the main question that is being answered in the group model building session. Both the goal and the main question are things that must be solved, but there is a small difference. The main question is defined in a variable fashion, and the goal is not. For instance if we look at the example situation of section 1.2 the goal would be *"to solve the declining profits to protect the company from going down."* A question defined in a variable fashion would be <profit>, because that is the variable with unwanted behavior. This behavior must be assorted to understand the messy problem the company has to cope with. Therefore the variable can be seen as a problem variable (see figure 4.7.

[3]As *State the observed problem* is trivial, it is not being explained in more detail in the following chapters.

It is very important to define this problem variable correctly. When it is not defined correctly, the group may solve the wrong problem, or it can be very difficult to create consensus within the group. For instance, when a mediator just writes down "profit" without checking this first with the group, you can assume that there is going to be some uncontrolled debate, and that is something that must be avoided at all times within a group model building session. Therefore it must also be clear that the participant has an understanding of the problem variable, in other words, he must know what the problem variable is, and therefore it is part of the knowledge of the participant.

The data shown in figure 4.7 thus represents the post-condition of *State the observed problem*, and represents the precondition of *Generate a detailed view of the problem variable*. Only when these data requirements are met, *Generate a detailed view of the problem variable* may start.

Post-condition for *State the observed problem* and precondition for *Generate a detailed view of the problem variable*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
  - skill
  - interest
- Process definition defined by rules, and actions
- Problem variable

4.3 Generate a detailed view of the problem variable

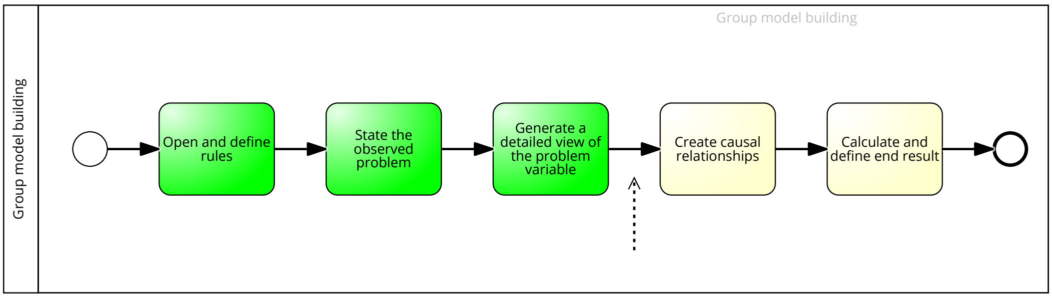

Figure 4.8: The main process of group model building: 4th data position.

Generate a detailed view of the problem variable is the equivalent of the *NGT on variables* step of Vennix (1996), Rouwette and Franco (2014). In this step, detail of the problem variable is being created. Detail can be seen as variables that come to mind when we thinks about the problem variable. For instance, when we think about <profit>, we likely think about <sales volume> and <cost>. We will not have a comprehensive look at how the list of details is being obtained here, as this will be done in section 5.1.

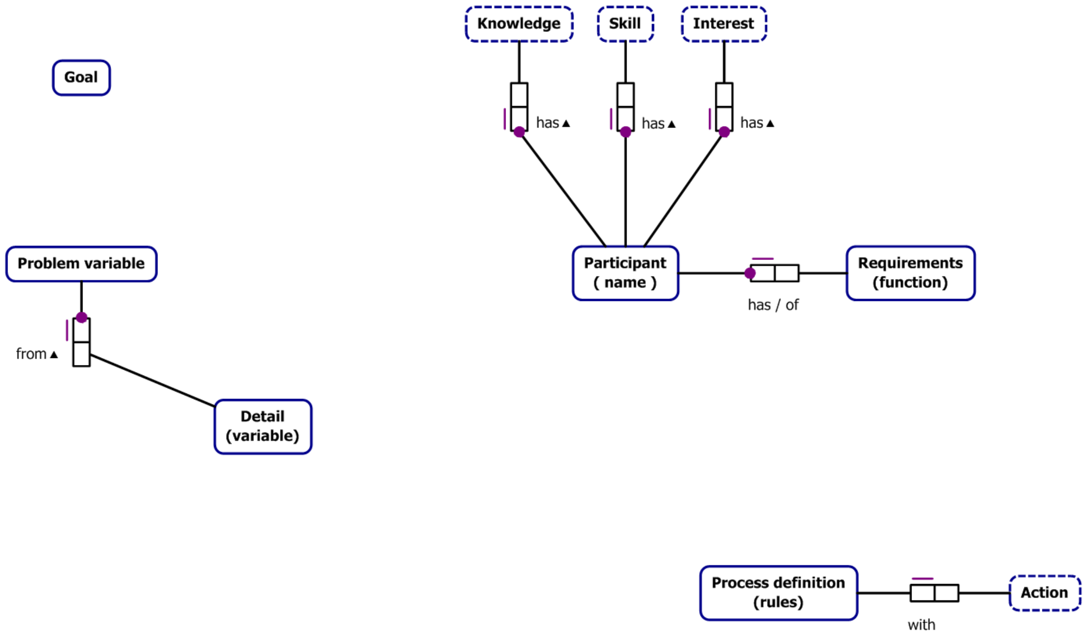

Figure 4.9: The main process of group model building: data on the 4th position.

When we look at how the data looks at the position shown in figure 4.8, the only thing that has being added is the list of detail. This list of detail is derived from the problem variable, so there is an explicit relation between them. Also the knowledge of the participant has been extended with this list of variables, as they all participated in the creating and sharing of this list. Therefore the data will look as shown in figure 4.9.

Here we can see that the detail is being identified by the type variable, and we can see that the problem variable has become part of the detail.[4]

The data, as showed in figure 4.9, thus forms the post-condition of *Generate a detailed view of the problem variable* and the precondition of *Create causal relationships*. This means that the latter can only start when these data requirements (as shown in the list below) are met.

Post-condition for *Generate a detailed view of the problem variable* and pre-condition for *Create causal relationships*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
  - skill
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself

[4] The *problem variable* can be seen as a *variable*, and therefore, as part of the list of variables, namely the *detail*.

4.4 Create causal relationships

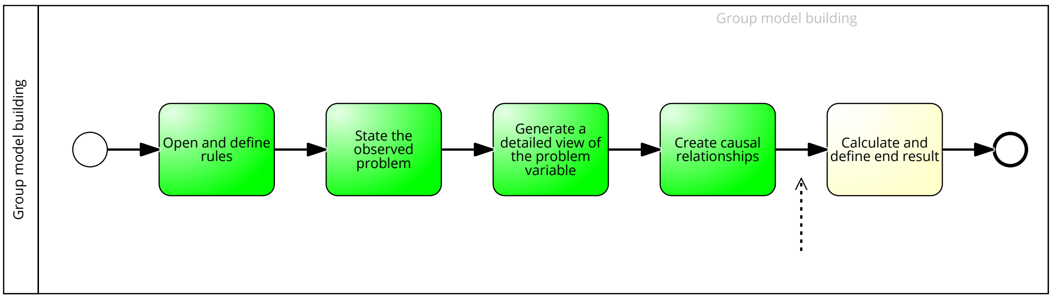

FIGURE 4.10: The main process of group model building: 5th data position.

After the step *Create causal relationships* (see figure 4.10) has finished, the variables of the list with detail have been connected to each other. This creates a system dynamics model (Forrester, 1975), where the relationships are defined as: positive, negative, context-dependent, and not of influence. Rouwette and Franco (2014) only work with positive and negative relationships, and leave the other relationships out. For the sake of formalization, every possible relationship must be processed, but you are allowed to say that variables are not influencing each other or that it is context-dependent. This creates a full system dynamics model, where all the possible influences are being modeled, and thus, creates a more sound quantitative analysis.

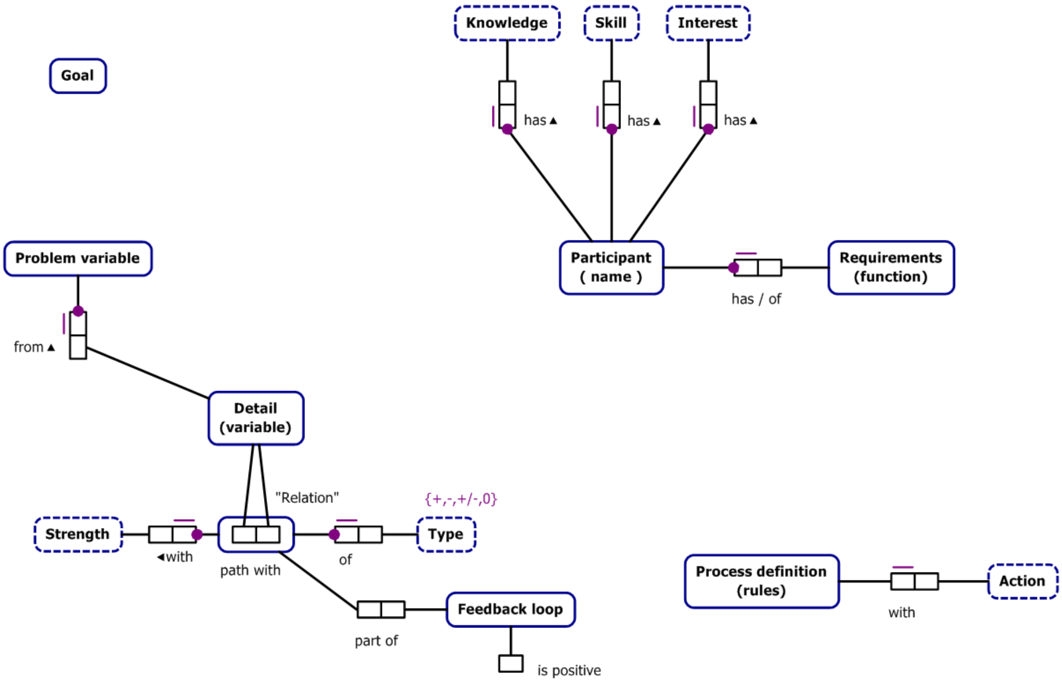

FIGURE 4.11: The main process of group model building: data on the 5th position.

We will not explain how these relationships are being derived from the group here, as this will be done in section 5.2. If we look at the data model as shown in figure 4.11, we can see that in this phase a lot of extra data is being modeled. Every part of detail is a variable so a *relation* is the connection of two variables. Like said before, every relation is of the *type*: positive, negative, context-dependent, or not of influence. Also a relation is of a specific strength, so it can be used within the quantitative analysis. Because quantitative analysis is out of the scope of this thesis, we will not describe the concept *strength* any further.

The last things that have been created after *Create causal relationships* are the feedback loops.[5] These loops are the most interesting part of the group model building sessions, as they represent the slippery nature of the messy problem. Also the type of a feedback loop has been defined.

The relations together with the defined feedback loops are now part of the presented system dynamics model, and therefore, are part of the knowledge of the participant. It can be very likely that the interest of a participant has changed at this stage, given the fact that the participant now may have a totally different view of the messy problem. Also his skills are expended with the ability to build a system dynamics model, as they now had a practical example of it.

This said, figure 4.11 represents the post-condition of *Create causal relationships* as well as the precondition of *Calculate and define end result.* This data (as shown below) thus is necessary to start *Calculate and define end result.*

Post-condition for *Create causal relationships* and precondition for *Calculate and define end result*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

[5]See section 2.2.1 for an explanation of these feedback loops.

4.5 Calculate and define end result

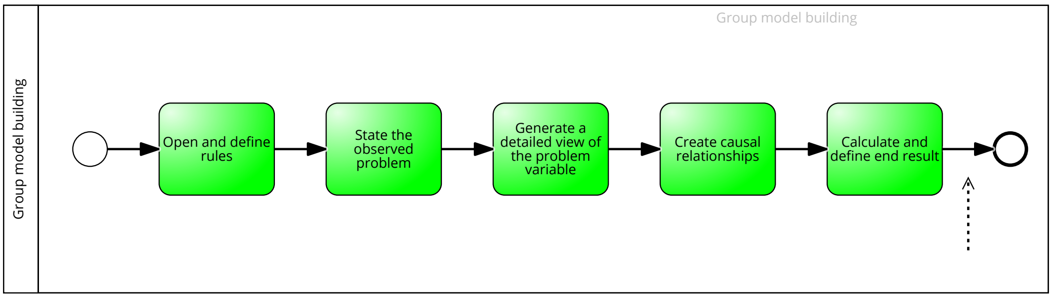

FIGURE 4.12: The main process of group model building: last data position.

After the step *Calculate and define end result* (see figure 5.91), the group model building session is finished. The closing of the session is the last action and stays the main action until a new group model building sessions is started. Now, not only the solution to the messy problem is being defined as variables, also there are some simulations that prove that the solutions lay in those variables. See section 5.3 for a detailed view of *Calculate and define end result* and for a detailed view of the construction of this data.

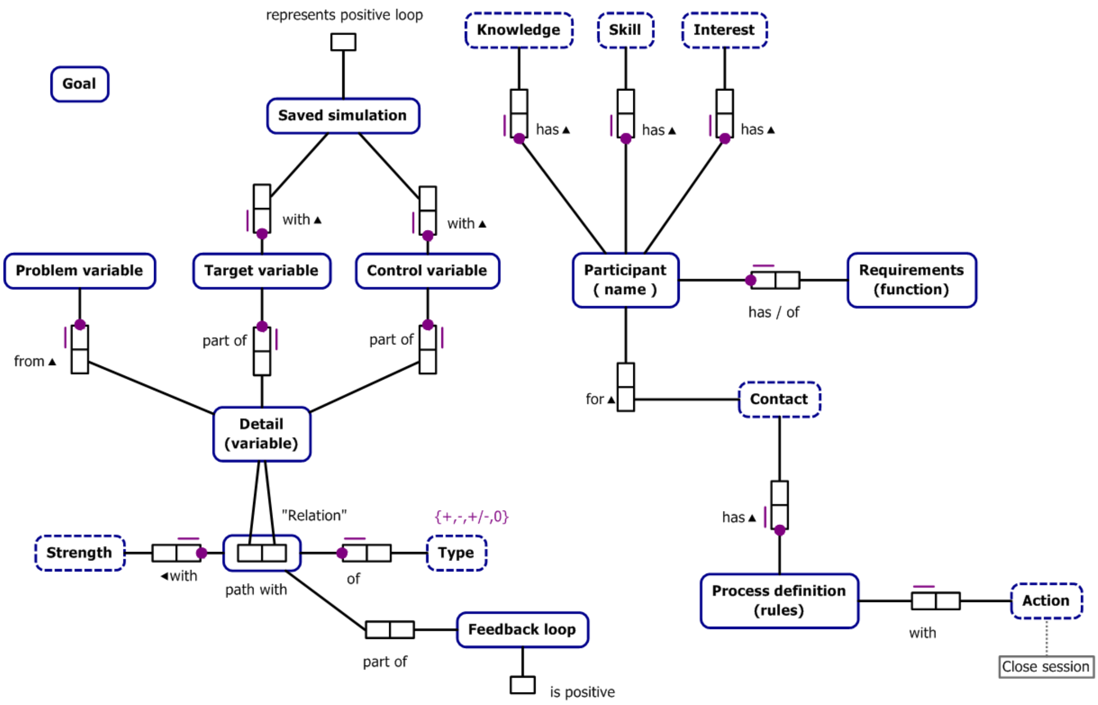

FIGURE 4.13: The main process of group model building: data on the last position.

The solution is defined by *target variables* and *control variables.* The first are the ones that you want to change (in order to change the problem variable), and the latter are the ones you can control as a company in order to change the target variables. If we look at the situation of the introduction (see section 1.2), you can imagine that <growth> and <cost> are target variables as they influence <profit>. Also after the session, the company has defined some control variables that the company is capable of changing them. Also the changing influence of the control variables, has been defined.

One can imagine this opens an unbiased discussion of what the solution could be. Now a sales manager may not be able to sketch a doom scenario for the company when they want to change some variable, as these have all been modeled, and the effects when changing them have been simulated. This also creates an incentive for more mutual understanding and respect between the participants, as they now understand each other's concerns about the changing of some variables.

The products of the group model building session are the *target variables* and the *control variables* with the supporting proof of the *simulations* that can be used within a debate. Also a *contact* will be given to the participant, which they can use if they need an extra explanation of the model or of the simulations.

As this is the end of group model building, it means that the model as described in figure 4.13 not only represent the post-condition of *Calculate and define end result*, but also of the total group model building session. Therefore we can conclude that only when these data requirements (as shown below) are met, the group model building session is finished.

Post-condition for *Calculate and define end result*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - an understanding of the effects of the variables
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative
  - that are simulated

- target variables
- control variables
- simulations
- contact information for question in the future

Now we have seen the formalization of the main process of group model building, we can look at the more detailed formalization of the sub-processes. These will be discussed in the next chapter. Also, a point has to be made, namely when we look at the role of the mediator and the recorder. These roles have been left out as these are considered out of scope of this thesis. These roles will be discussed in chapter 6, in which the further research suggestions are given.

Chapter 5

Group model building in greater detail

This chapter will look at the group model building technique in greater detail. The process models and data models made in chapter 4 are seen as the basis for the modeling of the detail. The pre- and post-conditions of chapter 4 can be seen as an agreement for how the detail should begin and end. Therefore, while we create the detailed processes we will check afterwards if the final post-condition matches the post-conditions of chapter 4.

Due to the amount of work, the readability, and the requirement for a bachelor's thesis, some detail is left out. The first two sub-processes of the main process of group model building,[1] namely *Open and define rules* and *State the observed problem*, are not modeled in detail, because this would not create any significant new information, since this has already been created in chapter 4. Beyond that, some other sub-processes are not being modeled in greater detail, because this is outside the scope of this thesis. Whenever a process is left out, it is colored red in the model.

The other sub-processes *Generate a detailed view of the problem variable* (section 5.1), *Create causal relationships* (section 5.2), and *Calculate and define end result* (section 5.3) will be modeled in detail as follows: First, we look at which data (and therefore which precondition) is already known before this process starts. Then, we will look at the process in more detail (which in turn will again create a chain of processes). Next, we will look the pre- and post-conditions of those more detailed processes (which will also create a formal report, and is defined by data models). And last, we check if the last post-condition matches the post-condition of the same position as defined in chapter 4.

[1] See figure 4.1 for the main process of group model building.

5.1 Generate a detailed view of the problem variable

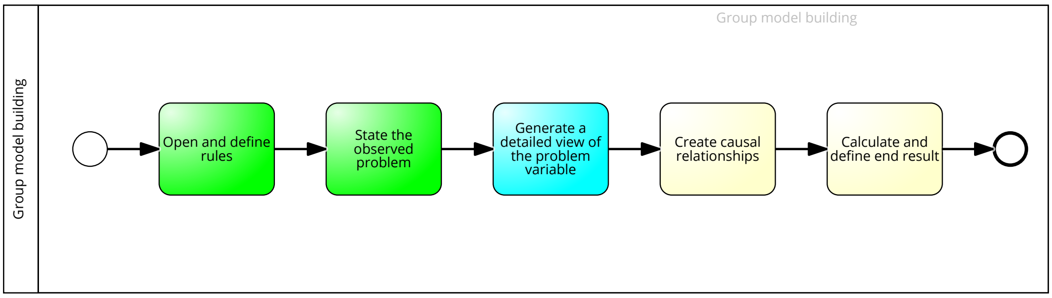

FIGURE 5.1: The position of Generate a detailed view of the problem variable in the main process (denoted in blue).

This section will discuss the detailed models of the third sub-process in the main process of group model building, namely *Generate a detailed view of the problem variable* (see figure 5.1). This sub-process is the group model building's implementation of the *nominal group technique* (Delbecq et al., 1975).[2] Therefore, these processes mostly matches the processes of the nominal group technique, as can be seen in figure 5.2. Remember that within group model building, the nominal group technique is used to generate variables to eventually create a system dynamics model.

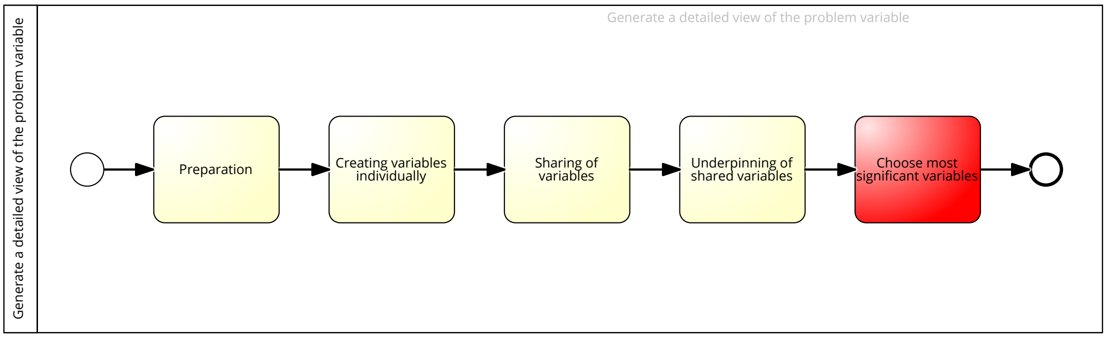

FIGURE 5.2: Generate a detailed view of the problem variable - main process.

If we look at the process chain of figure 5.2, we see that it consists of five processes, namely *Preparation* (section 5.1.1), *Creating variables individually* (section 5.1.2), *Sharing of variables* (section 5.1.3), *Underpinning of shared variables* (section 5.1.4), and *Choose most significant variables* (out of scope, therefore denoted in red). The last one is out of scope, because we assume for this thesis that all the variables that are shared will be used in the next phase. Therefore, choosing among them would be useless. The four remaining processes will be discussed in the following sections.

We will walk through the process sequentially, starting at the beginning. See figure 5.3, we know at this point how the data looks, because the precondition of *Preparation* is the same as the precondition of *Generate a detailed view of the problem variable* of the main process of group model building. Therefore, in order to start with *Preparation*, the data requirements (like in figure 5.4), should be met.

[2]See section 2.1.4 for an explanation of the nominal group technique.

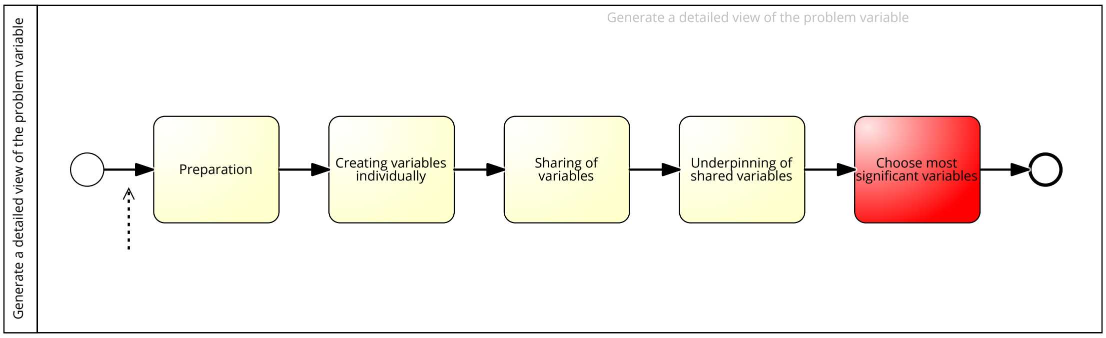

FIGURE 5.3: Generate a detailed view of the problem variable - 1st data position.

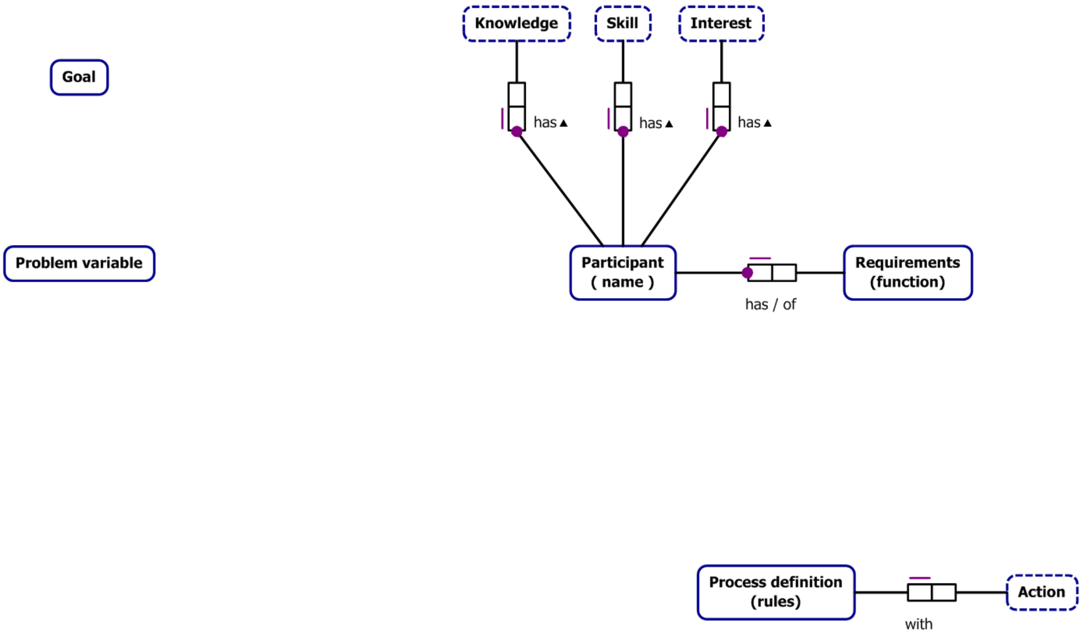

FIGURE 5.4: Generate a detailed view of the problem variable - data on the 1st position.

Remember that there is a *goal*, which is defined as something that must be solved. Like in our example of section 1.2, this would be *"how to stop the decreasing profits, to prevent the company from going down."* Then this *goal* was translated (in an earlier step of group model building) to a *problem variable*, in this case <profit>. Then there where *participants* who had *knowledge*, *skill*, and *interest*. Also the *requirement* for the participant to join the sessions was that he had a specific *function*, in other words represented a different part of the organization. Last, there where *process definitions* defined by *rules* and *actions*. In the main process, these were not so much defined, because of the way the processes were divided. In this chapter the importance of this concept will be made clearer.

To conclude, we can now present the list (and thus the report) of data that is necessary to start with *Preparation*. Remember it may only start when all these data requirements are met. Please note that this is exactly the same list as the *Post-condition for State the observed problem and precondition for Generate a detailed view of the problem variable* of section 4.2.

Precondition for *Preparation*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
  - skill
  - interest
- Process definition defined by rules, and actions
- Problem variable

5.1.1 Preparation

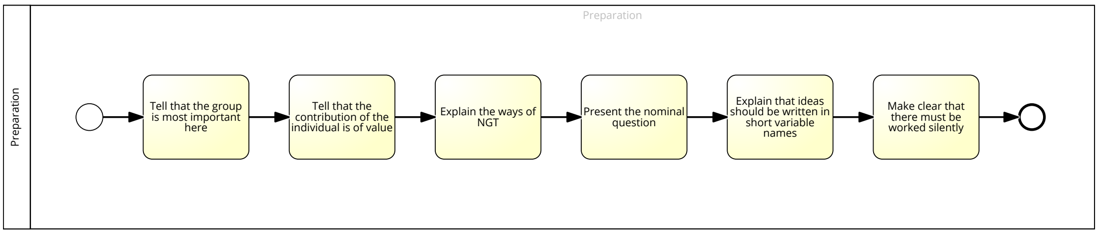

FIGURE 5.5: Overview of the preparation step.

The *Preparation* step is not that complex at all. It contains six sequential steps that will prepare the participant for the nominal group technique, see figure 5.5. To clarify this chain of steps, including the effect of the steps on the data model, we will look at them sequentially.

- *Tell that the group is most important here*: In this step, the participants are being made aware (by the mediator) of the fact that the group as a whole is the only entity that can deliver knowledge. Herewith, it is tried to create some mutual respect and trust in each other, as participant may began to realize that the solution must be found with these other participants. If we look at the data model, we will see that the knowledge of the participant for now is extended with the fact that the group is told to be important. The participant may not believe this, but he or she is aware that the group is found important.

- *Tell that the contribution of the individual is of value*: With this step, participants are being made aware that a group consists of individuals, and that the individuals have to produce the knowledge. This is the nominal aspect of nominal group thinking: Knowledge created individually (which per participant can be very little) is combined into one big pile of knowledge of the group. If we look at the data model here, we see that in this step the knowledge of the participant is also extended with this notion.

- *Explain the ways of NGT*: Here, the steps, rules, and regulations of the nominal group technique (NGT) are being explained. If we look at the data model, we will see that the process definition for the nominal group technique is created here. The rules are simple, discussion or consultation without the approval of the mediator is forbidden. The actions are as follows: First individual knowledge is written down, without any consultation or discussion (section 5.1.2). Next, the knowledge is shared with the group and written down centrally, also without consultation or discussion (section 5.1.3). Last, questions may be asked if any central collected knowledge is not clear (section 5.1.4). If a participant does not agree for instance with a variable, discussion and consultation is allowed here, but the mediator must have made clear, that the knowledge of the group as a whole, and not of the individual, is collected.

- *Present the nominal question*: In this step, the mediator will formulate a nominal question. If we look at the example situation from the introduction (section 1.2), this nominal question could be: "What variables influences profit within your organization?" This creates another concept, namely a label type *Nominal question* that is connected to the concept *Problem variable*. Also the knowledge of the participants is extended with the notion of the nominal question.

- *Explain that ideas should be written in short variable names*: Herewith, it is prevented that participants write small stories of experiences, or small sentences of what they mean. Participants are being made aware that their answers to the question should be written as small variables, for instance if we look at the nominal question above, an answer could be <growth>. This is also a rule that expands the data inside the *process definition* concept.

- *Make clear that there must be worked silently*: The mediator elucidates again that only with his approval, discussion and consultation is allowed, and for the next step (which will be explained in the next section), participants must work silently.

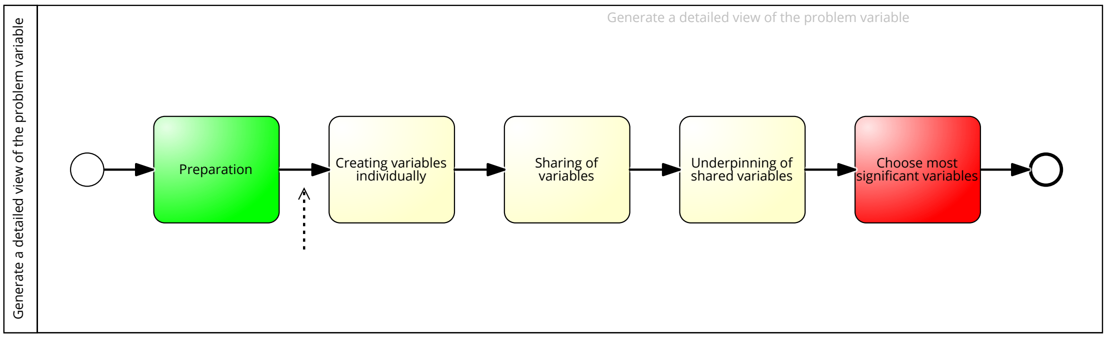

FIGURE 5.6: Generate a detailed view of the problem variable - 2nd data position.

After the step *Preparation* has completed (see figure 5.6), the data model has changed a bit. As explained above, the *knowledge* of the participants and the *process definition* is being expanded. However, this does not create new concepts for the data model, but fills the data within these concepts. The only concept that is created here, is the concept *Nominal question*. Therefore, the only difference you will see in the data model is the addition of the concept *Nominal question*. Figure 5.7 shows the data model at the position as shown in figure 5.6.

The fact that the data model only changed with the addition of the extra concept *Nominal question*, does not mean that the data inside the concepts did not change. As said above, the *knowledge* of the participants, and the *process definition*, has expanded. Therefore, the list of data requirements, that has to be met in order to start with the next step (*Creating variables individually*), has changed as follows.

Post-condition for *Preparation* and precondition for *Creating variables individually*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building

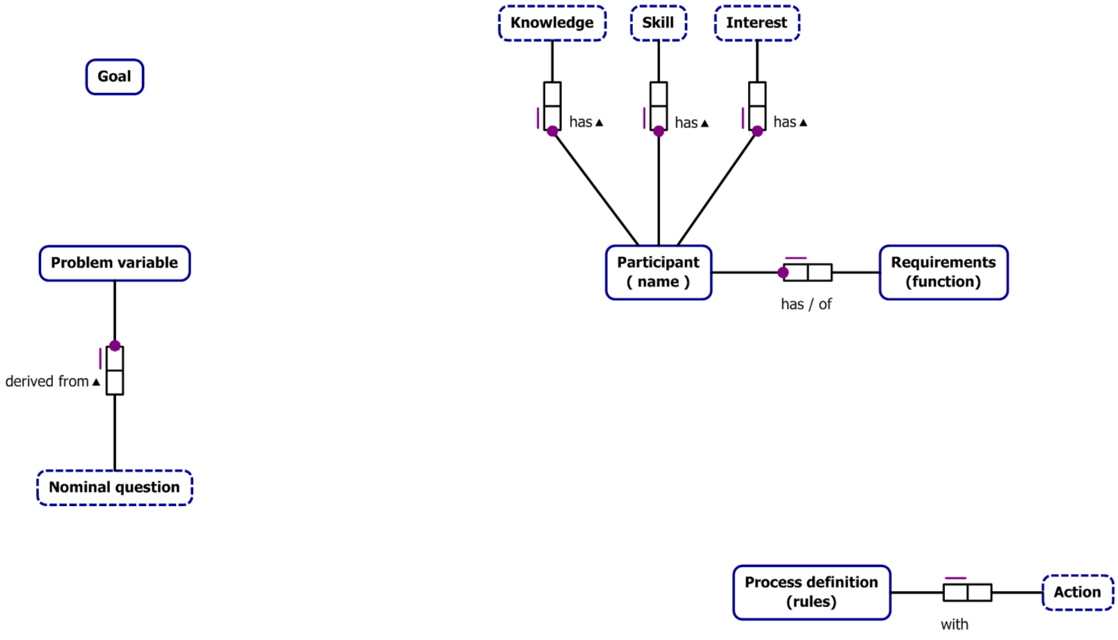

FIGURE 5.7: Generate a detailed view of the problem variable - data on the 2nd position.

  * an understanding of the way participants may interact with each other
  * problem variable
  * notion that the group is found to be important in this phase
  * notion of that the knowledge must be produced by the individuals
  * notion of the nominal question
- skill
- interest

- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: First individual knowledge is written down, without any consultation or discussion. Next, the knowledge is shared with the group and written down centrally, also without consultation or discussion. Last, questions may be asked if any central collected knowledge is not clear.
  - the rule that answers should be written as small variables
  - the rule that in the next step there will be worked silently
- Problem variable with a nominal question

5.1.2 Creating variables individually

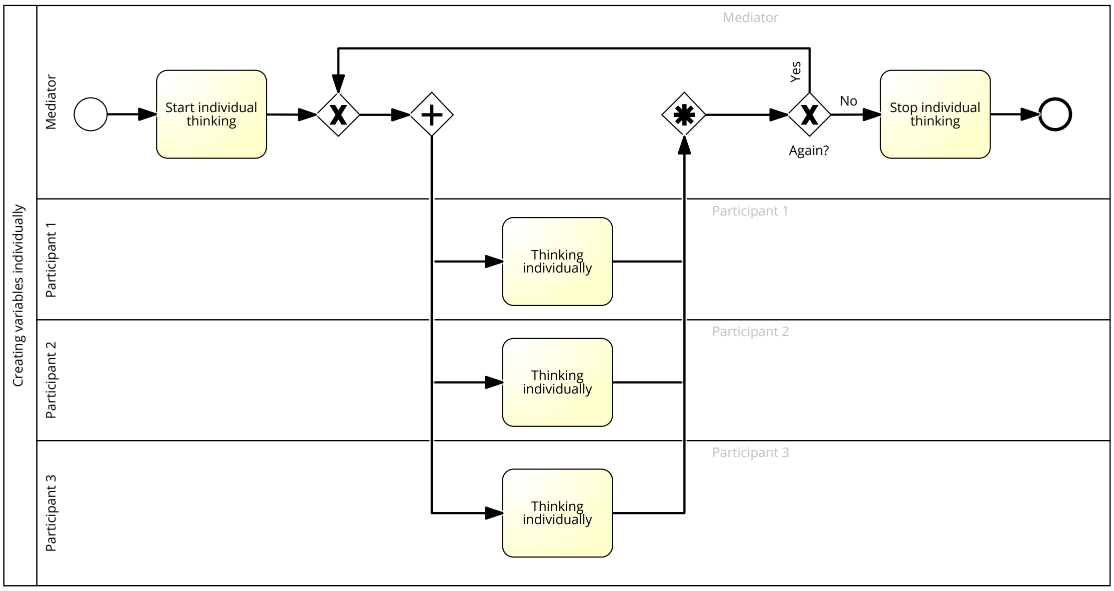

FIGURE 5.8: An overview of Creating variables individually.

With the step *Creating variables individually*, as seen in figure 5.8, the group will generate answers to the nominal question in a variable form. This is the phase where discussion and consultation between the participants is absolutely forbidden.

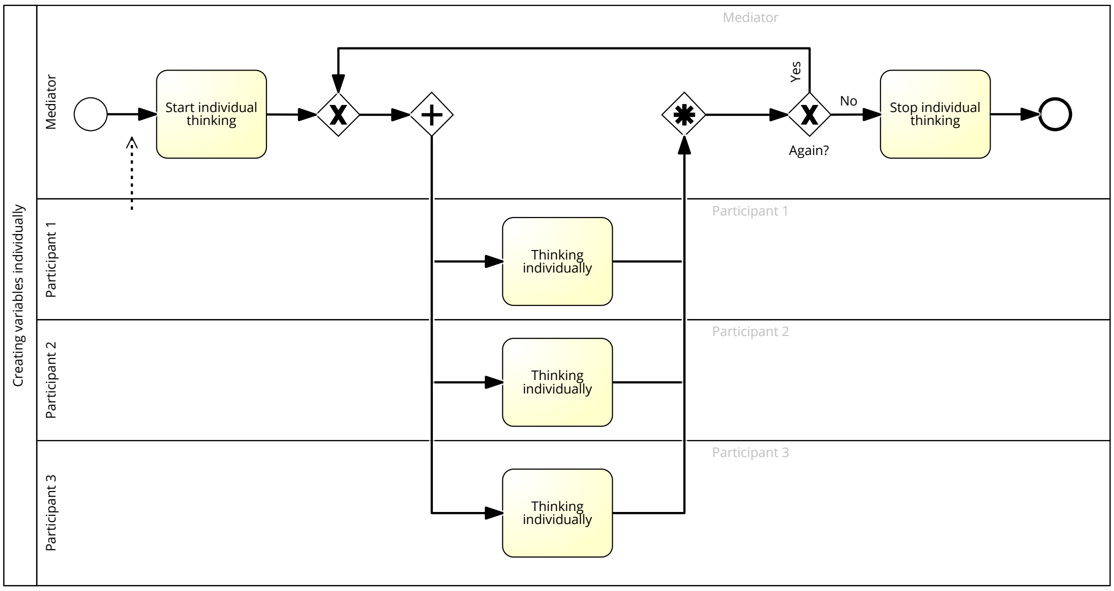

FIGURE 5.9: Creating variables individually step - 1st data position.

Creating variables individually has 3 steps, namely *Start individual thinking*, *Thinking individually*, and *Stop individual thinking*, of which the middle can loop until the mediator stops the thinking phase. After *Start individual thinking* has commenced, the participants get about 5 minutes to think about an answer, until the thinking phase is stopped. The following sections will discuss these 3 steps. Figure 5.9 denotes the place where we are now in the overall process of *Creating variables individually*. There are no new concepts and no changes in the data, as this position is exactly the same as the last position of the *Preparation* step (see section 5.1.1). Therefore the list of the data that has to be met is still the same.

Post-condition for *Creating variables individually* and precondition for *Start individual thinking*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest
- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: First individual knowledge is written down, without any consultation or discussion. Next, the knowledge is shared with the group and written down centrally, also without consultation or discussion. Last, questions may be asked if any central collected knowledge is not clear.
  - the rule that answers should be written as small variables
  - the rule that in the next step there will be worked silently
- Problem variable with a nominal question

Start individual thinking

In the *Start individual thinking* step, the mediator makes clear that the thinking step has begun. The participants should know by now that this means they have to work silently, without discussion or consultation. They also know that they now have to write answers for themselves in a variable fashion. If we look at the situation of the introduction (section 1.2), this would be the place to write down <growth> and <cost>.

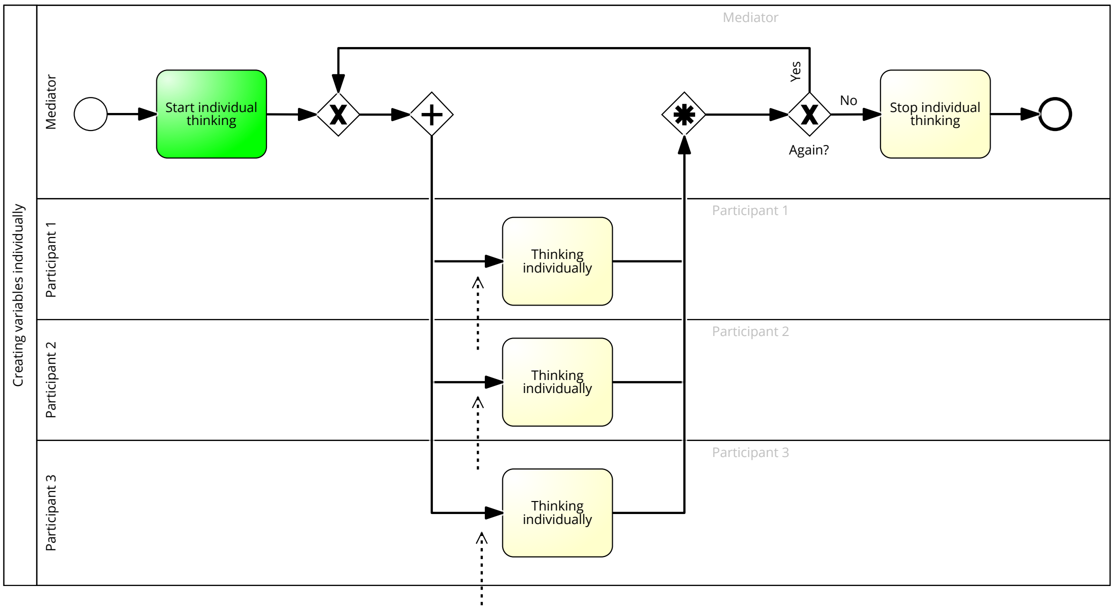

FIGURE 5.10: Creating variables individually step - 2nd data position.

Therefore, if we look at the data at the position shown in figure 5.10, there is changed something. Although no new concepts where derived, the data in the concept *Process definition* and the concept *action* has changed. The rules of no discussion and no consultation, have come into effect (*Process definition*), and there should be written answers individually (*action*). Therefore the post-condition for *Start individual thinking* and the precondition for *Think individually* is as follows. Remember, these data requirements have to be met before *Think individually* can start.

Post-condition for *Start individual thinking* and precondition for *Think individually*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals

        * notion of the nominal question
    - skill
    - interest

- Process definition defined by rules, and actions, such as
    - the rule that discussion or consultation without the approval of the mediator is forbidden
    - the notion that the actions next will be: First individual knowledge is written down, without any consultation or discussion. Next, the knowledge is shared with the group and written down centrally, also without consultation or discussion. Last, questions may be asked if any central collected knowledge is not clear.
    - the rule that answers should be written as small variables
    - Current action: Write answers individually and silently
- Problem variable with a nominal question

Think individually

The *Think individually* step is quite simple. In this step a participant thinks of exactly one answer in variable form. That is why this step is built into a loop, so the participant overall can think of more variables if he wants to. Also the example model shows three participants that can generate answers. These three branches are joined together by a so called *Complex port*[3], which means that none or more inputs have to enter to go further. This has been modeled in this way so it is not a restriction that every cycle, the three participants must all have generate a new answer. It is okay if one participant has thought of an answer, and the other have not.[4]

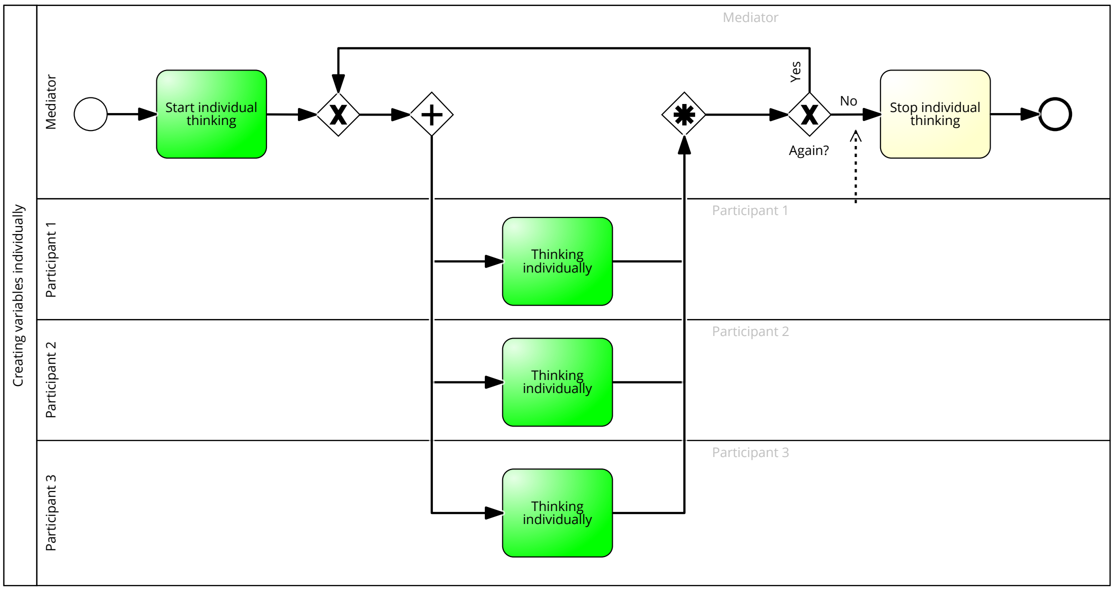

FIGURE 5.11: Creating variables individually step - 3rd data position.

After all the participants have finished and no new cycle has started, the XOR-port in the model will guide the participants further to the next step. The data on this position (see figure 5.11), is changed quite a bit. There has been created two new concepts, namely *Variable* with *Underpinning* (see figure 5.14). The variable is an answer that is written down by the individual participant. No participant just writes some variable down, it always has some sort of a reason. Therefore the variable has some underpinning to go with it. A participant is always able to explain why he has written something down.

This means that the post-condition of *Think individually* and the precondition of *Stop individual thinking* is as the list below. These data requirements should be met to start with *Stop individual thinking*.

Post-condition for *Start individual thinking* and precondition for *Think individually*:

- Goal

[3]A complex port is displayed as a star.

[4]This cycle is not actuated by the participant, but happens automatically. Also, none of the participant will notice if they have entered a new cycle, as they just write a new answer down. The reason this has been modeled like this, is the notion that it otherwise would not be clear in the model that the thinking of answers is quite flexible.

- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants are allowed to interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest
  - variable with underpinning (may be more than one)
- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: First individual knowledge is written down, without any consultation or discussion. Next, the knowledge is shared with the group and written down centrally, also without consultation or discussion. Last, questions may be asked if any central collected knowledge is not clear.
  - the rule that answers should be written as small variables
  - Current action: Write answers individually and silently
- Problem variable with a nominal question

Stop individual thinking

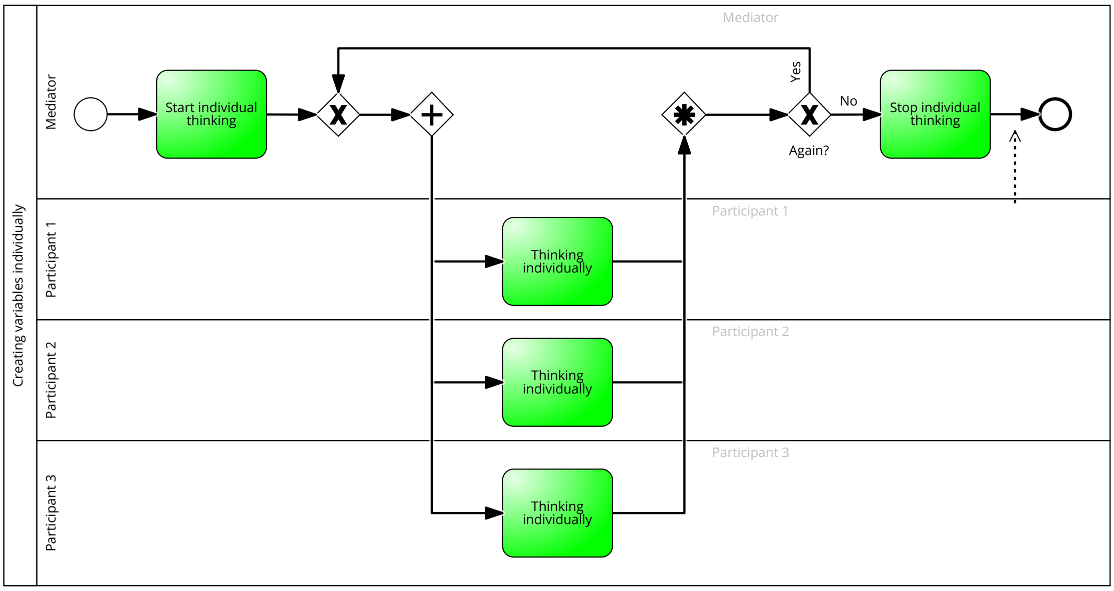

FIGURE 5.12: Creating variables individually step - last data position.

Now the mediator stops the individual thinking phase (see figure 5.12). At this point, the current action is not anymore to write down answers, and participants are still not allowed to discuss or consult with the other participants about the things they might have written down.

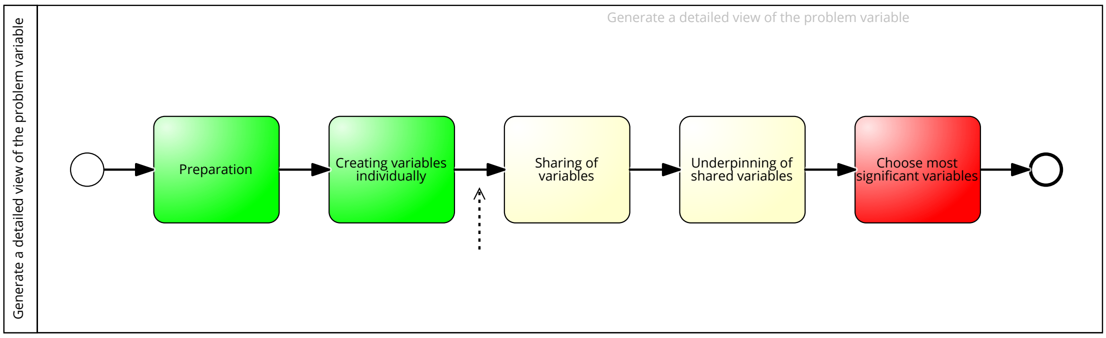

FIGURE 5.13: Generate a detailed view of the problem variable - 3rd data position.

The ceasing of the action is (together with the notion that the thinking step is over),[5] a thing that has changed in the data at the point as shown in figure 5.12, which is exactly the same point as figure 5.13, as this is the end of *Create variables individually*. Also the rule that answers should be written as small variables, is no longer important. The data model of these positions is shown in figure 5.14. Therefore we can now describe not only the post-condition of *Stop individual thinking* but also of *Creating variables individually*, as these are exactly the same. This would also be the precondition for *Sharing of variables*, so this step may only start when these data requirements are met.

[5]The participants thus know that there are 2 steps remaining.

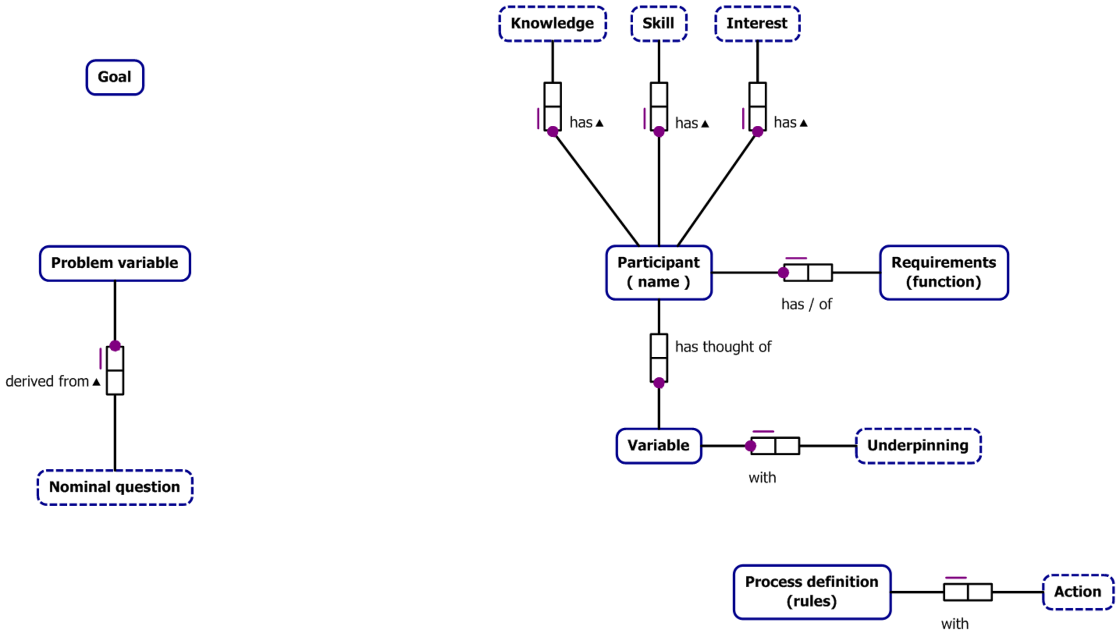

FIGURE 5.14: Generate a detailed view of the problem variable - data on the 3rd position.

Post-condition for *Stop individual thinking* and precondition for *Sharing of variables*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants are allowed to interact with each other
    * problem variable
    * notion that the group is found to be important in this phase
    * notion of that the knowledge must be produced by the individuals
    * notion of the nominal question
  - skill
  - interest
  - variable with underpinning (may be more than one)
- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: The knowledge is shared with the group and written down centrally, without consultation or discussion. Then, questions may be asked if any central collected knowledge is not clear.
- Problem variable with a nominal question

5.1.3 Sharing of variables

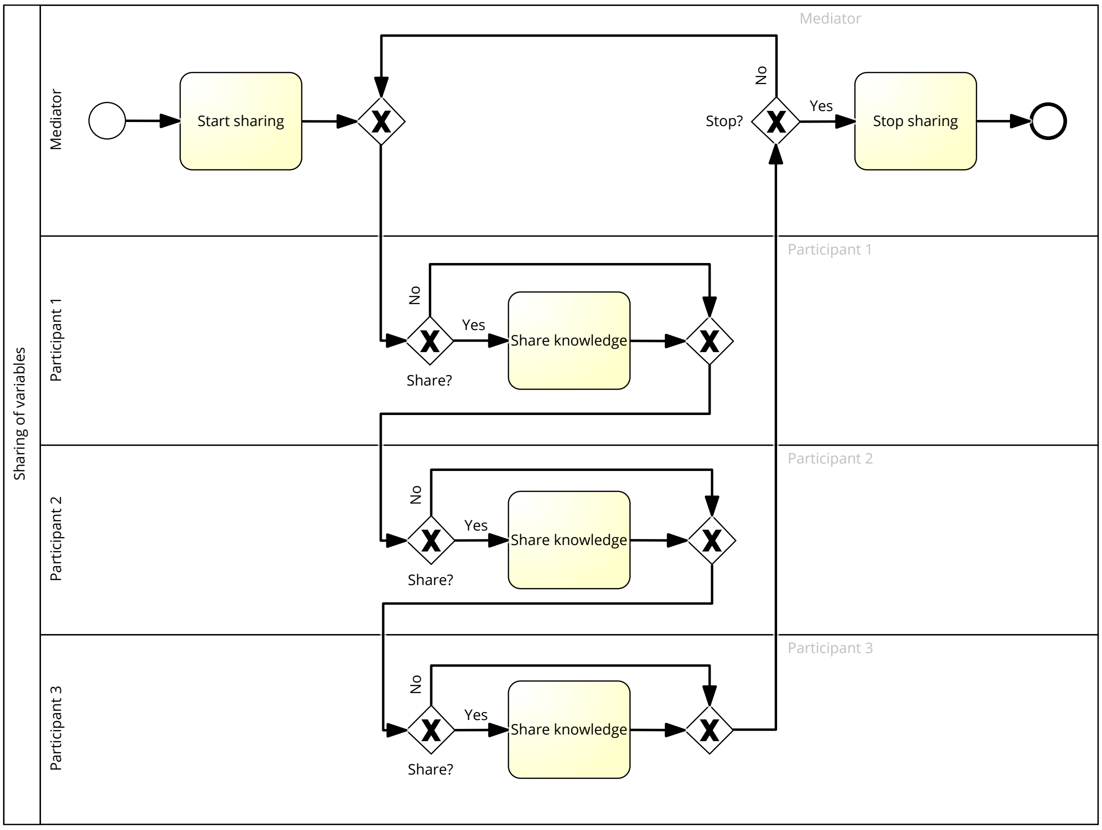

FIGURE 5.15: An overview of the sharing of variables step.

The previous step was about the creation of variables. Now the sharing of these variables will take place (see figure 5.15). This will happen in a round-robin fashion.[6] With each round the participant is allowed to say a maximum of one variable. If a participant does not have a variable to share, or he just want to pass this round, he is allowed to do so.

Let us look at the process *Sharing of variables* in more detail. It contains three steps, namely *Start sharing*, *Share knowledge*, and *Stop sharing*, of which the middle can loop, just as with the creation of knowledge in section 5.1.2. The following sections will look at the effect of these steps on the data.

But first, we start at the position as is shown in figure 5.16. This position is exactly the same as the last position of the previous section. Therefore the pre- and post-condition is exactly the same as well. So, the formal report at this position, and the precondition for *Start sharing*, is as shown below. Remember that this data requirement has to be met in order to start with *Sharing of variables* in general, and *Start sharing* in specific.

Post-condition for *Creating variables individually* and precondition for *Start sharing*:

- Goal

[6]Round-robin means that the participants are one at a time, sequentially in a circle. Given the fact they sit in a U-shape, this means starting at one end of the U and go one at the time to the other end, and start over again.

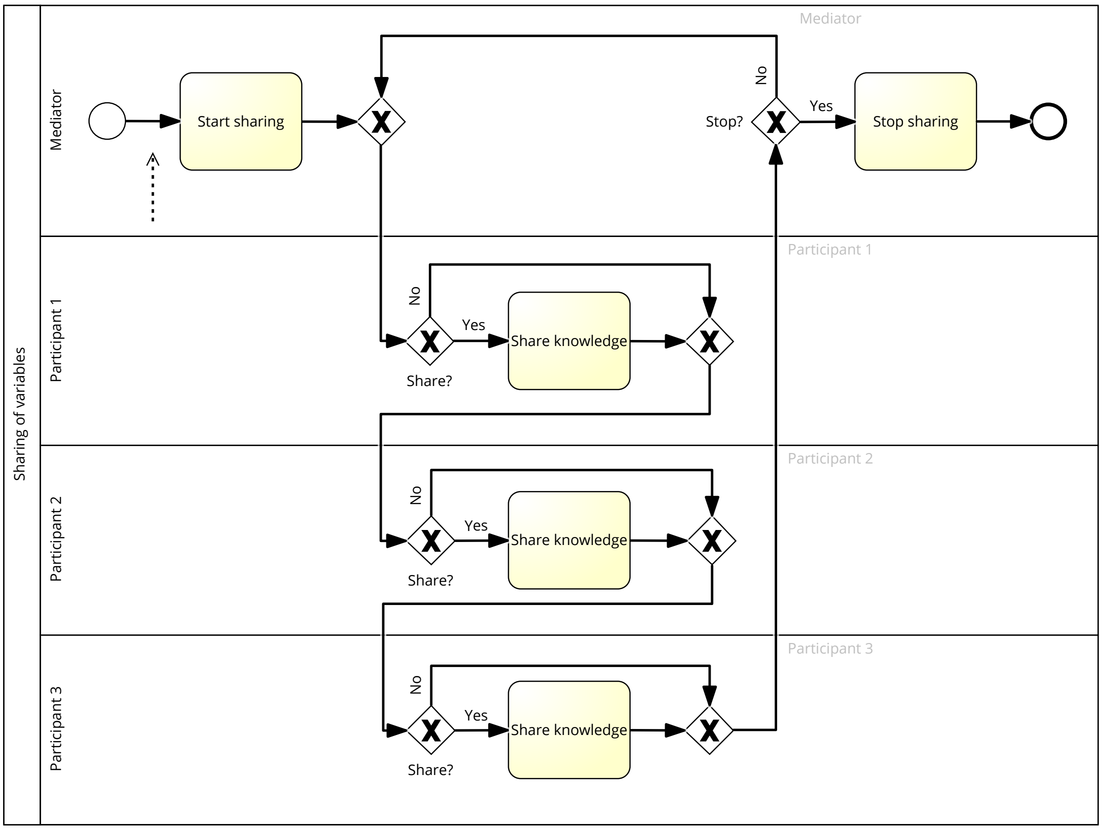

FIGURE 5.16: Sharing of variables step - 1st data position.

- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants are allowed to interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest
  - variable with underpinning (may be more than one)
- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: The knowledge is shared with the group and written down centrally, without consultation or discussion. Then, questions may be asked if any central collected knowledge is not clear.
- Problem variable with a nominal question

Start sharing

Now the sharing of the variables has started,[7] and the participants are aware of it. The mediator will start at the beginning of the U-shape (in which the participants sit), and will ask them sequentially for one variable. The participants are not allowed to share more than one variable per round. If they want to share more, they have to wait for their turn again next round. Participants have to decide for themselves, if they want to share at this moment.

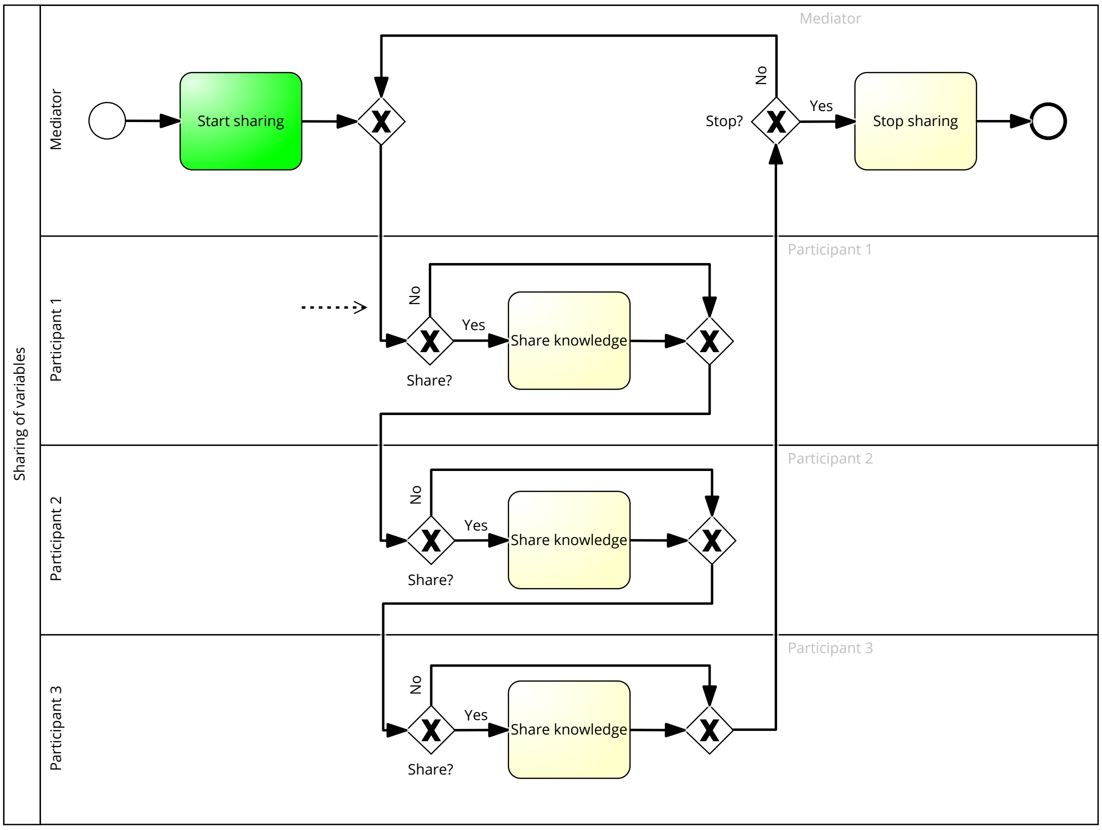

FIGURE 5.17: Sharing of variables step - 2nd data position

This means that the data at the position as shown in figure 5.17 has changed a bit. There are no new concepts, so the data model as shown in figure 5.14 is still accurate here. However, the data inside these concepts have changed. Now the *action* is to share if it is your turn, which also is a *rule*: *"You are not allowed to share unless it is your turn."* Furthermore, the rule that discussion and consultation is not allowed is still active.

The decision of the participant whether he or she will share a variable this round, is part of personal interest. There can be a feeling why you want or do not want to share something. This is a personal feeling, and to commit to personal feeling is personal interest. Therefore, we list the data under the concept *interest*. This means we can define the precondition for *Share knowledge*, which is also the post-condition for *Start sharing*. The result is shown below. Remember, as this is a precondition, the data requirements have to be met before you can start with *Share knowledge*.

[7]The mediator remembered the participants that discussion and consultation between them is still not allowed. The mediator also explained how the sharing is being realized (in the round-robin fashion).

Post-condition for *Start sharing* and precondition for *Share knowledge*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants are allowed to interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest, which determines if the participant wants to share a variable
  - variable with underpinning (may be more then one)
- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: The knowledge is shared with the group and written down centrally, without consultation or discussion. Then, questions may be asked if any central collected knowledge is not clear.
  - the notion that you may share at max one variable each round. So, you are allowed to pass a round
  - the rule that you are not allowed to share unless it is your turn
  - action: each round, share one variable if it is your turn
- Problem variable with a nominal question

Share knowledge

Share knowledge is a step that is quite similar to the *Think individually* step of the *Creating variables individually* process (see section 5.1.2). The only difference is that instead of the participant creating knowledge, he or she now actively shares his knowledge. When it is his or her turn, he can choose to share a variable this round or not. If he chooses not to share, *Share knowledge* will not execute this round.

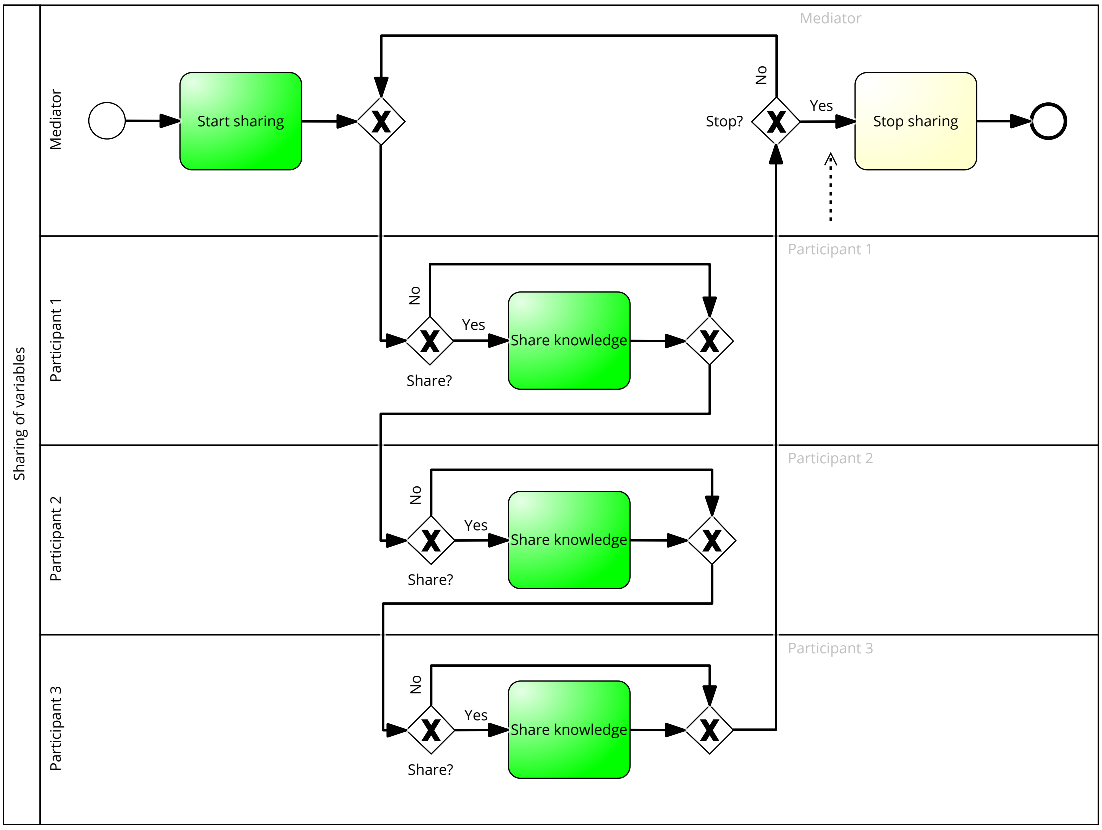

FIGURE 5.18: Sharing of variables step - 3rd data position.

But, if *Share knowledge* does execute, the participant names one variable of the list he written down in the previous phase. The mediator then writes this variable centrally on a whiteboard.[8] At this point the variable has become a shared variable, and all the participants are aware of it. Now, the next participant may share (if he wants to) a variable, and so forth. If all the participants are done with the sharing of variables, a central list of variables is now available to the whole group.

This means that we have a new concept for our data model, namely *Shared variable* which is identified by *variable*. This *Shared variable* has a relation with *Participant* as shared variables *"can be underpinned by"* the participant. Also the original link between participant and variable has gone, as this is now modeled by the concept *Shared variable.* The data model that relates to the data position of figure 5.18, is shown in figure 5.19.

There are also some changes of the data inside the concepts. The decision, if a participant wants to share, is not important anymore, as the sharing stage is over. Therefore, this

[8]Traditionally this meant to write it on a white board, but given that computers are at hand, one can imagine the use of projectors and smart-boards instead.

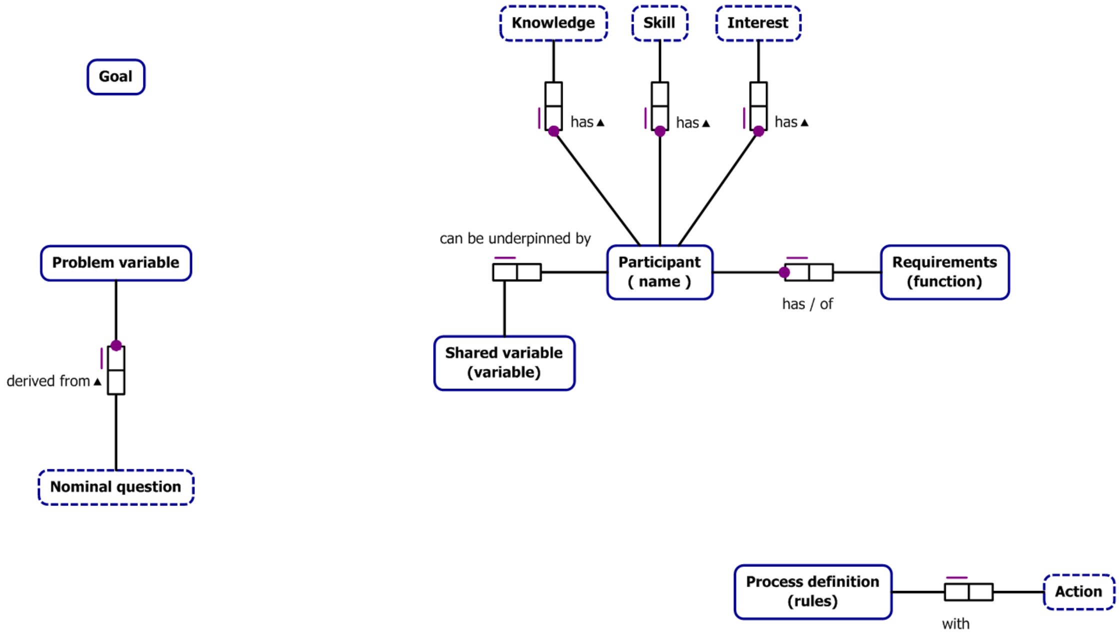

FIGURE 5.19: Generate a detailed view of the problem variable - data on the 4th position.

has been removed from the concept *interest*. Also the notion that you may share one variable at max, and the rule that you are not allowed to share unless it is your turn, are not important anymore and are removed form *Process definition*. Last, the action that participants may share each round, is removed from the concept *Action*, as this is not the case anymore.

This means we can now derive a post-condition for *Share knowledge* and a precondition for *Stop sharing*, as is shown below. Remember, this means that these data requirements have to be met in order to be able to start with *Stop sharing*.

Post-condition for *Share knowledge* and precondition for *Stop sharing*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants are allowed to interact with each other
    * problem variable
    * notion that the group is found to be important in this phase
    * notion of that the knowledge must be produced by the individuals
    * notion of the nominal question
  - skill
  - interest

- Shared variable, that has a relation with the participant, as the participant is able to underpin their part of the sharing
- Process definition defined by rules, and actions, such as
  - the rule that discussion or consultation without the approval of the mediator is forbidden
  - the notion that the actions next will be: The knowledge is shared with the group and written down centrally, without consultation or discussion. Then, questions may be asked if any central collected knowledge is not clear.
- Problem variable with a nominal question

Stop sharing

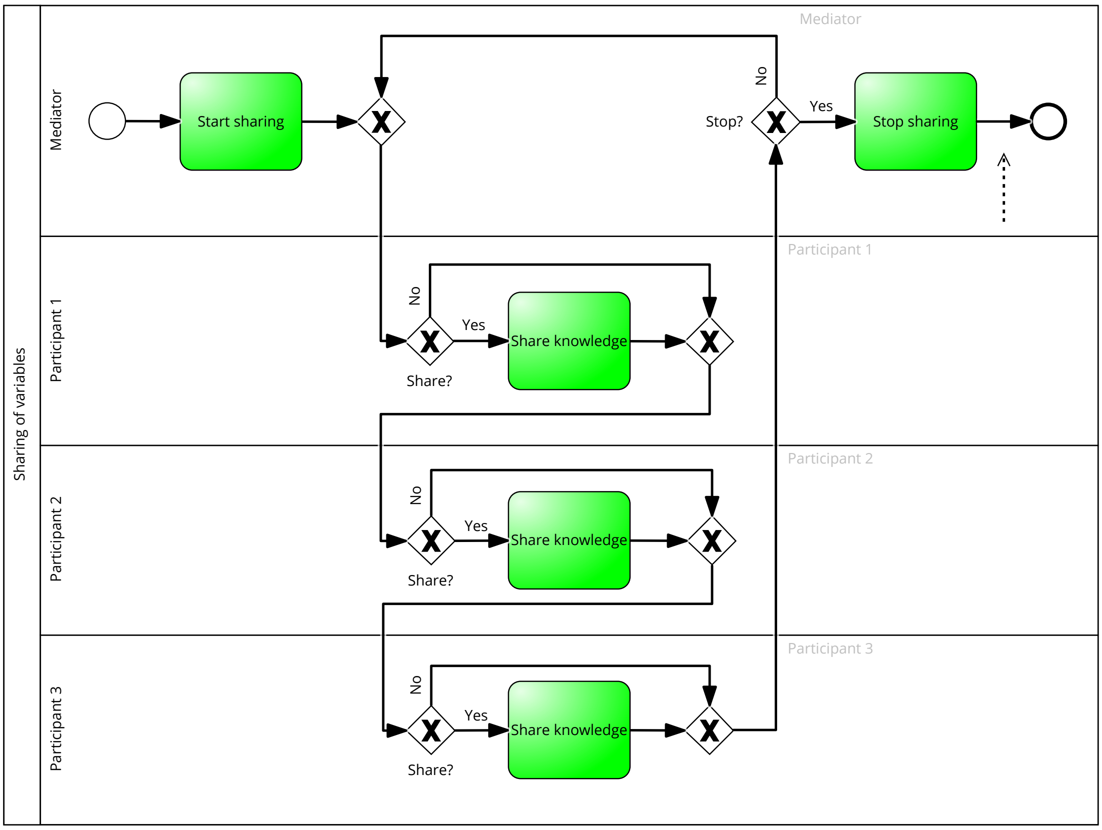

FIGURE 5.20: Sharing of variables step - last data position.

Now the last part of the *Sharing of variables* phase has begun. In the *Stop sharing* step, the mediator explains what the group is going to do next, as they will now have the ability to ask questions if a variable is not clear. This means that discussion and consultation is allowed from now on, but the mediator makes clear that discussion and consultation is only allowed to understand the variables, and not to judge them. This underpinning step will be discussed in the next section.

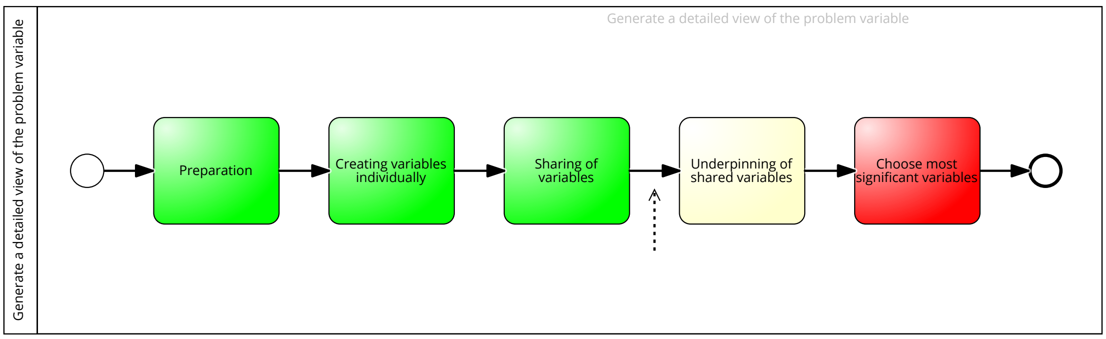

FIGURE 5.21: Generate a detailed view of the problem variable - 4th data position.

This means that on the data position of figure 5.20, which is the same position as that of figure 5.21, there are no new concepts. So, the data model shown in figure 5.19 is still accurate here. The data inside the concepts changed a bit, as the rule that *discussion and consultation is not allowed* is gone, and the notion of *in which way discussion and consultation is allowed* is added. Also the notion *what the next action will be*, is being made clear.

These are all changes in the *Process definition* concept, and these define the post-condition for *Stop sharing*, which is also the post-condition of the *Sharing of variables* phase. And, it defines the precondition for the *Underpinning of shared variables* phase. Remember that these data requirements have to be met in order to be able to start with *Underpinning of shared variables.*

Post-condition for *Stop sharing* and precondition for *Underpinning of shared variables*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants are allowed to interact with each other
    * problem variable
    * notion that the group is found to be important in this phase
    * notion of that the knowledge must be produced by the individuals
    * notion of the nominal question
  - skill
  - interest
- Shared variable, that has a relation with the participant, as the participant is able to underpin their part of the sharing
- Process definition defined by rules, and actions, such as
  - the notion that discussion and consultation is only allowed to make something clear, instead of judging something
  - the notion that the actions next will be: Questions may be asked if any central collected knowledge is not clear.
- Problem variable with a nominal question

5.1.4 Underpinning of shared variables

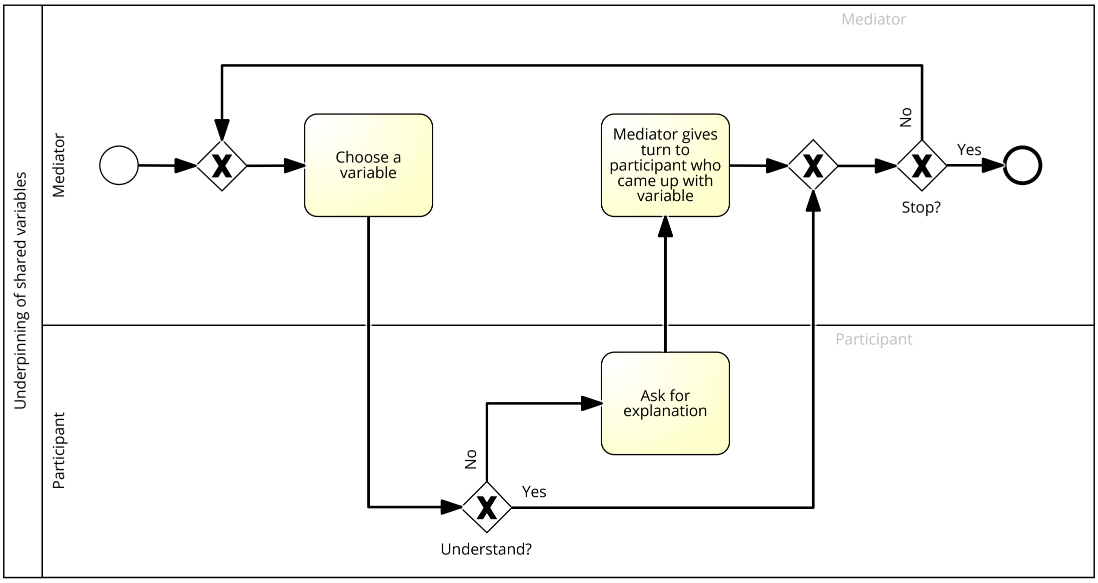

FIGURE 5.22: An overview of the underpinning of shared variables step.

This section is about the underpinning of the created and shared knowledge by the participants. It is also the last step in the *Generate a detailed view of the problem variable* step in the main group model building process.

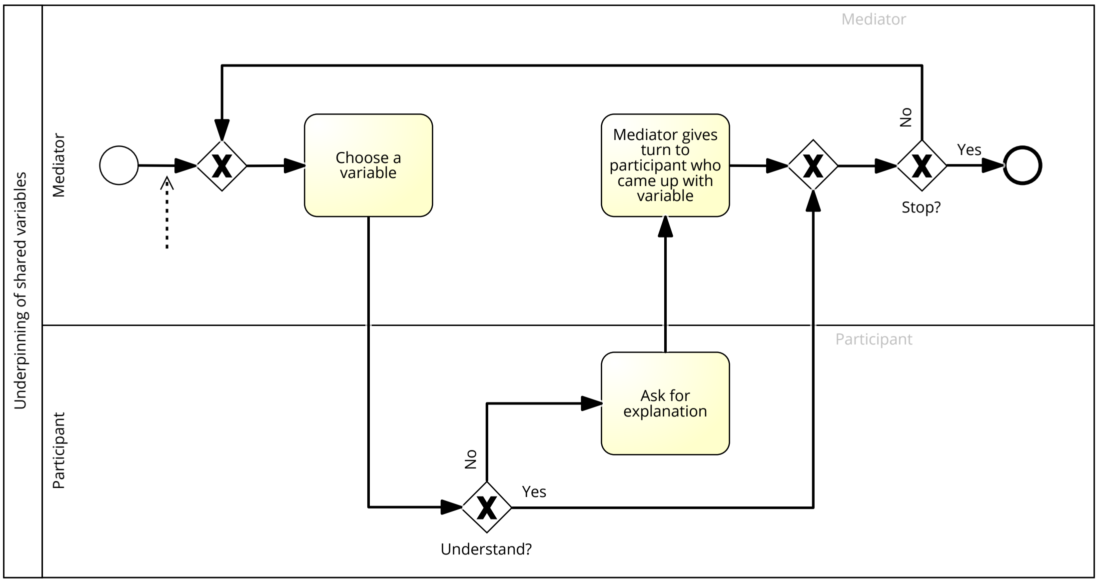

FIGURE 5.23: Underpinning of shared variables - 1st data position.

The process, see figure 5.22, contains three processes, namely *Choose a variable*, *Ask for explanation*, and *Mediator gives turn to participant who came up with variable*, of which the last two loop and are optional if none of the participants had a question.

We can state that the data of the position as shown in figure 5.23, is exactly the same as that of the last position of the previous phase, namely figure 5.20 and figure 5.21.

Therefore, the data model shown in figure 5.19 is still accurate. This means that the precondition of the *Underpinning of shared variables* phase and the *Choose a variable* step, is the same as the post-condition of the *Sharing of variables* phase and the *Stop sharing* step. Only if the data requirements as below have been met, the step *Choose a variable* can be executed.

Post-condition for *Sharing of variables* and precondition for *Choose a variable*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants are allowed to interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest
- Shared variable, that has a relation with the participant, as the participant is able to underpin their part of the sharing
- Process definition defined by rules, and actions, such as
  - the notion that discussion and consultation is only allowed to make something clear, instead of judging something
  - the notion that the actions next will be: Questions may be asked if any central collected knowledge is not clear.
- Problem variable with a nominal question

Choose a variable

In *Choose a variable*, the mediator not only chooses a variable from the list of shared variables, but also explains in what fashion question can be asked. The mediator asks the participants if they can decide for themselves if they understand why this variable is here, and what it is meant for.

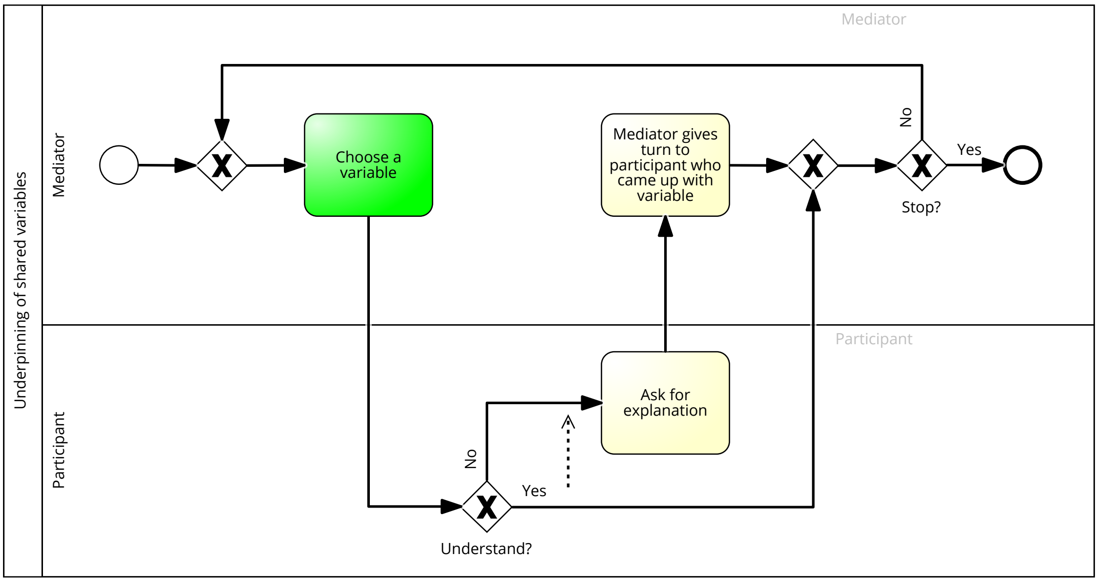

FIGURE 5.24: Underpinning of shared variables - 2nd data position.

Let's assume a variable is not clear to a participant. A variable can be unclear for two reasons:

- *A participant does not understand what it means*: This can happen if the variable is defined as jargon. For instance when we look at the example situation of the introduction (section 1.2), this could be a variable defined by the head of marketing in marketing jargon (e.g. <abandonment rate>[9]).
- *A participant does not understand why a variable is on the list*: This means he or she does understand what it means, but cannot place it in the context of the problem variable.

Given that the variable is not understood, we would be on the data position shown in figure 5.24. The fact that a participant does not understand a shared variable, would mean the concept *Participant* has another relation to the concept *Shared variable*. This is shown in figure 5.25. If we look at the data inside the concepts, we see a change in *Action*, as participants now have to decide if they understand the chosen variable. Also within *Shared variable*, a variable is added that is not understood by the participant.

[9]Abandonment rate is a marketing measurement for shopping carts on websites that are left alone by the customer. You can imagine that you add something to a shopping cart on a website, and then leave the website to never come back. The rate at which this is done, can have an effect on growth and therefore on profit.

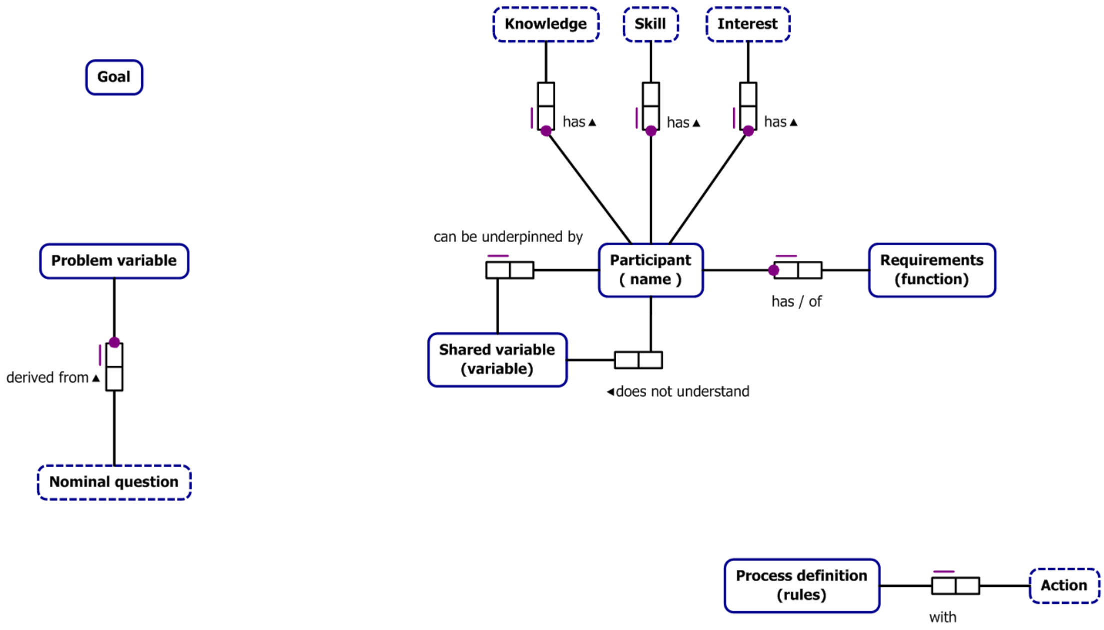

FIGURE 5.25: Underpinning of shared variables - data on the 2nd position.

This means we can now define the post-condition for *Choose a variable* and a precondition for *Ask for explanation*. Remember that the data requirement, as stated below, must be met in order to be able to start with *Ask for explanation*.

Post-condition for *Choose a variable* and precondition for *Ask for explanation*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants are allowed to interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest
- Shared variable, of which
  - one has a relation with the participant, as the participant is able to underpin their part of the sharing
  - another is not understood by the participant
- Process definition defined by rules, and actions, such as

  - the notion that discussion and consultation is only allowed to make something clear, instead of judging something
  - the notion that the actions next will be: Questions may be asked if any central collected knowledge is not clear.
  - action: decide if the variable in question is understood

- Problem variable with a nominal question

Ask for explanation

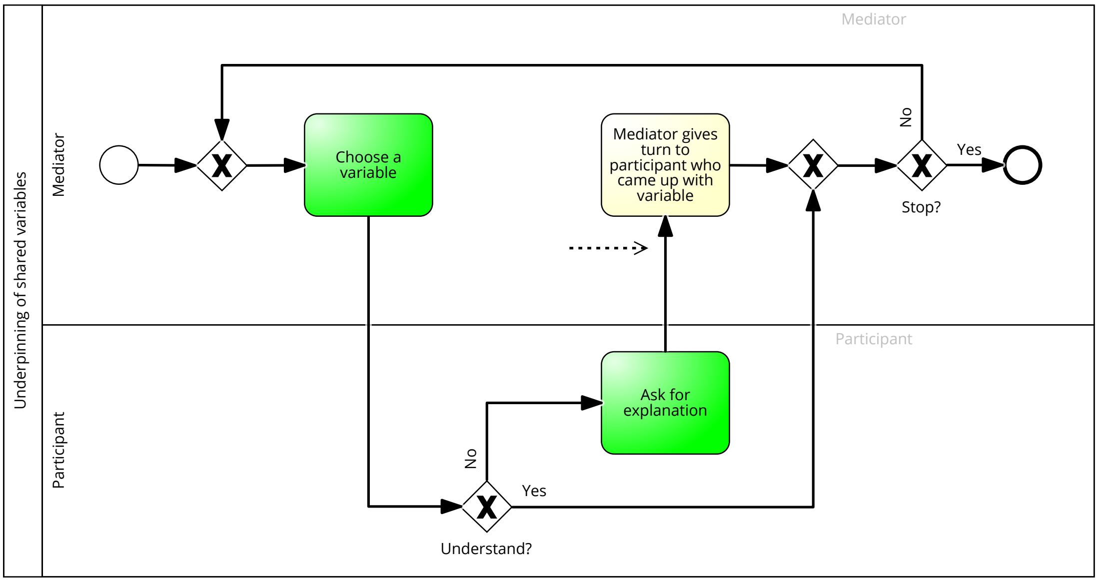

FIGURE 5.26: Underpinning of shared variables - 3rd data position.

In *Ask for explanation*, the participant makes it clear to the mediator and the rest of the group, that he does not understand the variable in question. This is the only thing that is happening in this step, therefore (as we look at the data at the position as shown in figure 5.26), we see a very small change in the concept *Process definition*. No new concepts were created, so the data model shown in figure 5.25, is still accurate.

Hence, we can create the post-condition of *Ask for explanation*, as well as the precondition of *Mediator gives turn to participant who came up with variable*. The latter can only start if the data requirement, as stated below, is met.

Post-condition for *Choose a variable* and precondition for *Ask for explanation*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants are allowed to interact with each other
    - problem variable
    - notion that the group is found to be important in this phase
    - notion of that the knowledge must be produced by the individuals
    - notion of the nominal question
  - skill
  - interest
- Shared variable, of which

  - one has a relation with the participant, as the participant is able to underpin their part of the sharing
  - another is not understood by the participant

- Process definition defined by rules, and actions, such as
  - the notion that discussion and consultation is only allowed to make something clear, instead of judging something
  - the notion that the actions next will be: Questions may be asked if any central collected knowledge is not clear.
  - action: decide if the variable in question is understood
  - the mediator should answer the question of the participant, in which it is stated that he or she does not understand the variable

- Problem variable with a nominal question

Mediator gives turn to participant who came up with variable

In the step *Mediator gives turn to participant who came up with variable*, the mediator points at the participant who can answer the question of the participant that does not understand the shared variable in question. At this point, consultation and discussion is allowed. This is a very complex game of questions and answers that is out of the scope of this thesis, and therefore not being formalized.

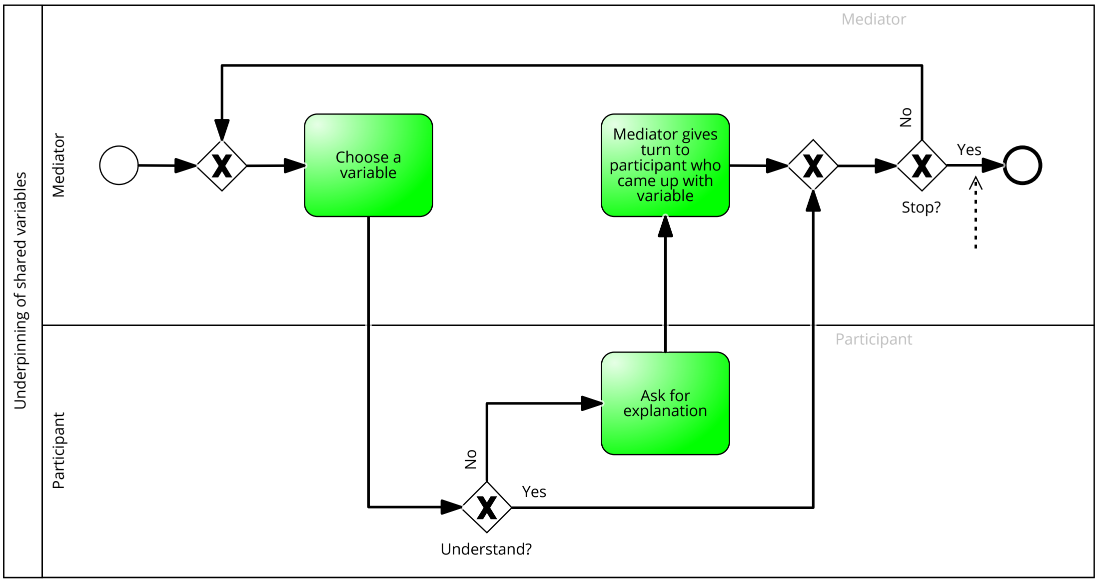

FIGURE 5.27: Underpinning of shared variables - last data position.

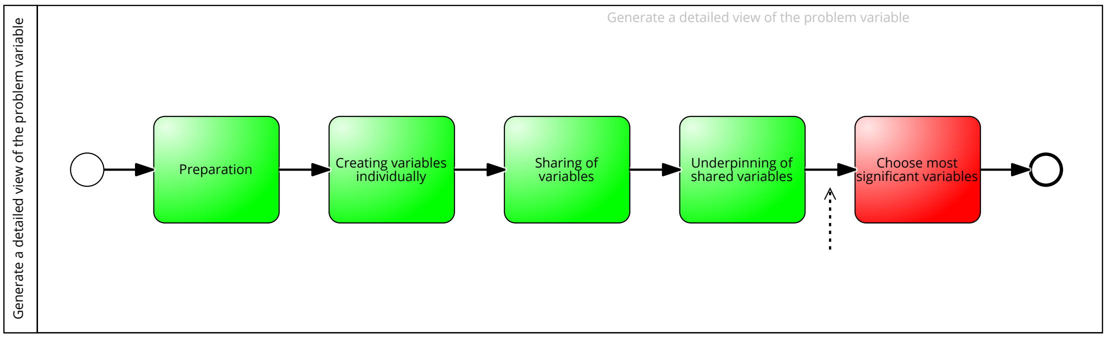

FIGURE 5.28: Generate a detailed view of the problem - last data position.

We will assume that the two participants can help each other, and the variable is understood eventually. When this is the case, the mediator can choose if he wants to stop with the underpinning phase or not. If he does not want to stop, the whole process of *Underpinning of shared variables* will start over again, and a new variable is chosen.

When all the variables have come past, the mediator stops the underpinning phase. At this point we are at the position shown in figure 5.27. As this is the end of *Underpinning of shared variables*, this means we are also at the position shown in figure 5.28.

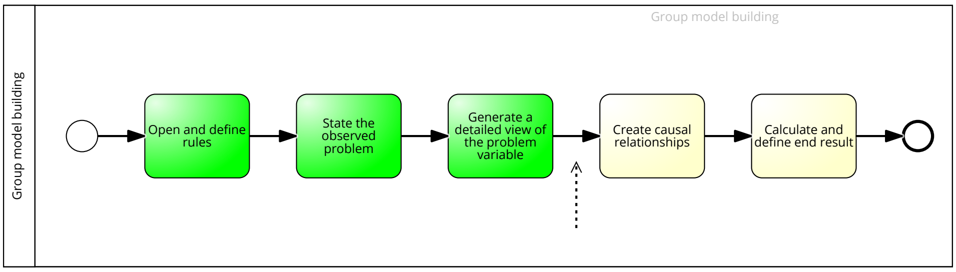

FIGURE 5.29: The main process of group model building: the end of the 3rd step.

Because we assume[10] that all the shared variables are used to create a causal loop diagram (see figure 2.2), we skip the next step in the *Generate a detailed view of the problem variable*. That is why *Choose most significant variable* is displayed in red. This means that we are also at the end of *Generate a detailed view of the problem variable*, as is shown in figure 5.29.

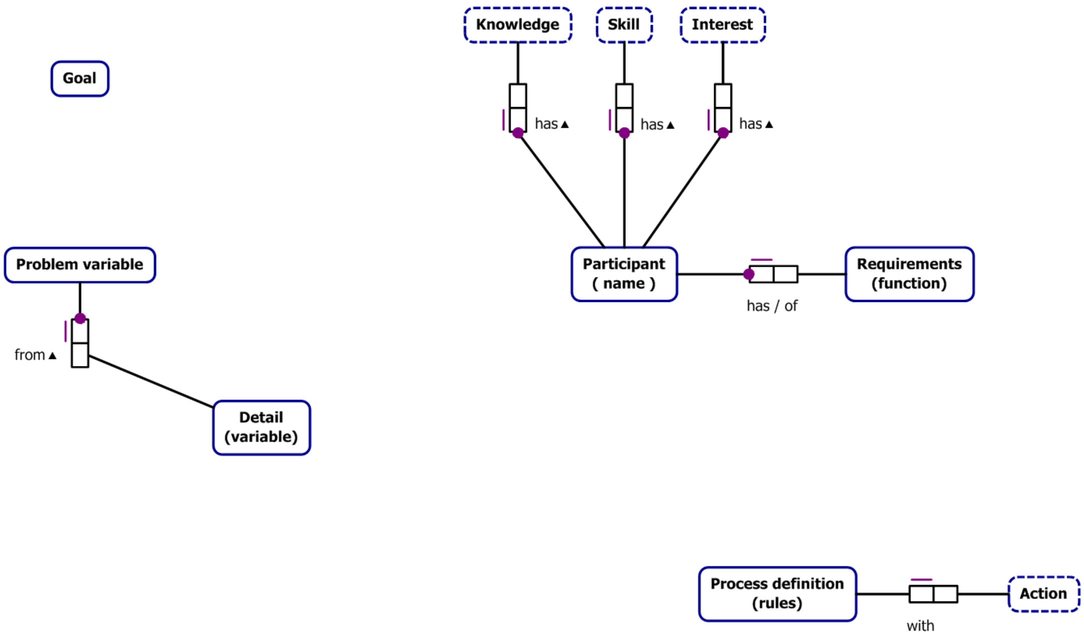

FIGURE 5.30: Generate a detailed view of the problem - data on the last position.

If we look at the data model at the position shown in figure 5.27, figure 5.28, and figure 5.29, we get what is shown in figure 5.30. Because the whole group now understands all the shared variables, the individual participant does not have to have a specific relationship with these variables. Therefore, the concept *Shared variable* is translated into the concept *Detail*, which is also identified by a variable. The problem variable itself, is added to this detail.

The translation of the concept and the addition of the problem variable to the list of detail, is all done in the last step of *Generate a detailed view of the problem variable*,

[10]See the first part of this section, namely section 5.1

but because this step is out of scope, the exact ins and outs of how this is done are left out.

If we look within the concepts, there are some changes to the concept *Process definition*. First, the mediator has answered the question of the participant, who did not understand the variable. Second, the notions about what the next step would be, is irrelevant here, as is the notion that discussion and consultation is only allowed if the participant says so. Also within the concept *knowledge*, the notions that were there, are now irrelevant. This irrelevancy is because this is the end of the *Generate a detailed view of the problem variable*, and new notions will be created in the next step (which will be discussed in the next section).

The last change in the data model, is that there are now no actions left. That stated, we can now define the post-condition for *Mediator gives turn to participant*, which is also the post-condition for *Underpinning of shared variables*, as well as the post-condition for *Generate a detailed view of the problem variable* (as stated in section 4.3). The list below represent these post-conditions as well as the precondition for the next step, namely *Create causal relationships*. There can only be started with the next step, if these data requirements are met.

Post-condition for *Mediator gives turn to participant who came up with variable* and precondition for *Create causal relationships*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
  - skill
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself

5.2 Create causal relationships

The models of the fourth sub-process of group model building are being discussed in this chapter. In *Create causal relationships* (see figure 5.31) the previous created and shared variables (combined called as detail), are being connected to each other to create a system dynamics model (Forrester, 1975).[11] This model forms the basic answer to a messy problem (Ackoff, 1974, 1979), as system dynamics models makes it possible to derive control- and target variables (Vennix, 1996)(Rouwette and Franco, 2014).[12] This will give the organization in its turn the possibility to define a set of tasks to get a grip on the unwanted situation.

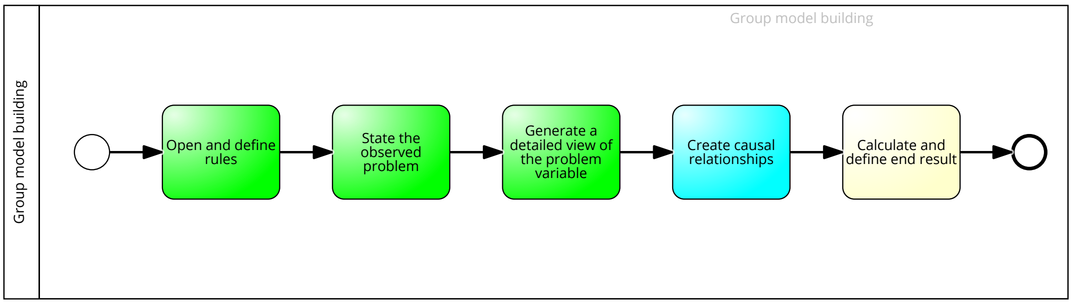

FIGURE 5.31: The position of Create causal relationships in the main process (denoted in blue).

When we look at the fourth sub-process of group model building in more detail, we get a set of processes as defined in figure 5.32. Here, we see two processes, namely *Use the detail to find causes and effects of the problem variable* (section 5.2.1), and *Check for feedback loops* (section 5.2.2). In the first process, the group will create the system dynamics model from the previous derived variables. In the second process, the group will look for feedback loops that will help them in finding target- and control variables in the future.

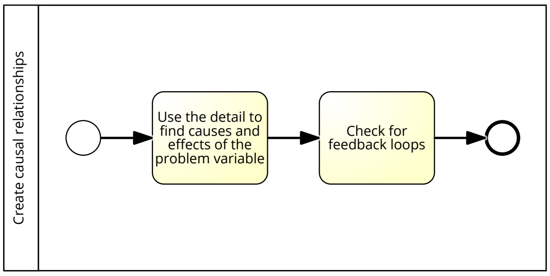

FIGURE 5.32: Create causal relationships - main process.

To identify which information is necessary to start with the first step *Use the detail to find causes and effects of the problem variable* (see figure 5.33), we have to look at the last post-condition of the previous section (section 5.1.4). This is in fact the same as the precondition for *Use the detail to find causes and effects of the problem variable.*

[11]See section 2.2.1 for a detailed explanation of a system dynamics model.
[12]Control- and target variables are being discussed in section 5.3.

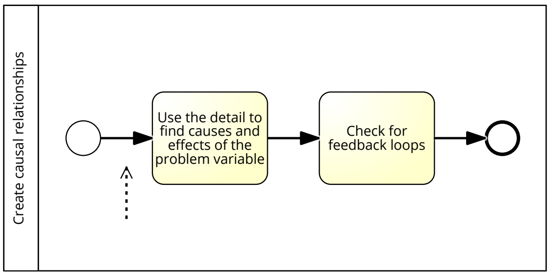

FIGURE 5.33: Create causal relationships - 1st data position.

Therefore, the concepts of the data model remains unchanged, as is shown in figure 5.34. Remember that the concept *Detail* is the list of variables including the problem variable. This list is very important for the upcoming part of the group model building process, as these are the materials to build a system dynamics model with.

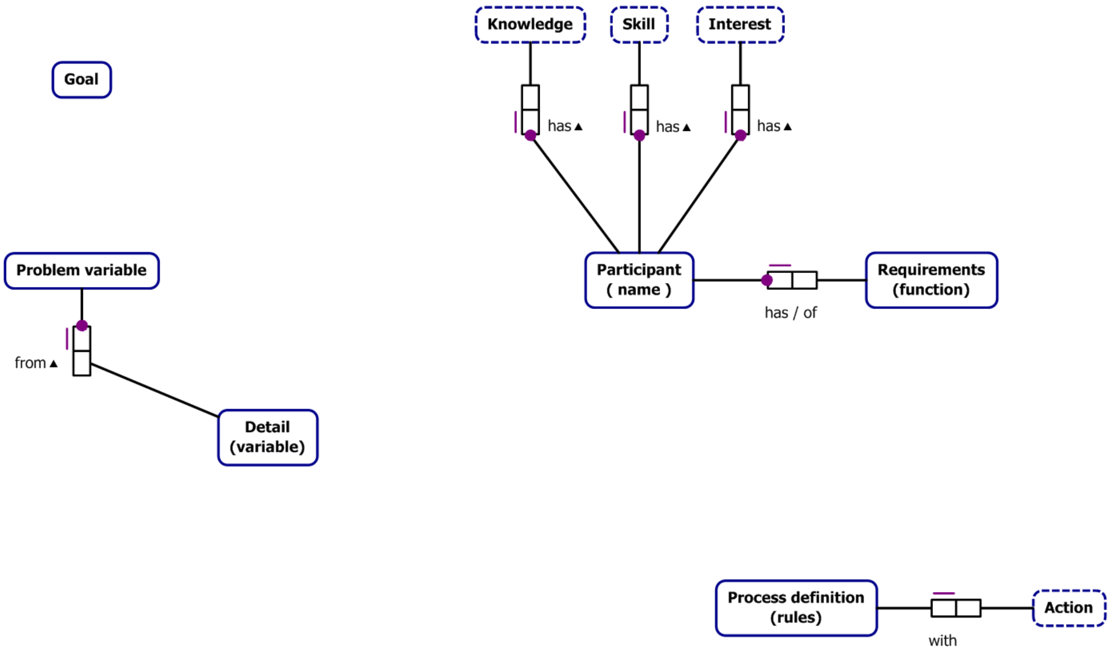

FIGURE 5.34: Create causal relationships - data on the 1st position.

As the concepts are the same, so is the information inside the concepts. Therefore, the list that defines the precondition for *Use the detail to find causes and effects of the problem variable*, is the same as the most recent defined list of information of the previous section. This list is shown below.[13] Remember that these data requirements have to be met in order to start with *Use the detail to find causes and effects of the problem variable.*

[13]Please note that this list is the same as that of the precondition defined in section 4.3, in which we looked at the main process of group model building.

Precondition for *Use the detail to find causes and effects of the problem variable*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
  - skill
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself

5.2.1 Use the detail to find causes and effects of the problem variable

The *Use the detail to find causes and effects of the problem variable* step contains seven processes that are connected in a complex way, as is shown in figure 5.35. This is due to fact that there can be made a decision twice. First, the participant can decide whether or not he or she wants to suggest a variable from the list of detail. Second, another participant can choose whether or not he or she agrees with a suggestion being made, which creates two possible paths within the already divided route. The details of these possible paths will be explained gradually.

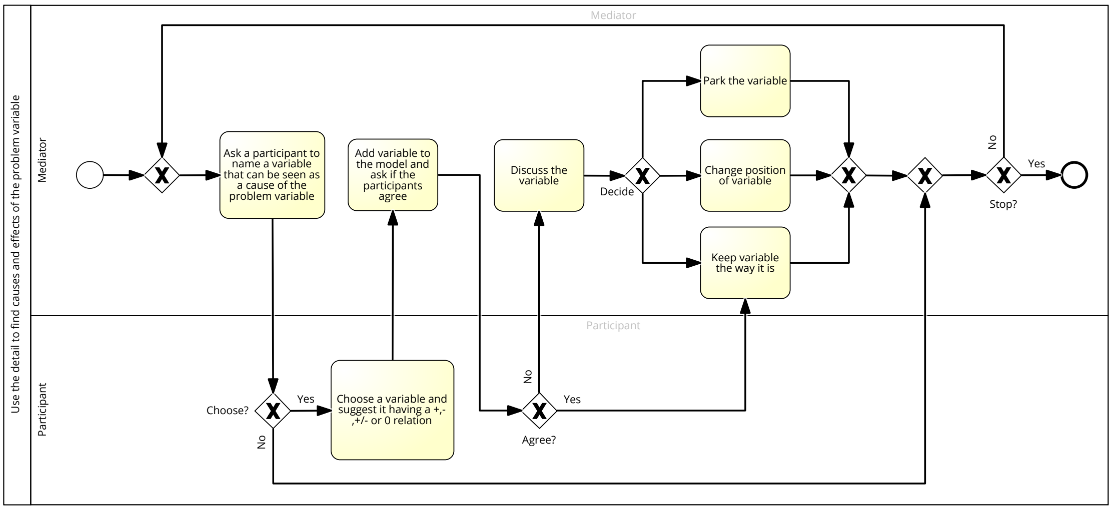

FIGURE 5.35: An overview of Use the detail to find causes and effects of the problem variable.

The seven processes, which are *Ask a participant to name a variable that can be seen as a cause of the problem variable*, *Choose a variable and suggest it having a +,-,+/-, or 0 relation*, *Add variable to the model and ask if the participants agree*, *Discuss the variable*, *Park the variable*, *Change position of variable*, and *Keep variable the way it is*, will be explained in the following sections in sequential order. This sequential order will be realized by choosing the path with the most processes.[14]

The precondition for the first step, *Ask a participant to name a variable that can be seen as a cause of the problem variable*, is the same as that of the whole process of *Use the detail to find causes and effects of the problem variable*. Therefore, the data model as shown in figure 5.34, is still accurate here, and the list of information is the same as that of the previous section. For consistency reasons, this list is given again below. The information at hand has to match this list in order to start with *Ask a participant to name a variable that can be seen as a cause of the problem variable*.

Precondition for *Use the detail to find causes and effects of the problem variable*:

- Goal
- Participant with

[14]The reason for doing this is that then all the actions will be processed.

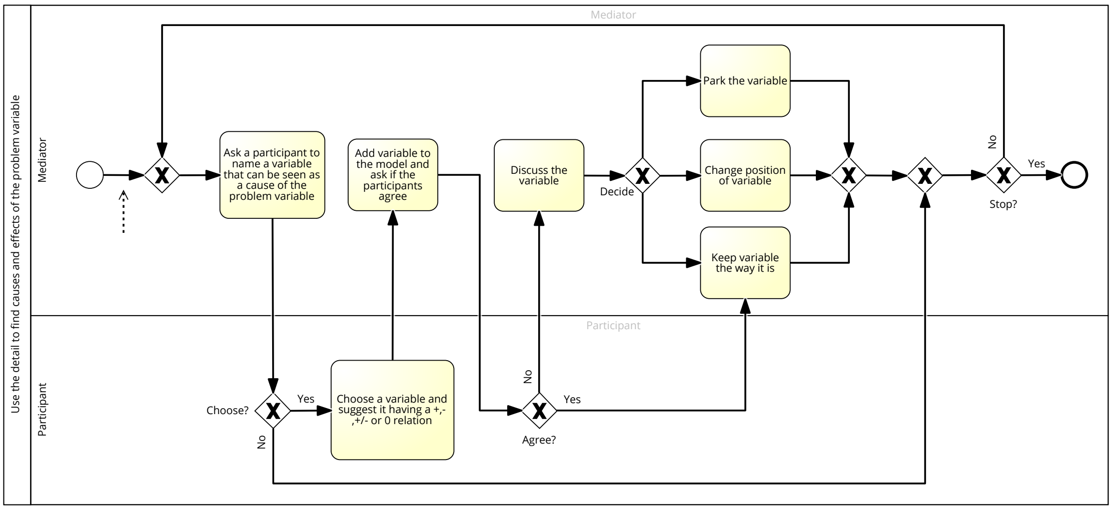

FIGURE 5.36: Use the detail to find causes and effects of the problem variable - 1st data position.

- name
- function
- knowledge with
  * a basic understanding of group model building
  * an understanding of the way participants may interact with each other
  * problem variable
  * a list of detail of the problem variable including the problem variable itself
- skill
- interest

- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself

Ask a participant to name a variable that can be seen as a cause of the problem variable

In the first step, *Ask a participant to name a variable that can be seen as a cause of the problem variable*, the mediator explains (if necessary) to the participants what is going to happen now. This will be the explanation of the process, in which first a variable (which can be seen as a cause of the problem variable) is being connected to the problem variable. The participants are from now on allowed to group wise suggest a variable, including the type of the relation to the variable it is being connected to.

If we look at the example situation given in the introduction (section 1.2), it would be possible that the variable <growth> will be connected to the problem variable <profit> with a positive ("+") relation, as growth has a positive influence on profit. This would be the first step in creating a system dynamics model. Next, the suggested variable and relation is added to the model, and the other participants are asked by the mediator if they agree with this suggestion.

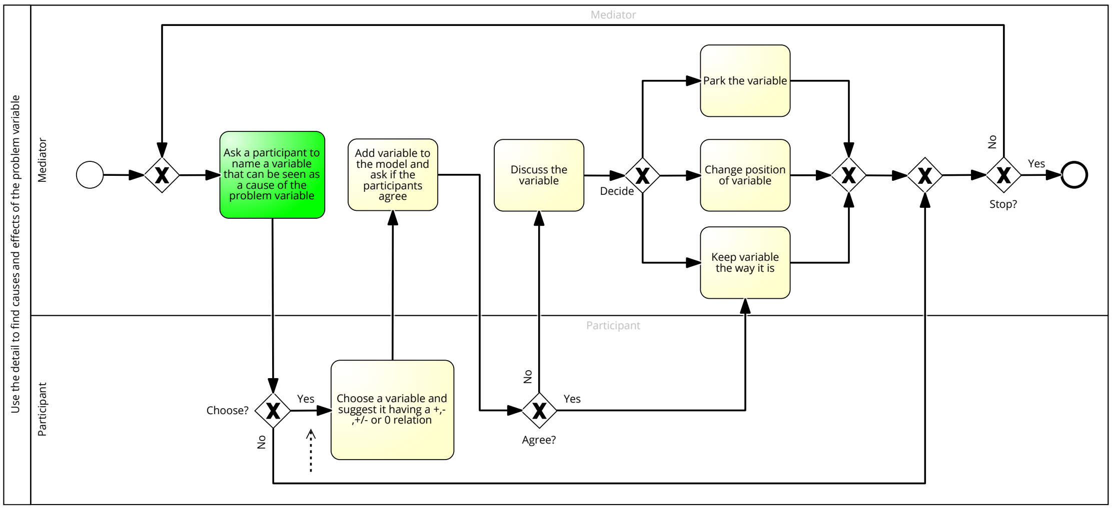

FIGURE 5.37: Use the detail to find causes and effects of the problem variable - 2nd data position.

Now, there are no new concepts at this point, so the data model shown in figure 5.34 is still accurate. But, since the participants are now familiar with the upcoming process and the notion that group wise suggesting of variables is allowed, the information within the concepts (at the position shown in figure 5.37) has changed a bit. That said, we can now define the post-condition for *Ask a participant to name a variable that can be seen as a cause of the problem variable* and the precondition for *Choose a variable and suggest it having a +,-,+/- or 0*. This list of data requirements is given below, and should be met in order to proceed.

Post-condition for *Use the detail to find causes and effects of the problem variable* and precondition for *Choose a variable and suggest it having a +,-,+/- or 0 relation*:

- Goal
- Participant with

  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
  - skill
  - interest

- Process definition defined by rules, and actions, such as
  - action: naming a variable that can be seen as a cause for the problem variable, and connect it with a specific relation. There can be chosen between +,-,+/-, or 0
  - the notion that the following actions is: check whether every participant agrees, and if necessary, discuss
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind

- Problem variable

- List of detail of the problem variable including the problem variable itself

Choose a variable and suggest it having a +,-,+/- or 0 relation

In this step, the participant names a variable with a specific relation that can be seen as a cause of the problem variable.[15] Like said before, in case of the example of the introduction (section 1.2), this can be <growth> connected to <profit>. This connection would probably be a positive one, because higher growth will have a positive influence on profit.[16]

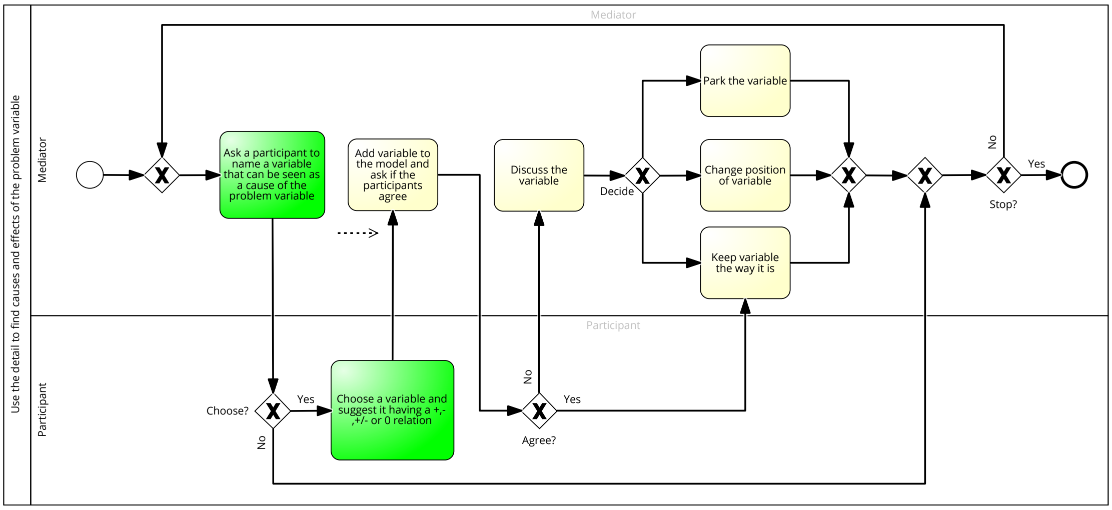

FIGURE 5.38: Use the detail to find causes and effects of the problem variable - 3rd data position.

Not only the variable and relationship is being named, also the strength of the relation is being mentioned. This forms the basis for quantitative analysis of a system dynamics model, but because this is out of the scope of this thesis, the exact ways of how to define them, is left out. So, we limit ourselves with just the term *strength*. This means the data of the position shown in figure 5.38 changes a bit, as is shown below. This is the post-condition for *Choose a variable and suggest it having a +, -, +/- or 0 relation* and the precondition for *Add variable to the model and ask if the participants agree*. The latter cannot start until these data requirements are met.

Post-condition for *Choose a variable and suggest it having a +,-,+/- or 0 relation* and precondition for *Add variable to the model and ask if the participants agree*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building

[15]As stated earlier we choose the path with the most processes. In this case, this means that the participant decided to suggest a variable with a specific relation type. So, the previous XOR-port will guide the process to this step.

[16]Given that other variables do not change.

        * an understanding of the way participants may interact with each other
        * problem variable
        * a list of detail of the problem variable including the problem variable itself
    - skill
    - interest

- Process definition defined by rules, and actions, such as
    - action: naming a variable that can be seen as a cause for the problem variable, and connect it with a specific relation. There can be chosen between +,-,+/-, or 0
    - participant has just named a variable with specific connection to the problem variable and the mediator should react to this mentioning
    - the notion that the following actions is: check whether every participant agrees, and if necessary, discuss
    - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind

- Problem variable

- List of detail of the problem variable including the problem variable itself

Add variable to the model and ask if the participants agree

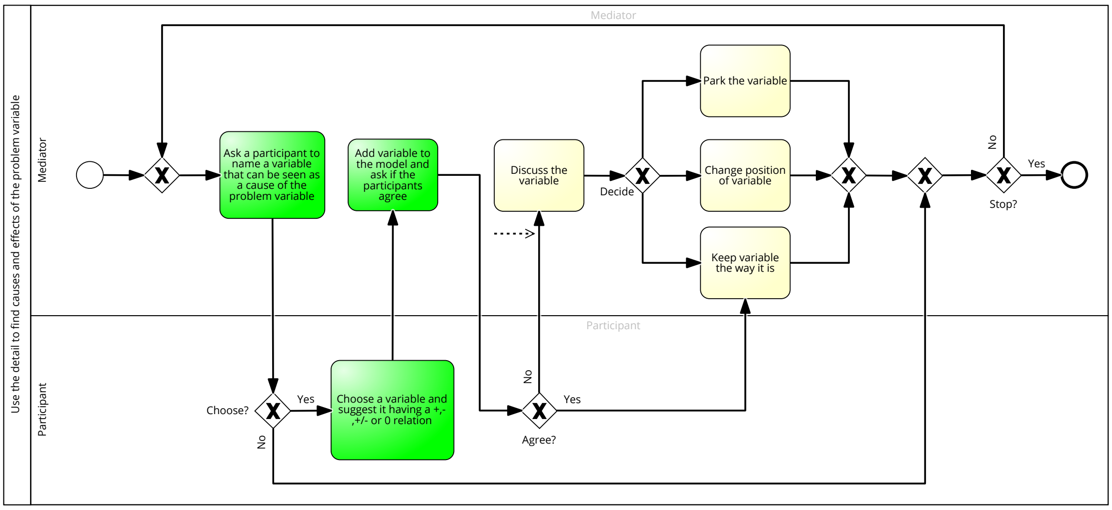

FIGURE 5.39: Use the detail to find causes and effects of the problem variable - 4th data position.

Now, the mediator reacts to the suggested variable with a specific relation to the problem variable, by adding it to the system dynamics model. Then he asks the participants if they agree with this suggestion. It is important for the mediator to guide the discussion if it arises here, which will be explained in the next section.

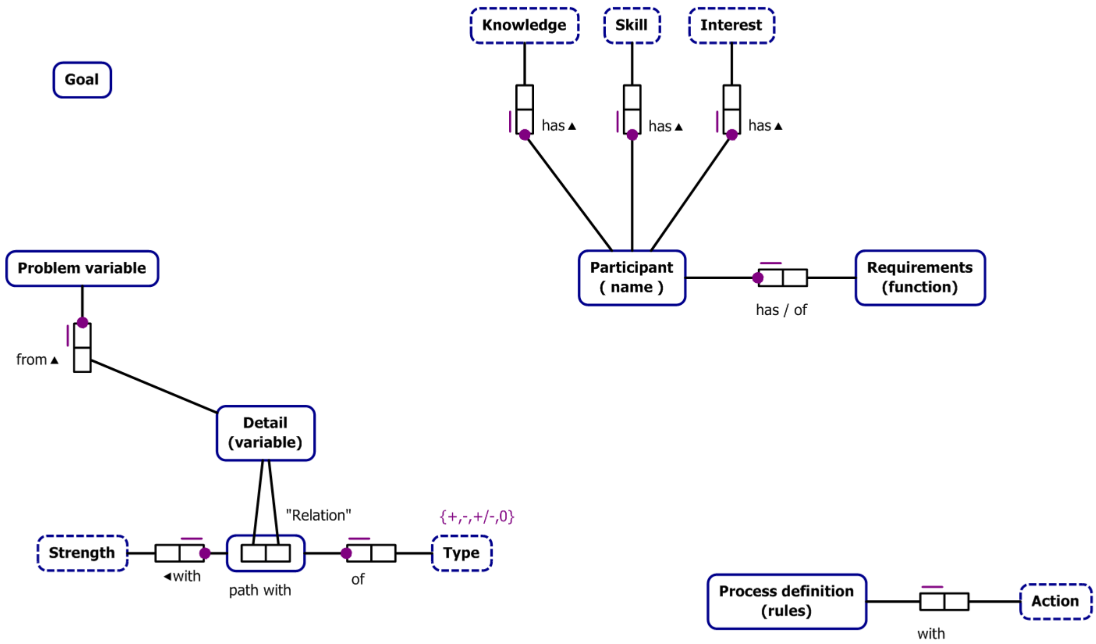

FIGURE 5.40: Create causal relationships - data on the 2nd position.

This means that if we look at the data on the position shown in figure 5.39, there are some new concepts and data inside the concepts. Figure 5.40 shows the data model. If a variable is being connected to the problem variable, this is none more than a relation between two variables of the concept *Detail*. Therefore this addition to the system dynamics model is being formalized as a relation from *Detail* to *Detail*, which is called *Relation*. A *Relation* can then be of a specific *Type* ("+", "-", "+/-", or "0") and of a specific *Strength* (out of scope of this thesis).

This automatically changes the information within the concepts, as is shown below. First, the action is not to suggest a variable anymore, but to discuss the suggested variable. The mediator should initiate this discussion, by asking if everyone agrees with the suggested variable. Participants should now understand that the discussion phase of the building of the model is started. Last, the system dynamics model is now part of the information that is required. So, we now can define a post-condition for *Add variable to the model and ask if the participants agree* and a precondition for *Discuss the variable*. The latter can only start when this data requirements are met.

Post-condition for *Add variable to the model and ask if the participants agree* and precondition for *Discuss the variable*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
  - skill
  - interest
- Process definition defined by rules, and actions, such as
  - action: discuss the variable that has just been added
  - mediated asked if the participants agree with this suggested variable and relation
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence

Discuss the variable

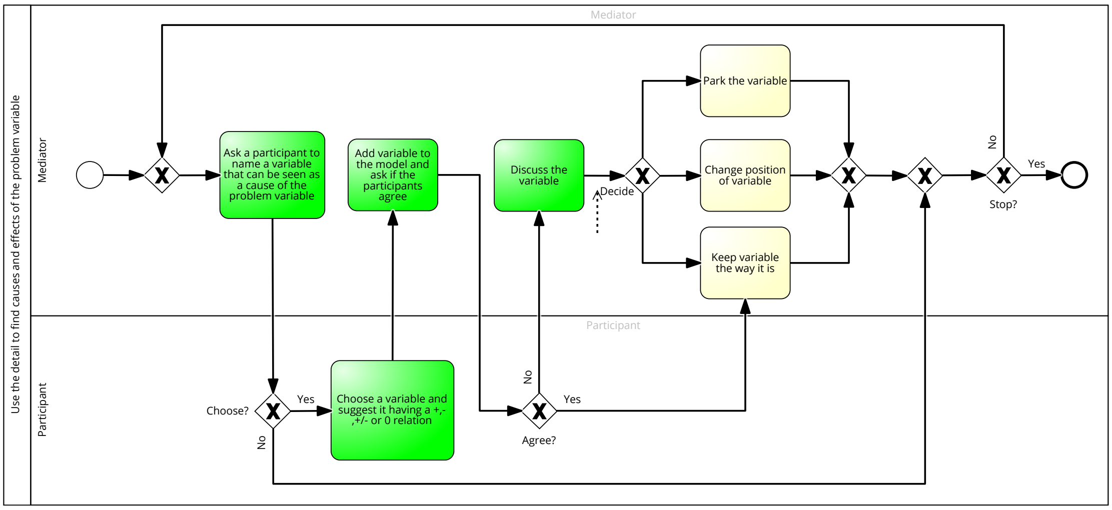

FIGURE 5.41: Use the detail to find causes and effects of the problem variable - 5th data position.

Now, the mediator should guide the discussion,[17] in which he should make clear to all the participant that the relations can always be changed in the future, and that it could be interesting to see were the current suggestion might bring the total model. The exact way in which the discussion is being guided, is out of scope of this thesis. We assume that the mediator prepares the participants to make a decision between 3 possibilities. These possibilities will be discussed in the next section.

This also means the data model at the position shown in figure 5.41, has not changed, and figure 5.40 is thus still accurate. But, the information inside these concepts has changed. This is shown below, and defines the post-condition for *Discuss the variable* and the precondition for *Park the variable, Change position of variable, Keep variable the way it is*. The latter may only start when these data requirements are met.

Post-condition for *Discuss the variable* and precondition for *Park the variable, Change position of variable, Keep variable the way it is*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself

[17]Given that we assume the longest path is taken, this means that participants do not agree with the suggestion. If they do, the discussion is of course not necessary and should be skipped to *Keep variable the way it is* (see next section).

  - skill
  - interest

- Process definition defined by rules, and actions, such as
  - action: discuss the variable that has just been added
  - mediated guides the discussion and makes clear that the participants can choose between three possibilities, namely *Park the variable*, *Change position of variable*, and *Keep the variable the way it is.*
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind

- Problem variable

- List of detail of the problem variable including the problem variable itself

- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence

Park the variable, Change position of variable, Keep variable the way it is

Now, the participants have to decide which discussion they make. As said before, the way in which this is achieved (through discussion) is left out of this thesis. The participants may choose between three options, namely:

- *Park the variable*: When a discussion gets stuck, because it is not clear to the participants why that variable has a specific relation, it can be parked. Meanwhile other variables are being discussed and added to the model, and this addition can provide more information about the effect of the parked variable. Therefore at the end, the parked variables are discussed again with the hope that participants have created more consensus, as the total system dynamics model is clearer now.
- *Change position of the variable*: When participants understand what the influence of the variable is, but not agree it should be linked in the way it is now, or, when the way it is linked is agreed upon, but the type of relation is not, the position or relation of the variable in the system dynamics model may be changed.
- *Keep the variable the way it is*: When the discussion led to consensus and the participants now understand (and therefore more likely agree) why the variable and relation is suggested the way it is, it can be kept on the position it was.

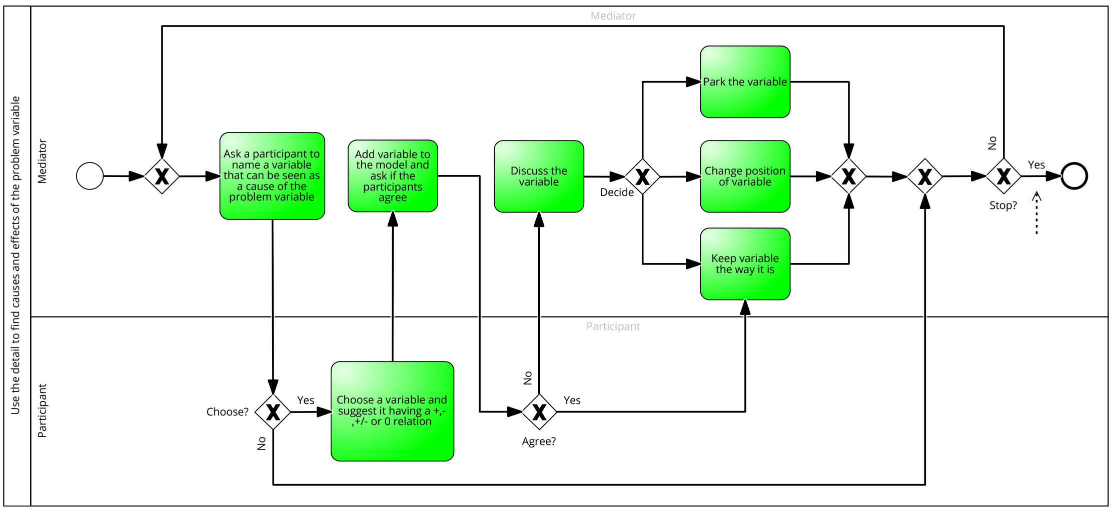

FIGURE 5.42: Use the detail to find causes and effects of the problem variable - last data position

After the decision is being made, the mediator can choose if another variable must be added to the model. Normally this answer would be yes if there are still variables left in the list of detail. Further in the process, the variables are not just linked to the problem variable, but also to other variables. Later, the mediator can choose not to look for causes but for effects of the problem variable or other variables. This means that *Use the detail to find causes and effects of the problem variable* will loop until all the variables of the list of detail have been processed.

This also means that the first step, *Ask a participant to name a variable that can be seen as a cause of the problem variable*, changes to another question that asks for effects of the problem variables, or causes and effects of other variables to each other. The building of the system dynamics model is not done until all the possible relations have been named. It is not possible that a relation remains unprocessed. If participants do not know what the type of the relation would be, they can say it is context-dependent ("+/-").

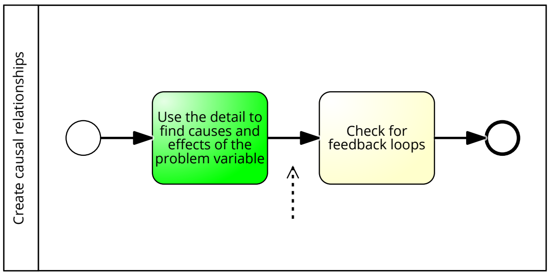

FIGURE 5.43: Create causal relationships - 2nd data position.

If the mediator decides to stop, we are at the position shown in figure 5.42. Since this is also the end of *Use the detail to find causes and effects of the problem variable*, this means we are also at the position shown in figure 5.43. We now assume that the system dynamics model has been build, and the participants agree with that model. Therefore the concepts of figure 5.40, are still accurate, but the data inside has changed a bit (as is shown below).

Inside the concept *knowledge*, the participant is now aware of the system dynamics model as it was centrally build. Also, the current action has become irrelevant, and the mediator has explained what will happen next.[18] This means that we can now define the post-condition for *Park the variable, Change position of variable, Keep variable the way it is*, which is also the post-condition for *Use the detail to find causes and effects of the problem variable* and the precondition for *Check for feedback loops*. Remember that the latter can only start when these data requirements have been met.

Post-condition for *Discuss the variable* and precondition for *Park the variable, Change position of variable, Keep variable the way it is*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill
  - interest

[18] This is one of the many actions of the mediator that are left out of this thesis. For further explanation see chapter 6 about future research suggestions.

- Process definition defined by rules, and actions, such as
  - mediator explained that there will be looked for feedback loops next
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence

5.2.2 Check for feedback loops

Now that we have a system dynamics model with interrelated variables, we can use it as the basis to form answers to the messy problem.[19] The first step would be to find feedback loops in the system dynamics model, see figure 5.44.

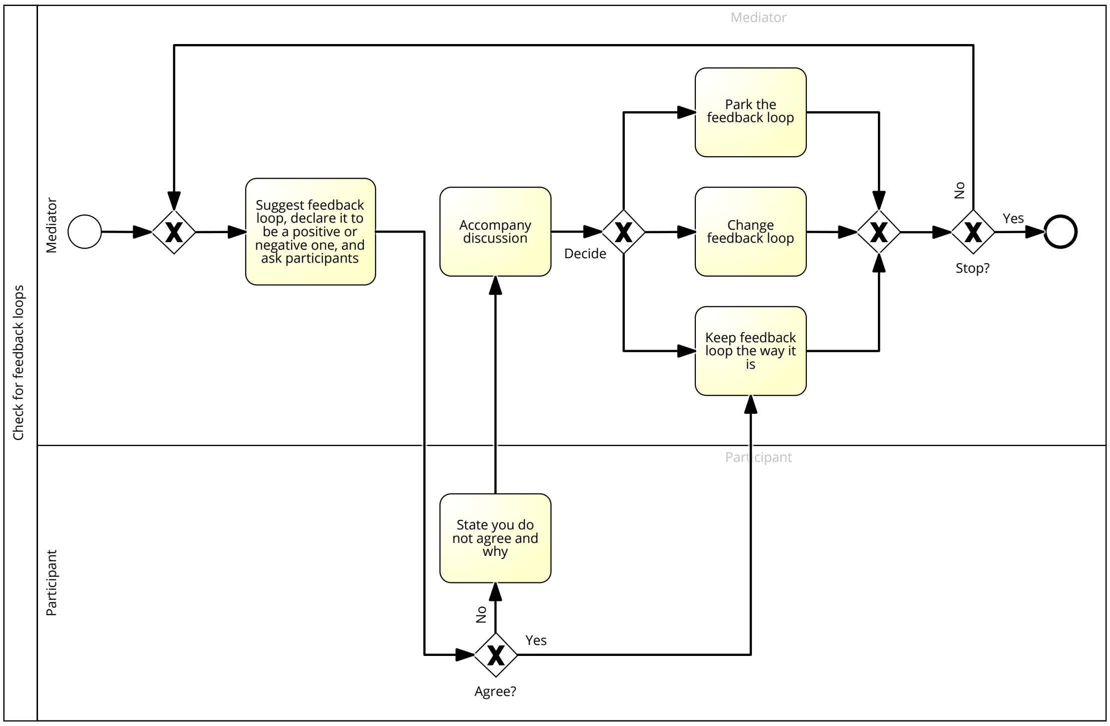

FIGURE 5.44: An overview of Check for feedback loops.

A feedback loop is a cycle of connected variables that in some way amplifies each other's behavior. A positive feedback loop is where variables increase each other's behavior, a negative feedback loop is where variables decrease each other's behavior. Let's look again at the example given in section 2.2.1, see figure 5.45.

Here the upper cycle of *Perception judge difference duration sentence and time served*, *Average duration detention*, and *Difference duration sentence and time served* is a positive feedback loop. This is because you see that each relation is a positive one. So if one of these three variables increases, the other two would increase, which would again affect the first, which would affect the other two, and on and on and on... These feedback loops are therefore the most important parts in defining an answer to messy problems, as they give insight in how to get a grip on the unwanted effects of the problem.

If we look again at figure 5.44, we see that *Check for feedback loops* contains six subprocesses, namely *Suggest feedback loop, declare it to be a positive or a negative one, and ask participants*, *State you do not agree and why*, *Accompany discussion*, *Park the feedback loop*, *Change feedback loop*, and *Keep feedback loop the way it is.*

These steps are connected in a complex way, but in almost the same way as with *Use the detail to find causes and effects of the problem variable* (section 5.2.1). This is because

[19]See section 2.1.2 for an explanation of messy problems.

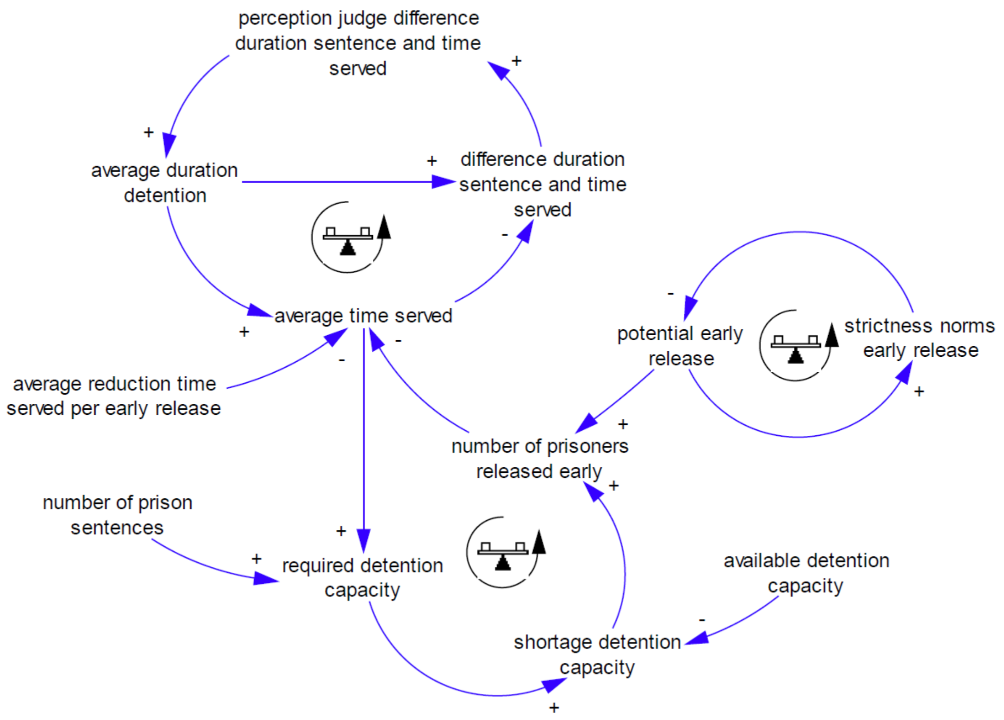

FIGURE 5.45: Example causal loop diagram (system dynamics) on early release policy (Rouwette and Vennix, 2007).

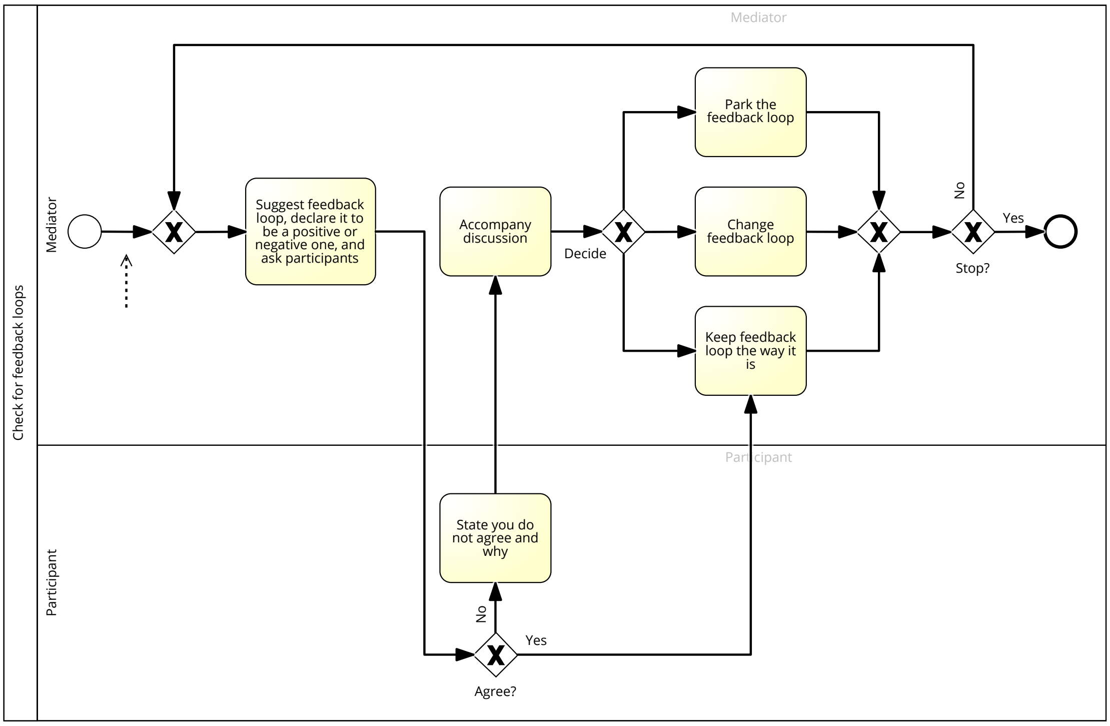

FIGURE 5.46: Check for feedback loops - 1st data position.

there are two decision points. One in which participants can agree (or not) with a suggestion, and another to decide what to do after the discussion.

The starting point, as shown in figure 5.46 is the same as the ending-point of *Use the detail to find causes and effects of the problem variable*. Therefore the data model shown in figure 5.40 is still accurate here, and the last defined post-condition is as well. For the sake of consistency, this is given again below. This now defines the precondition for *Suggest feedback loop, declare it to be a positive or negative one, and ask participants*, and these data requirements thus have to be met in order to start this process.

Post-condition for *Use the detail to find causes and effects of the problem variable* and precondition for *Suggest feedback loop, declare it to be a positive or negative one, and ask participants*:

- Goal
- Participant with
    - name
    - function
    - knowledge with
        - a basic understanding of group model building
        - an understanding of the way participants may interact with each other
        - problem variable
        - a list of detail of the problem variable including the problem variable itself
        - system dynamics model of the messy problem
    - skill
    - interest
- Process definition defined by rules, and actions, such as
    - mediator explained that there will be looked for feedback loops next
    - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
    - have a specific strength
    - are of a specific type, namely: positive, negative, context-dependent, or not of influence

Suggest feedback loop, declare it to be a positive or negative one, and ask participants

In this step, the mediator suggests a feedback loop, and explains if he thinks it is a positive or a negative one. He does this while following the relations path, and argues whether this is an overall positive, balanced, or negative path. Normally the strengths of the path determine whether it is actually a positive or a negative feedback loop. But, for the sake of understanding, group model building first determines this qualitatively with the participants. The feedback loop is then explicitly written down, and the mediator asks the participants if they agree with this suggestion.

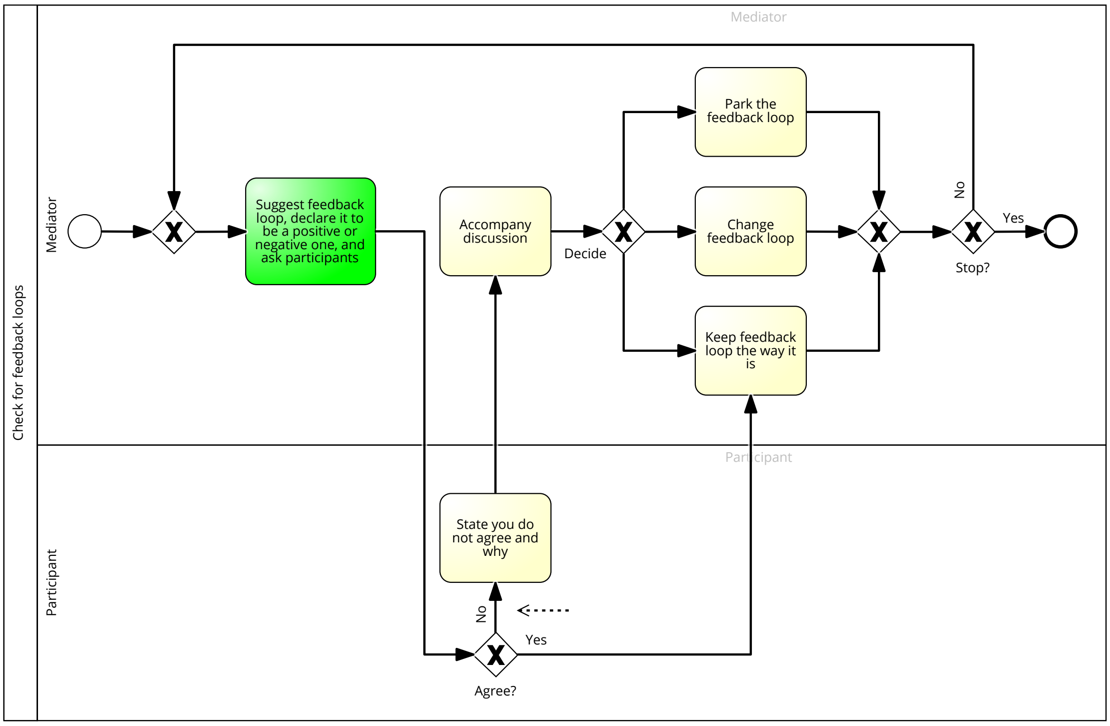

FIGURE 5.47: Check for feedback loops - 2nd data position.

Remember that we follow the longest path, therefore we assume that the participants do not agree (or at least one does not). This will get us at the position shown in figure 5.47, the XOR-port guides us upwards after the participant decided for himself that he did not agreed with the suggestion of the mediator. The data model on this position has changed a bit, as the concept *Feedback loop* has been added. A feedback loop can be positive or not (which automatically means that it is negative). The data model is shown in figure 5.48.

If we look at the information inside the concepts, we see a small difference with the previous one. As said above the concept *Feedback loop* has been added. Also, the concept *Process definition* has been expanded with the suggestion of the mediator and the not agreeing participant. This gives us, as is shown below, the post-condition for *Suggest feedback loop, declare it to be a positive or negative one, and ask participants* and the precondition for *State you do not agree and why*. The latter can only begin if these data requirements are met.

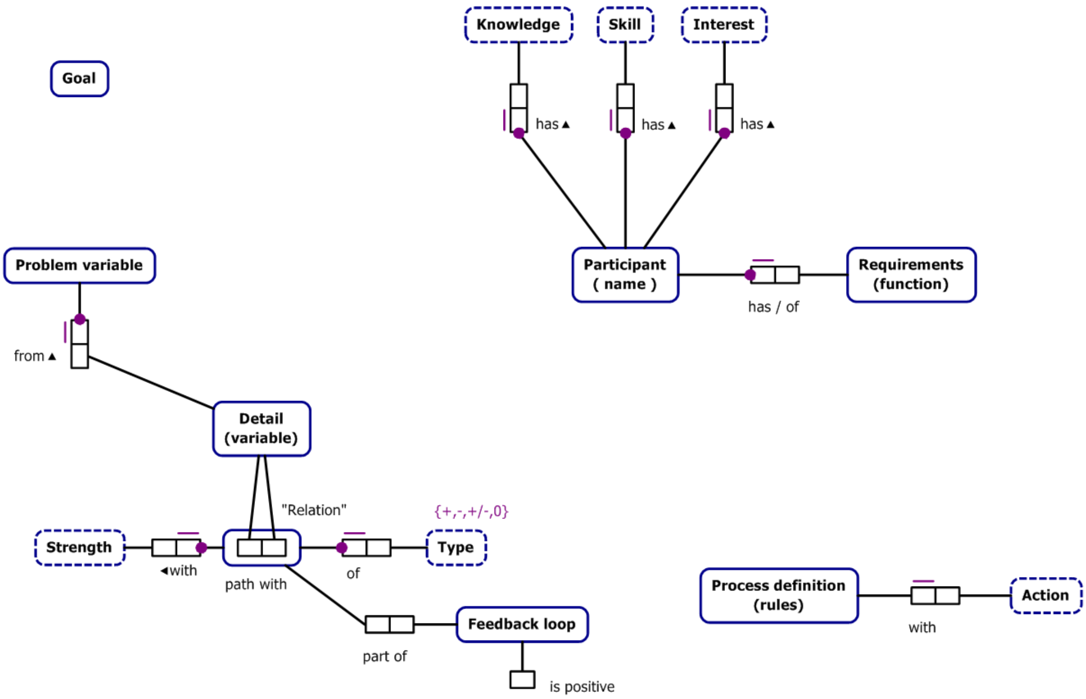

FIGURE 5.48: Create causal relationships - data on the last position.

Post-condition for *Suggest feedback loop, declare it to be a positive or negative one, and ask participants* and precondition for *State you do not agree and why*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill
  - interest
- Process definition defined by rules, and actions, such as
  - mediator has suggested a feedback loop including if it is a positive or a negative one
  - participant decided for himself he does not agree with this suggestion
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind
- Problem variable

- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

State you do not agree and why

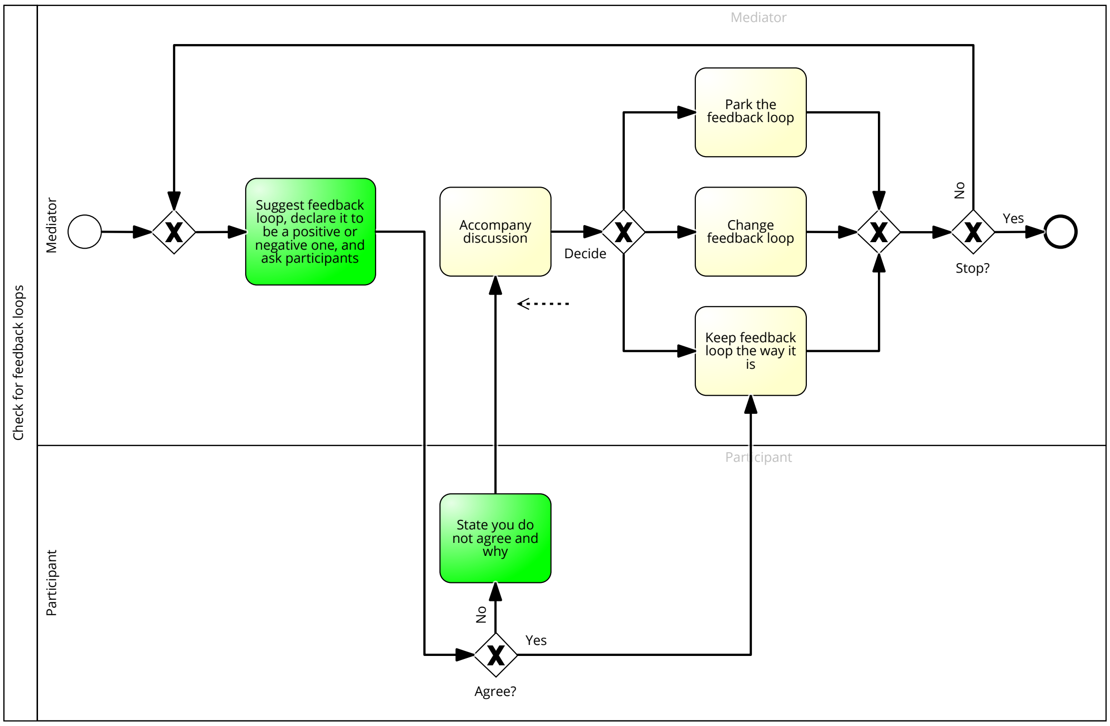

FIGURE 5.49: Check for feedback loops - 3rd data position.

There can be a couple of reasons for a participant to not agree with the suggestion of the mediator. First, he might not understand how the different relations add up to the conclusion of the mediator. Second, he understands why the mediator has come to this conclusion, but he does not agree with the result. The latter can be caused by a defect in the system dynamics model (e.g. missing variables or wrong relations), as the participants now might not agree with it anymore. This can be input for the discussion which brings us to the data position as shown in figure 5.49.

This input does not create a new concept for the data model, so the model shown in figure 5.48 is still accurate. The arguments of the participant are in the *Process definition* concept, as this is where rules and actions are being defined. Therefore, we can now provide a post-condition for *State you do not agree and why* and a precondition for *Accompany discussion*. The latter can only begin if these data requirements have been met.

Post-condition for *State you do not agree and why* and precondition for *Accompany discussion*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building

    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
    * system dynamics model of the messy problem
  - skill
  - interest

- Process definition defined by rules, and actions, such as
  - mediator has suggested a feedback loop including if it is a positive or a negative one
  - participant decided for himself he does not agree with this suggestion
  - participant gave arguments why he does not agree
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Accompany discussion

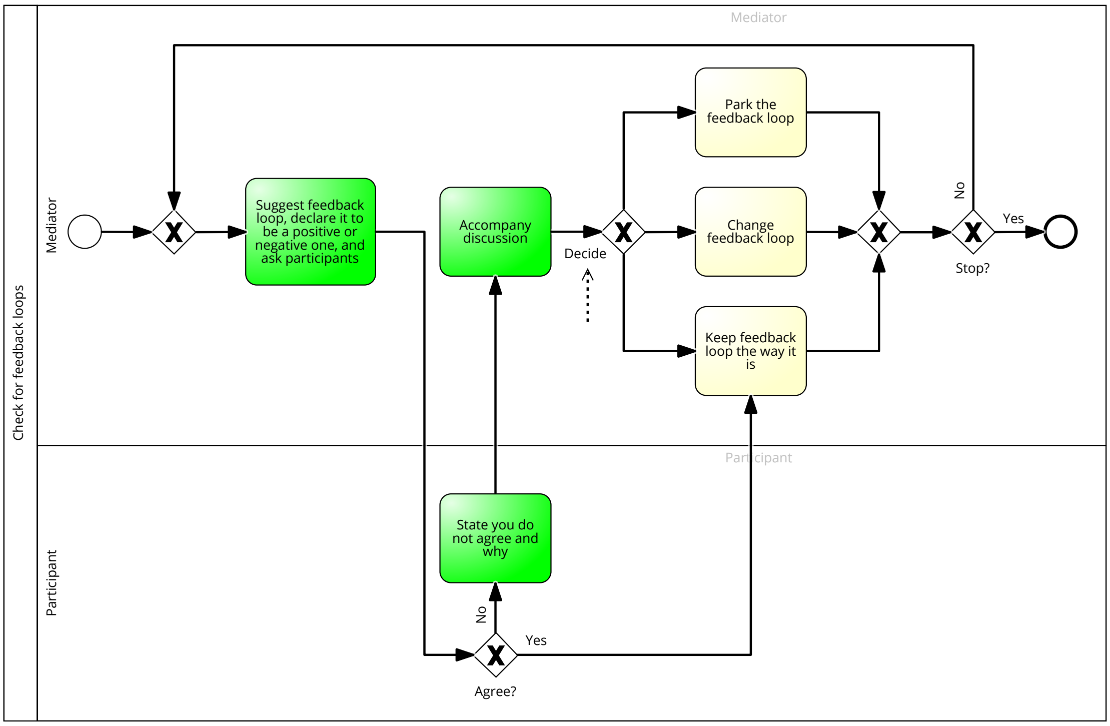

FIGURE 5.50: Check for feedback loops - 4th data position

The accompanying of the discussion in greater detail is out of the scope of this thesis, but we can say the mediator tries to guide the discussion into the making of a decision between three options, namely: *Park the feedback loop*, *Change feedback loop*, and *Keep feedback loop the way it is*. This means the data model as shown in figure 5.48 is still accurate, but the information inside the concepts have changed a bit.

Within the *Process definition* concept, the addition is being made of the mediator that guides the discussion. This makes it possible to define, as is shown below, a post-condition for *Accompany discussion* and a precondition for *Park the feedback loop, Change feedback loop, Keep feedback loop the way it is.* Remember that the latter can only start when these data requirements have been met.

Post-condition for *Accompany discussion* and precondition for *Park the feedback loop, Change feedback loop, Keep feedback loop the way it is*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable

    * a list of detail of the problem variable including the problem variable itself
    * system dynamics model of the messy problem
  - skill
  - interest

- Process definition defined by rules, and actions, such as
  - mediator has suggested a feedback loop including if it is a positive or a negative one
  - participant decided for himself he does not agree with this suggestion
  - participant gave arguments why he does not agree
  - the notion that it is not necessary anymore to be silent, and you may name a variable when it comes to mind

- Problem variable

- List of detail of the problem variable including the problem variable itself

- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Park the feedback loop, Change feedback loop, Keep feedback loop the way it is

In the last step of *Check for feedback loops*, a decision is being made of what to do with the feedback loop that is subject of discussion. There are three option from which can be chosen (see figure 5.51):

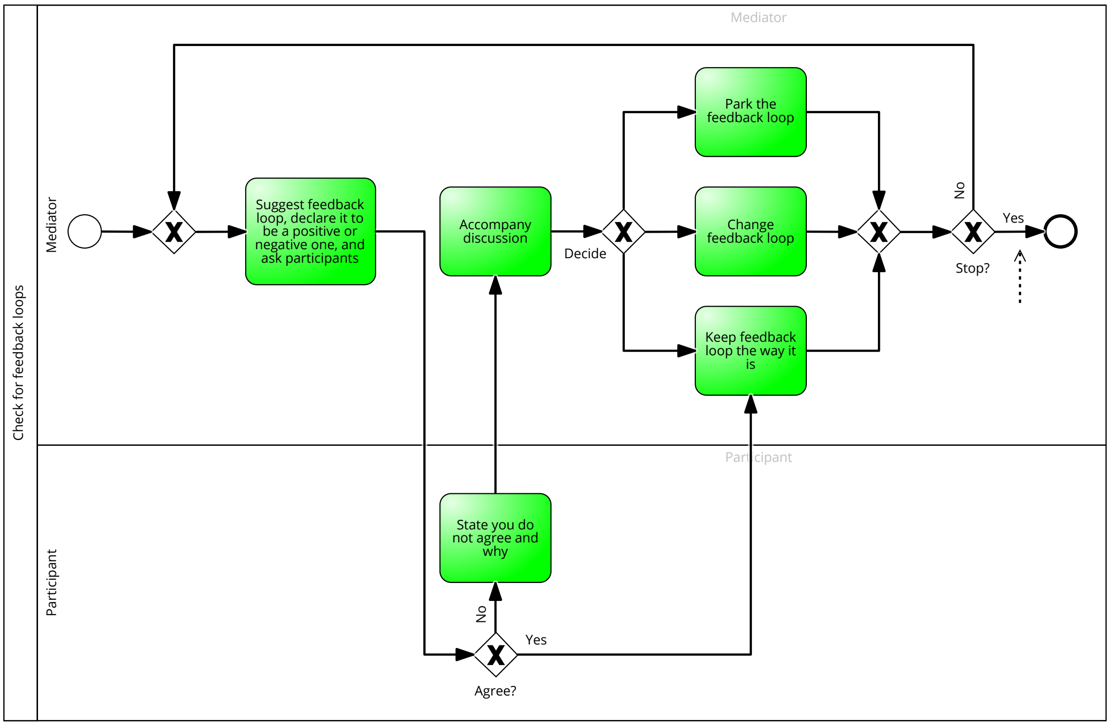

FIGURE 5.51: Check for feedback loops - 5th data position.

- *Park the feedback loop*: When the discussion is not going anywhere, the mediator can decide to park the feedback loop. Maybe the idea of the feedback loop must settle for a moment, or the participants must have a better understanding of the system dynamics model as a whole. All the parked feedback loops are being discussed at the end, in the hope it is confronted with less discussion. The mediator can always decide to abandon the idea of the feedback loop, but only if all the participant agree on it.[20] But, since the step of identifying the feedback loops is just a translation of the relations that are already there, this abandonment is most unlikely.

- *Change feedback loop*: This can happen if all the participants after the discussion changed their view on the system dynamics model. Sometimes a feedback loop contains many steps, so it can be tricky to identify the right path and the right type of feedback loop. Therefore, going back and change this path may be necessary in order to create a better under stander of the system dynamics model, and thus the messy problem.

[20]This can happen for the sake of continuation. If the participants keep debating, the session is going nowhere, therefore it is very likely they will eventually all accept this abandonment.

- *Keep feedback loop the way it is*:[21] If the discussion leads to consensus, it is most likely the feedback loop is kept the way it is.

After the decision is being made, the mediator can choose to identify more feedback loops or he can decide to stop. When he chooses to identify more feedback loops, the whole process of *Check for feedback loops* would start over again. But we assume the mediator has discussed all the possible feedback loops.[22] At this point we would be at the position shown in figure 5.51.

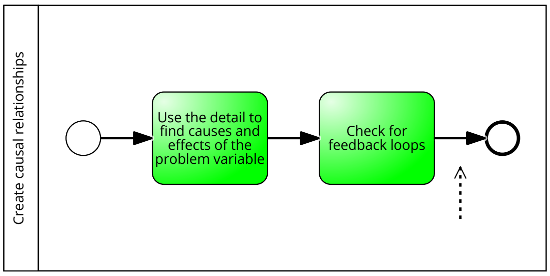

FIGURE 5.52: Create causal relationships - 3rd data position.

This means we would be at the end of *Check for feedback loops*, which means we would also be at the end of *Create causal relationships* as shown in figure 5.52. Therefore we can conclude that we are at the end of the fourth sub-process of the main group model building process, as is shown in figure 5.53.

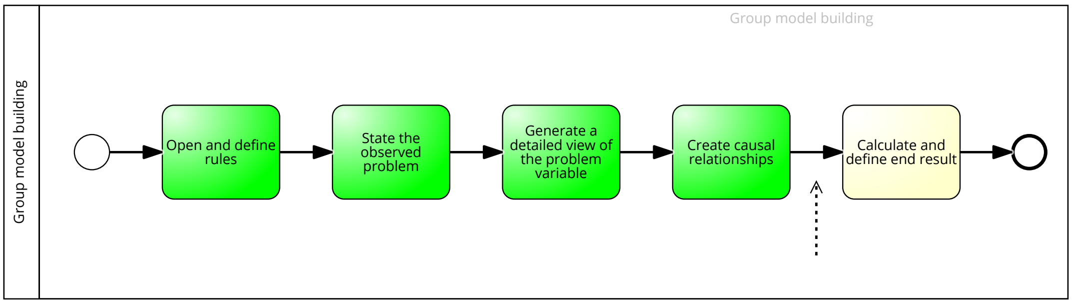

FIGURE 5.53: The main process of group model building: the end of the 4th step.

The data model at this point has not changed, because no new concepts where defined. This means the model given in figure 5.48, is still accurate here. There is some changing within the data concepts, most of them inside the *Process definition* concept. The notion that the mediator suggested a feedback loop, and the disagreement of the participant are now irrelevant and therefore removed from the information list. Also the notion that it is not necessary to be silent, is irrelevant here and therefore removed.

This gives us the possibility to define the post-condition for *Park the feedback loop, Change feedback loop, Keep feedback loop the way it is*, which is also the post-condition

[21]Please note that this step would be the first after *Suggest feedback loop, declare it to be a positive or negative one, and ask participants*, if the participants decided not to argue the suggested feedback loop.
[22]In real life, the participants could identify another feedback loop. This initiation is not only the privilege of the mediator. But these type of discussion would be very complex and out of scope of this thesis, therefore there is chosen for the situation where the mediator initiates.

for *Create causal relationships.* Since this means that it is the end of the fourth sub-process of the main process of group model building, this means we also define the precondition for the last sub-process of group model building, which is *Calculate and define result.* Remember that *Calculate and define result* can only start when the data requirements, as shown below, have been met.

Post-condition for *Park the feedback loop, Change feedback loop, Keep feedback loop the way it is* and precondition for *Calculate and define end result*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

5.3 Calculate and define result

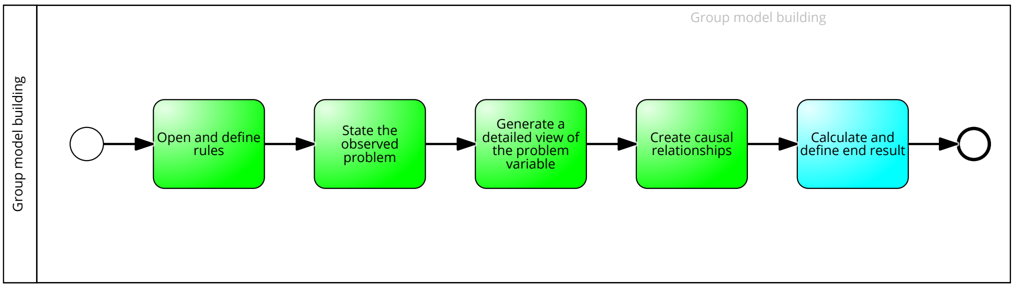

FIGURE 5.54: The position of Calculate and define result in the main process (denoted in blue).

This section will discuss the last sub-process of the main group model building process, namely *Calculate and define result* (see figure 5.54). In this sub-process the previous derived system dynamics model is being interpreted to create a possible solution to the messy problem. This is realized by defining so called control variables (which are variables that can be controlled by the organization) and target variables (which are variables that must get under control by the company)[23]. At the end, the company should try to change the values of the control variables in order to change the target variables. When these target variables change in a desired direction, the problem variable will probably change in a desired direction as well.

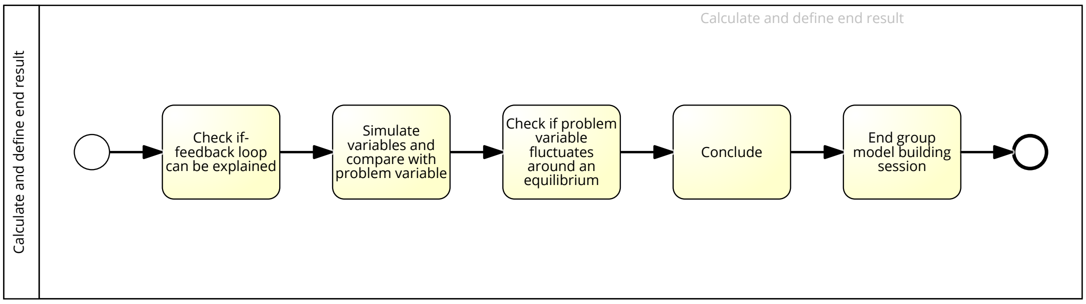

FIGURE 5.55: Calculate and define result - main process.

If we look closer at *Calculate and define result*, shown in figure 5.58, we see it contains five processes, namely: *Check if feedback loop can be explained* (section 5.3.1), *Simulate variables and compare with problem variable* (section 5.3.2), *Check if problem variable fluctuates around an equilibrium* (section 5.3.3), *Conclude* (section 5.3.4), and *End group model building session* (section 5.3.5). The last step, *End group model building session*, is not only the end of *Calculate and define result*, but also the end of the whole group model building session. In this step some announcements are made. One can argue that this means *End group model building session* should get its own sub-process in the main group model building process, but for readability (because this would have meant a small sub-process), it is chosen to add the *End group model building session* step to the rest of *Calculate and define result*.

[23]These variables are not the same as the problem variable, but may be variables that directly influence the problem variable.

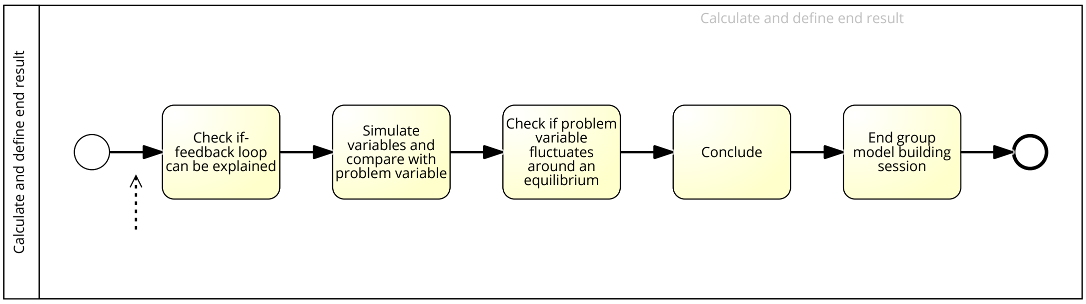

FIGURE 5.56: Calculate and define result - 1st data position.

We will walk through these processes sequentially, starting at the beginning as shown in figure 5.56. We know at this point how the data looks, because the precondition for *Calculate and define result* is exactly the same as the post-condition of the previous set of processes (*Create causal relationships*). For the sake of consistency we will show the data model and the data inside the concepts again. Figure 5.57 shows the data model which is exactly the same as the one of figure 5.48 of section 5.2.2.

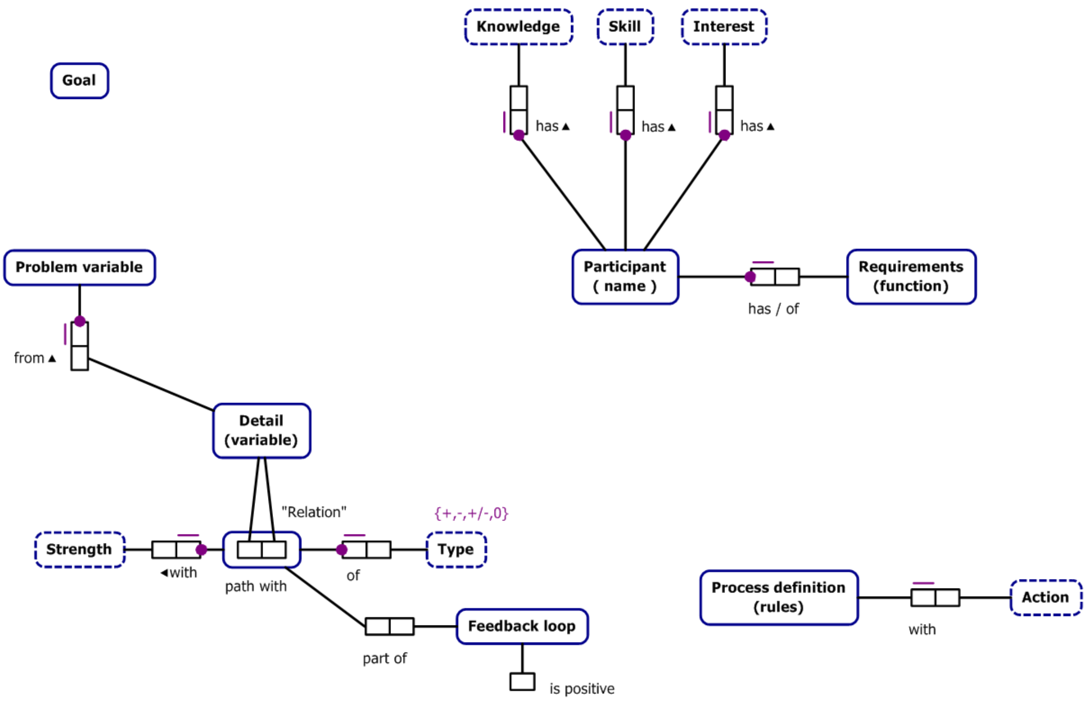

FIGURE 5.57: Calculate and define result - data on the 1st position.

So now we can define a precondition for the first step, *Check if feedback loop can be explained*, which is (as said before) the same as the post-condition for *Create causal relationships*. Remember that these data requirements have to be met in order to be able to start with *Check if feedback loop can be explained*.

Precondition for *Check if feedback loop can be explained*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

5.3.1 Check if feedback loop can be explained

The first part of *Calculate and define results* is *Check if feedback loop can be explained.* In this step, all the previous defined feedback loops are checked again to make absolutely clear that every participant understands the feedback loops, and sees the necessity of it. This may seem superfluous, as the checking of feedback loops is done in the previous step, but there is a small deference here. In the previous step, every feedback loop was check incrementally. This means that given the list of feedback loops as it was known then (which is not the complete list as it was still growing with new feedback loops), the participants argued if they understood the feedback loop. Therefore, the feedback loops where never checked with the complete list of feedback loops known. For example, it may be possible that a feedback loop is double or overflowing, given another feedback loop. This could be filtered out in this step, when all the feedback loops are checked again.

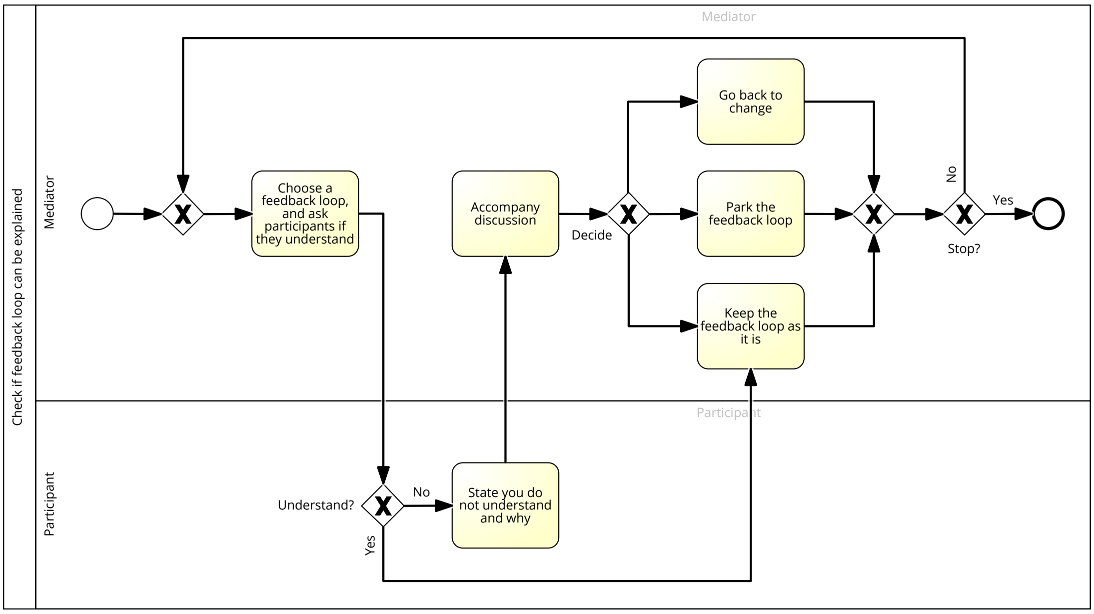

FIGURE 5.58: Check if feedback loop can be explained - Main process.

In figure 5.58, the overview of the steps of *Check if feedback loop can be explained*, is given. *Check if feedback loop can be explained* contains six steps, of which some may be skipped if a feedback loop is understood. These steps are: *Choose a feedback loop and ask participants if they understand*, *State you do not understand and why*, *Accompany discussion*, *Go back to change*, *Park the feedback loop*, and *Keep the feedback loop as it is.* First, a feedback loop is chosen by the mediator, and then he asks the participants if they understand it. When they do not understand it, a discussion is being held in order to try make things clear. After the discussion, a decision of what to do with the feedback loop is being made.

Before we go through the steps, we want to analyze the data at the position shown in figure 5.59. As this is the first data position of *Check if feedback loop can be explained*, it is the same as the first data position of *Calculate and define result.* Therefore, the precondition for the first step, *Choose a feedback loop and ask participants if they understand*, is the same as that of *Calculate and define result.* For the sake of consistency,

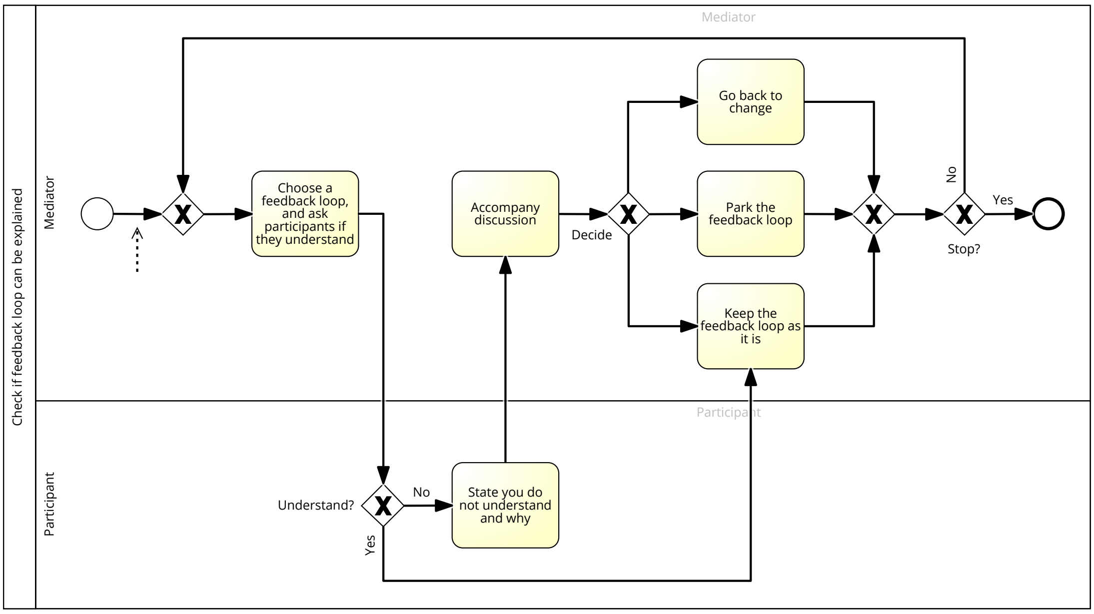

FIGURE 5.59: Check if feedback loop can be explained - 1st data position.

it is given again below. Remember that *Choose a feedback loop and ask participants if they understand* may only start when these data requirements are met.

Precondition for *Choose a feedback loop and ask participants if they understand*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Choose a feedback loop and ask participants if they understand

The mediator will now choose a feedback loop from the list of feedback loops, and present it to the participants. The mediator will also ask the group if they understand how this feedback loop works and why it is here, given the complete list of feedback loops. The participants have to decide whether or not they understand the feedback loop.

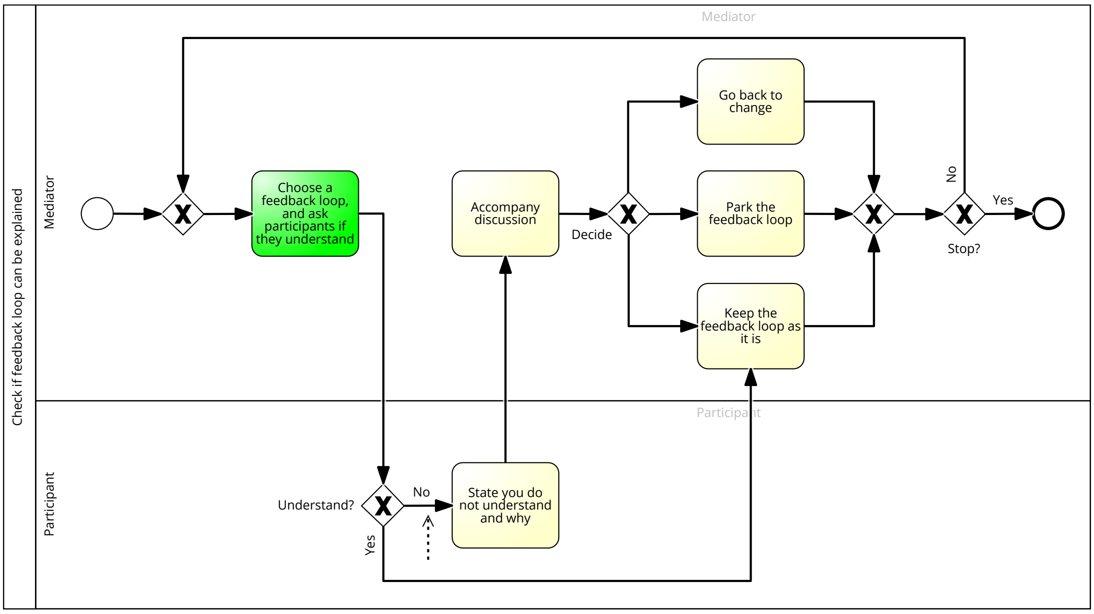

FIGURE 5.60: Check if feedback loop can be explained - 2nd data position.

We will assume the participant does not understand the feedback loop completely, which can mean that he does not agree with the substantively part of it, or with the position of it. Therefore, we can assume that we now are at the position as shown in figure 5.60. At this point, there is not much difference in the data model, as no new concepts have been defined (which means that the data model of figure 5.57 is still accurate here), but there is a small change in the information inside these concepts. In *Choose a feedback loop and ask participants if they understand*, the mediator explains to the participants what will happen next. Also as said before, a feedback loop and a question if it is understood, is given. Last, the participant has decided if he understands the ways of this feedback loop, which is defined in the concept *knowledge*.

Therefore, we can now define the post-condition for *Choose a feedback loop and ask participants if they understand*, which is also the precondition for *State you do not understand and why*. Remember that the latter can only start if the data requirements, as given below, have been met.

Post-condition for *Choose a feedback loop and ask participants if they understand* and precondition for *State you do not understand and why*:

- Goal
- Participant with
  - name

  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
    * system dynamics model of the messy problem
    * does not understand the given feedback loop
  - skill, expanded with
    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - the mediator has explained what the next steps would be, which is if a disagreement of the feedback loop arises the feedback loop must be discussed
  - the mediator has given a feedback loop and ask the participants to decide whether they understand it or not

- Problem variable

- List of detail of the problem variable including the problem variable itself

- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

State you do not understand and why

In this phase, the participant states he or she does not understand the given feedback loop. This can happen if according to the participant, the feedback loop is superfluous or incorrect. Therefore, the participant has to state why he does not understand the feedback loop as it is given, which should be the input for the discussion of the next step.

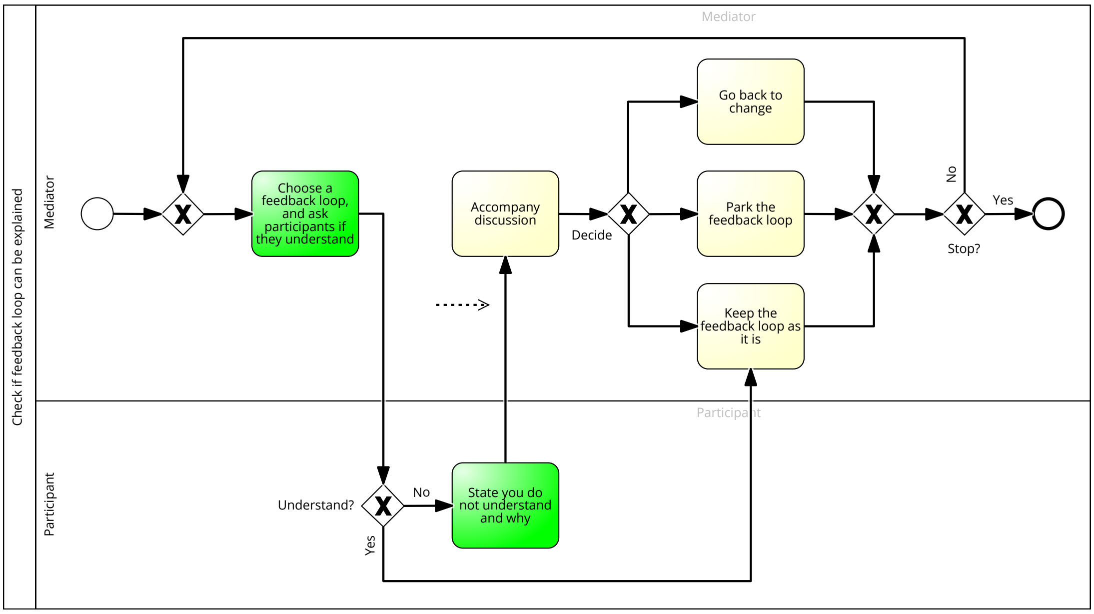

FIGURE 5.61: Check if feedback loop can be explained - 3rd data position.

If we look at the data at the position shown in figure 5.61, there is no change in the data model, so the one shown in figure 5.57, is still accurate. The only difference is the data inside the concept *Process definition*, as the participant now stated he or she does not agree and why. We can now therefore define the post-condition for *State you do not understand and why*, which is also the precondition for *Accompany discussion*. Remember that the latter can only start if the data requirements, as shown below, are being met.

Post-condition for *Choose a feedback loop and ask participants if they understand* and precondition for *State you do not understand and why*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself

        * system dynamics model of the messy problem
        * does not understand the given feedback loop
    - skill, expanded with
        * system dynamics building skills
    - interest

- Process definition defined by rules, and actions
    - the mediator has explained what the next steps would be, which is if a disagreement of the feedback loop arises the feedback loop must be discussed
    - the mediator has given a feedback loop and ask the participants to decide whether they understand it or not
    - participant has made clear that he does not understand the feedback loop and why

- Problem variable

- List of detail of the problem variable including the problem variable itself

- A system dynamics model with causal relations that
    - have a specific strength
    - are of a specific type, namely: positive, negative, context-dependent, or not of influence
    - are part of a feedback loop that can be positive or negative

Accompany discussion

In *Accompany discussion*, the mediator tries to discuss the haziness of the feedback loop with the argument of the participant kept in mind. This means that all the participants are allowed to discuss and give their opinions. The mediator must try to help the participants decide what to do with the current feedback loop (see the next steps).

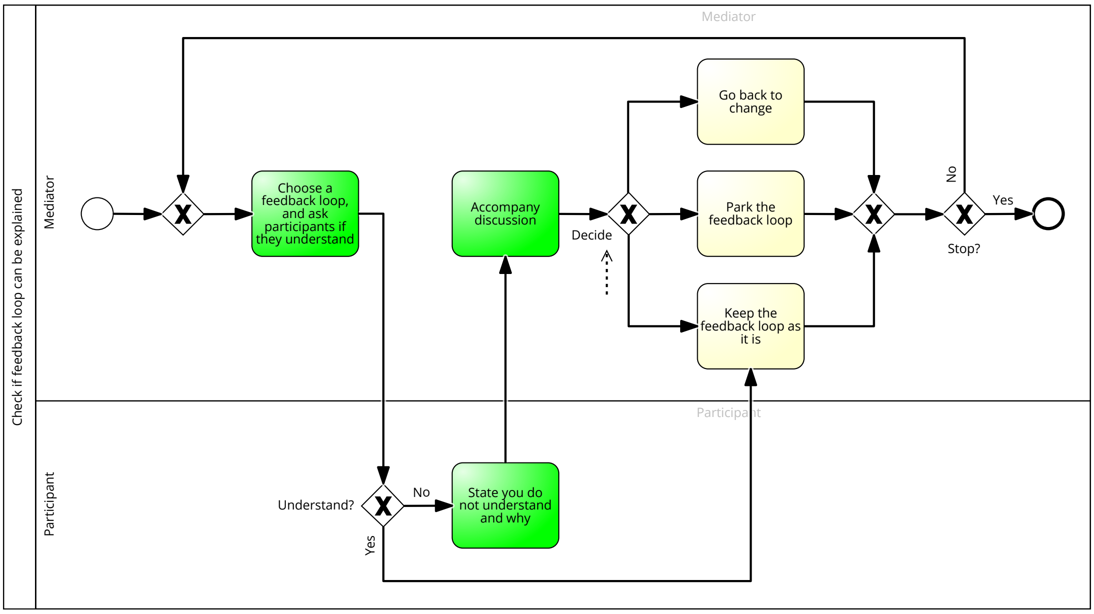

FIGURE 5.62: Check if feedback loop can be explained - 4th data position.

If we look at the data model at the position, as shown in figure 5.62, there is no new concept derived, so the data model shown in figure 5.57, is still accurate. The only difference here is that within the concept *Process definition*, the mediator steers the discussion into a decision. Therefore, we can now define the post-condition for *Accompany discussion*, which is also the precondition for *Go back to change, Park the feedback loop, Keep the feedback loop as it is.* Remember that the latter can only start if the data requirements, as shown below, are met.

Post-condition for *Accompany discussion* and precondition for *Go back to change, Park the feedback loop, Keep the feedback loop as it is*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem

    * does not understand the given feedback loop
  - skill, expanded with
    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - the mediator has explained what the next steps would be, which is if a disagreement of the feedback loop arises the feedback loop must be discussed
  - the mediator has given a feedback loop and ask the participants to decide whether they understand it or not
  - participant has made clear that he does not understand the feedback loop and why
  - the mediator steers the discussion into the making of a decision

- Problem variable

- List of detail of the problem variable including the problem variable itself

- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Go back to change, Park the feedback loop, Keep the feedback loop as it is

After a discussion, the participants have to choose what they want to do with the feedback loop in question. The mediator makes clear that the participants can choose between three choices, namely:

- *Go back and change*: If, after the discussion, it is made clear that the misunderstanding of the feedback loop is derived from a variable that is wrongly placed in the model, or it can be the case that variables are missing. If the latter is the case, the session should go back to the creating variables or creating causal relationships phase, in order to complete the network of which the feedback loop has effect. This means that the correct process of procession each feedback loop is being interrupted.
- *Park the feedback loop*: If the discussion is going nowhere, or if the participants agree that the feedback loop in question has no value anymore, they can park the feedback loop. Parked feedback loops can be discussed at the end if all the other feedback loops have been discussed, or they can choose to leave the feedback loop parked, and therefore remove it from the list of feedback loops.
- *Keep the feedback loop as it is*: If the discussion has created consensus about the feedback loop, and all the participants understand how it works and why it is the way it is, they can choose to leave the feedback loop as it is.

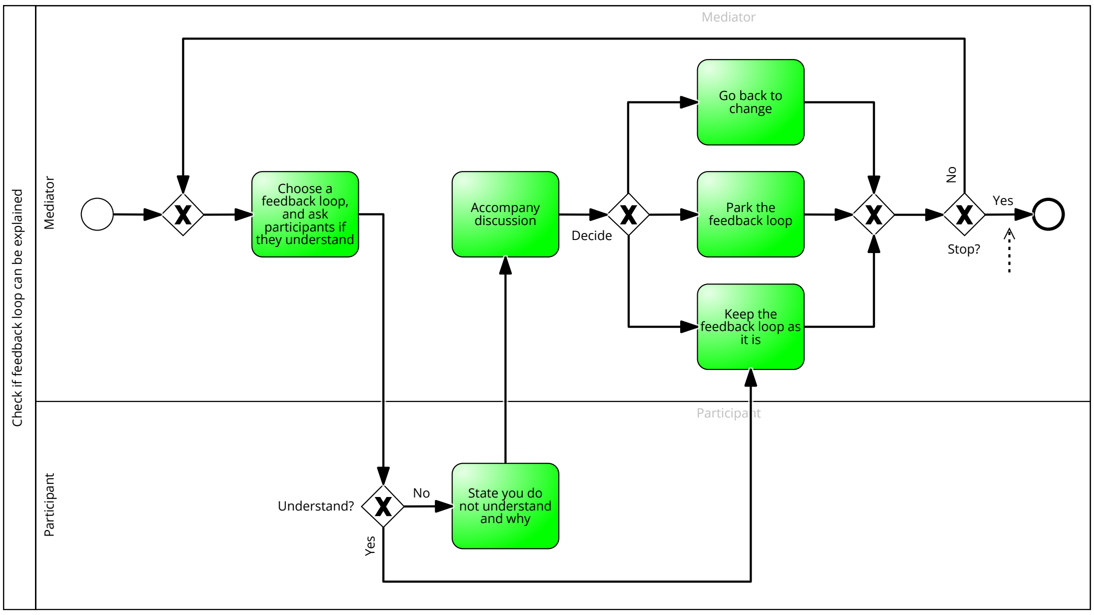

FIGURE 5.63: Check if feedback loop can be explained - 5th data position.

When a decision is being made, the mediator has to choose if another feedback loop from the list must be discussed. Normally this question would be answered with a yes if there are still non-discussed feedback loops in this phase. We assume that all the feedback loops have been discussed, and that all the participants understand the remaining[24] feedback loops. This means we are now at the data position shown in figure 5.63.

[24]If some feedback loops are kept in the parked state, these feedback loops are being removed from the list of feedback loops.

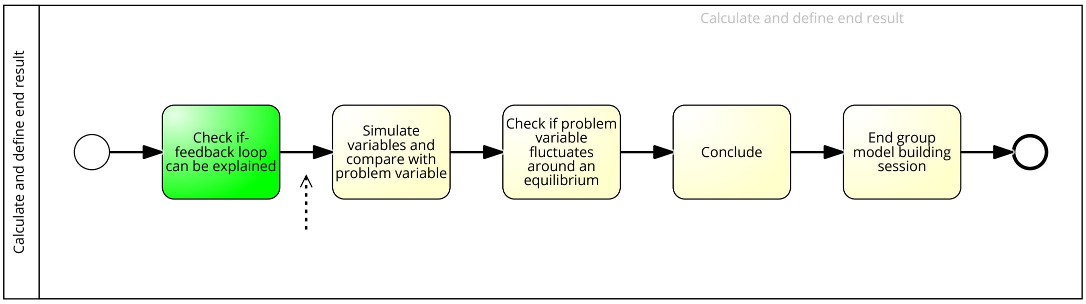

FIGURE 5.64: Calculate and define result - 2nd data position.

As this is the end of *Check if feedback loop can be explained*, we are also at the data position shown in figure 5.64. No new concepts have been derived, so the data model shown in figure 5.57 is still accurate here, but there are some changes within concepts. Inside the concept *Process definition*, all the notions of the discussion became irrelevant and are removed. The only thing that remains, is that all the feedback loops are understood. This relates to the remaining feedback loops, because the others have been removed. This creates a small change in the concept *Feedback loop*.

This means we can now derive a post-condition for *Go back to change, Park the feedback loop, Keep the feedback loop as it is* (which is also the post-condition for *Check if feedback loop can be explained*), and a precondition for the next phase, namely *Simulate variables and compare with problem variable.* The latter can only start when the data requirements, as given below, have been met.

Post-condition for *Go back to change, Park the feedback loop, Keep the feedback loop as it is* and precondition for *Simulate variables and compare with problem variable*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
  - all the feedback loops are understood
- Problem variable
- List of detail of the problem variable including the problem variable itself

- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

5.3.2 Simulate variables and compare with problem variable

Now that every participant agrees with the list of feedback loops, the session continues by simulating variables from those feedback loops against the problem variable. This will generate a diagram that shows the behavior of the feedback loop, and this can only be done if quantitative measurements are known. Because quantitative analysis is out of scope of this thesis, we will summarize this with the concept *Strength*.

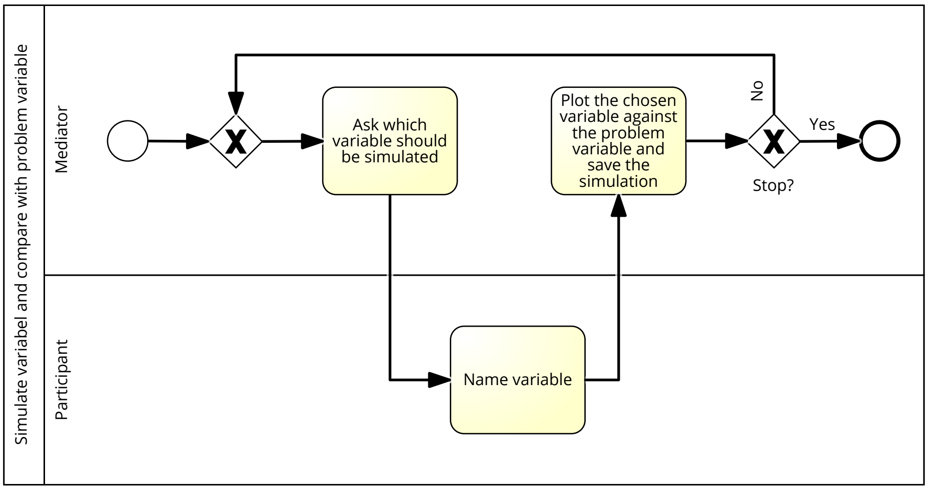

FIGURE 5.65: Simulate variables and compare with problem variable - main process.

In *Simulate variables and compare with problem variable* (see figure 5.65), the mediator asks the participants to name a variable. The variable that is mentioned is being simulated against the problem variable, and this simulation is saved. *Simulate variables and compare with problem variable* contains three processes, namely *Ask which variable should be simulated*, *Name variable*, and *Plot the chosen variable against the problem variable and save the simulation*, which loops until all the variables that are in feedback loops have been processed.[25]

We will walk through this process sequentially, and start at the position shown in figure 5.66. As this is the start of *Simulate variables and compare with problem variable*, the precondition for *Ask which variable should be simulated* is the same as the post-condition for *Check if feedback loop can be explained* (which is also the precondition for *Simulate variables and compare with problem variable*). Therefore the data model shown in figure 5.57, is still accurate here. The list of information is also exactly the same, but for consistency reasons it is given again below. Remember that *Ask which variable should be simulated* may only start when these data requirements are met.

Post-condition for *Check if feedback loop can be explained* and precondition for *Ask which variable should be simulated*:

- Goal

[25]In regular group model building, this step can be done in two ways: The first way is to ask the participants to name a variable which will be plotted (like we are doing here). The second way is to automatically generate simulations of all the variables that are part of feedback loops. The benefit of the second option is speed, while the benefit of the first option is understanding among participants, because the simulations are slowly created, therefore the participant can fully understand the dynamics.

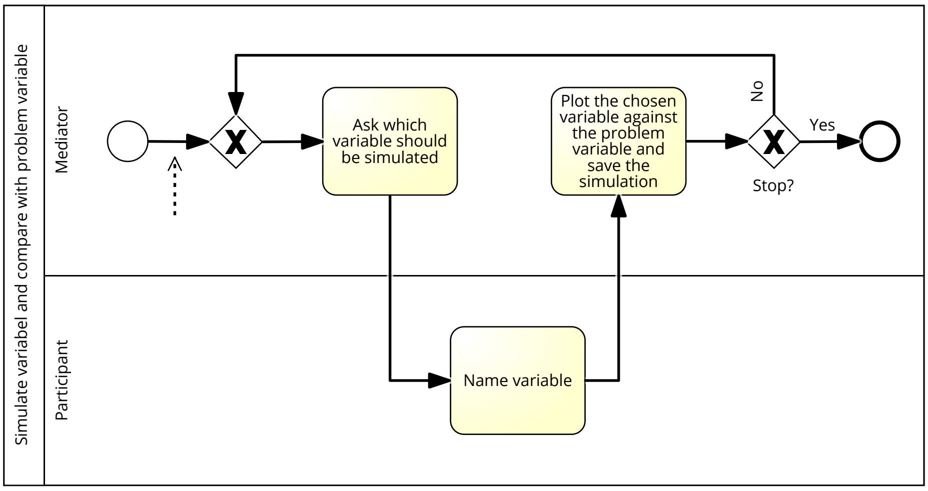

FIGURE 5.66: Simulate variables and compare with problem variable - 1st data position.

- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
  - all the feedback loops are understood
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Ask which variable should be simulated

In *Ask which variable should be simulated*, the mediator asks the participants to name a variable that they find interesting and want to simulate to understand its dynamic behavior in the system dynamics model.

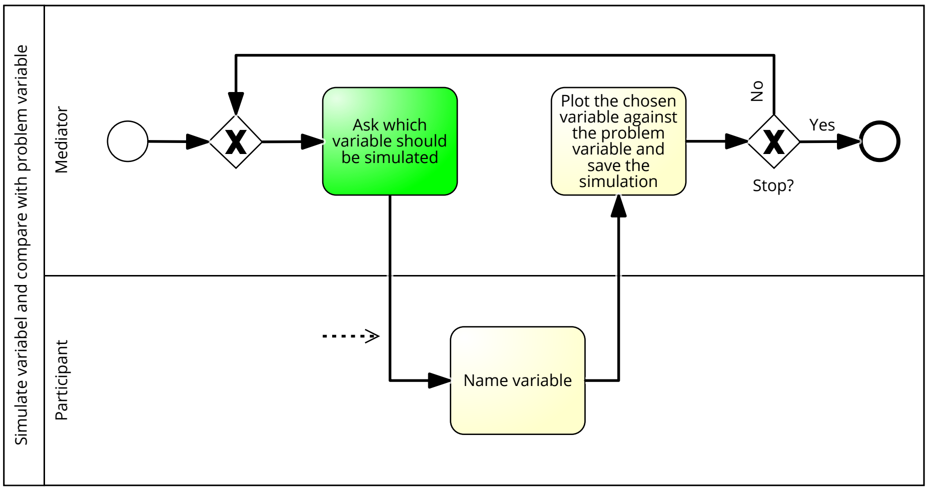

FIGURE 5.67: Simulate variables and compare with problem variable - 2nd data position.

Therefore, if we look at the data at the position shown in figure 5.67, we see a small change of the information inside the concepts, but no change in the data model. Therefore, the data model shown in figure 5.57, is still accurate here. The information inside the concept *Process definition*, has changed here, as the mediator now asked a question. We can now therefore define the post-condition for *Ask which variable should be simulated* which is the same as the precondition for *Name variable*. This is given below, and these data requirements have to be met in order to be able to start with *Name variable*

Post-condition for *Ask which variable should be simulated* and precondition for *Name variable*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
    * system dynamics model of the messy problem
  - skill, expanded with
    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - all the feedback loops are understood
  - mediator asked the participants to name a variable that must be simulated against the problem variable, in order to understand its dynamics behavior within the system dynamics model
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Name variable

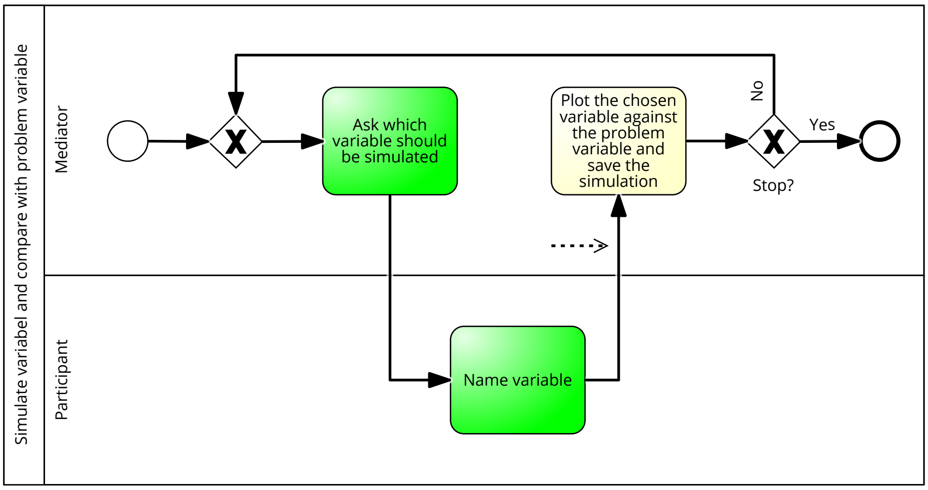

FIGURE 5.68: Simulate variables and compare with problem variable - 3rd data position.

In *Name variable*, a participant names a variable he or she finds interesting and wants to simulate against the problem variable. This is a very simple step, and therefore, only generates a small change of the information inside the concepts. So, the data model of 5.57 is still accurate here, and inside the concept *Process definition*, the calling of a variable is taken in. Therefore, we can now define the post-condition for *Name variable*, which is the same as the precondition for *Plot the chosen variable against the problem variable and save the simulation.* The latter can only begin if the following data requirements have been met.

Post-condition for *Name variable* and precondition for *Plot the chosen variable against the problem variable and save the simulation*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
  - all the feedback loops are understood

  - mediator asked the participants to name a variable that must be simulated against the problem variable, in order to understand its dynamics behavior within the system dynamics model
  - a participant has named a variable

- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Plot the chosen variable against the problem variable and save the simulation

If the participant has chosen a variable, the mediator will plot[26] it against the problem variable. This simulation shows the behavior of the variable, and will be used in the next steps. Therefore, the simulation must be saved.

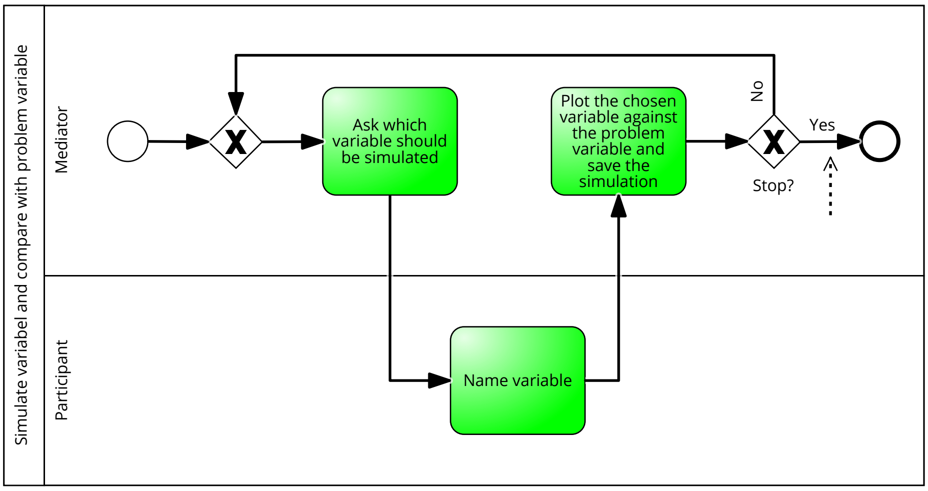

FIGURE 5.69: Simulate variables and compare with problem variable - 4th data position.

Also the participants are asked to remember simulations that looked interesting. How a simulation may look interesting, is left out of this thesis, but one can imagine that if all the variables show the same relations to the problem variable except one who has a different relation to the problem variable, this is interesting behavior, and therefore, must be remembered for the next steps.

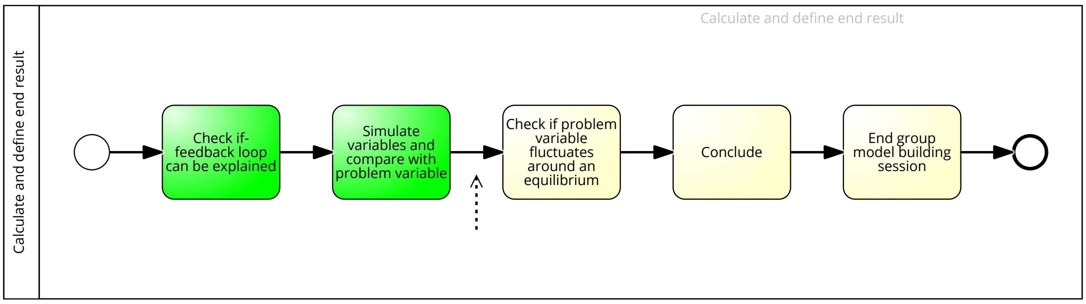

FIGURE 5.70: Calculate and define result - 3rd data position.

The mediator than has to decide if all the variables have been processed. If so, the *Simulate variable and compare with problem variable* can end, and we are then at the position shown in figure 5.69. As this is the end of *Simulate variable and compare with problem variable*, we are also at the position shown in figure 5.70.

If we look at the data at this point, there are some changes. The saved simulations form a new concept, namely *Saved simulations*. So, the data model is changed as is shown in figure 5.71. Inside the concept *Knowledge*, the participant remembered an

[26]The way this is been done is out of scope of this thesis.

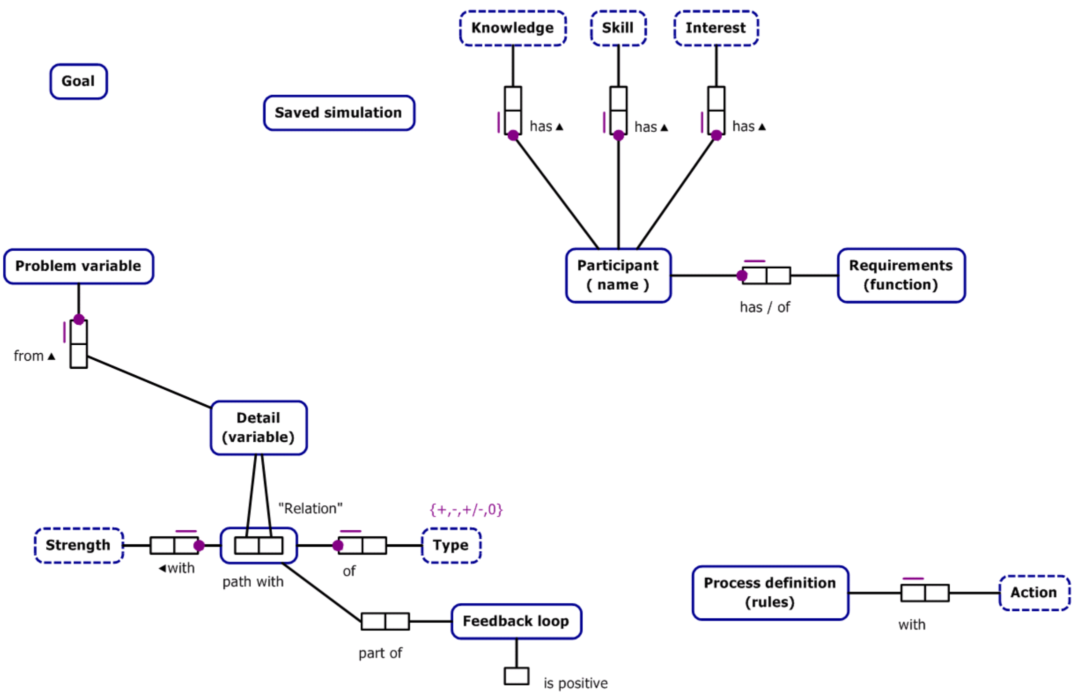

FIGURE 5.71: Calculate and define result - data on the 3rd position.

interesting simulation, and inside the concept *Process definition*, the mediator asked the participants to remember interesting simulations. Also the notions that a participant has named a variable, and the question of the mediator to name a variable, have become irrelevant and are therefore removed.

Thus, we can now define the post-condition for *Plot the chosen variable against the problem variable* which is also the post-condition for *Simulate variable and compare with problem variable*, and the precondition for *Check if problem variable fluctuates around an equilibrium*. The latter can only start if the data requirements below have been met.

Post-condition for *Plot the chosen variable against the problem variable and save the simulation* and precondition for *Check if problem variable fluctuates around an equilibrium*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - finds a simulation interesting

  - skill, expanded with
    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - all the feedback loops are understood
  - the mediator asked the participants to remember simulations that looked interesting
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

5.3.3 Check if problem variable fluctuates around an equilibrium

In *Check if problem variable fluctuates around an equilibrium*, the group will look at all the simulations in order to find proof for the feedback loops. This proof is derived from the fact that a negative feedback loop shows some typical characteristics, namely an equilibrium-seeking simulation (Rouwette and Franco, 2014). Because quantitative analysis is out of scope of this thesis, the exact ways in how to find proof of a feedback loop is left out.[27]

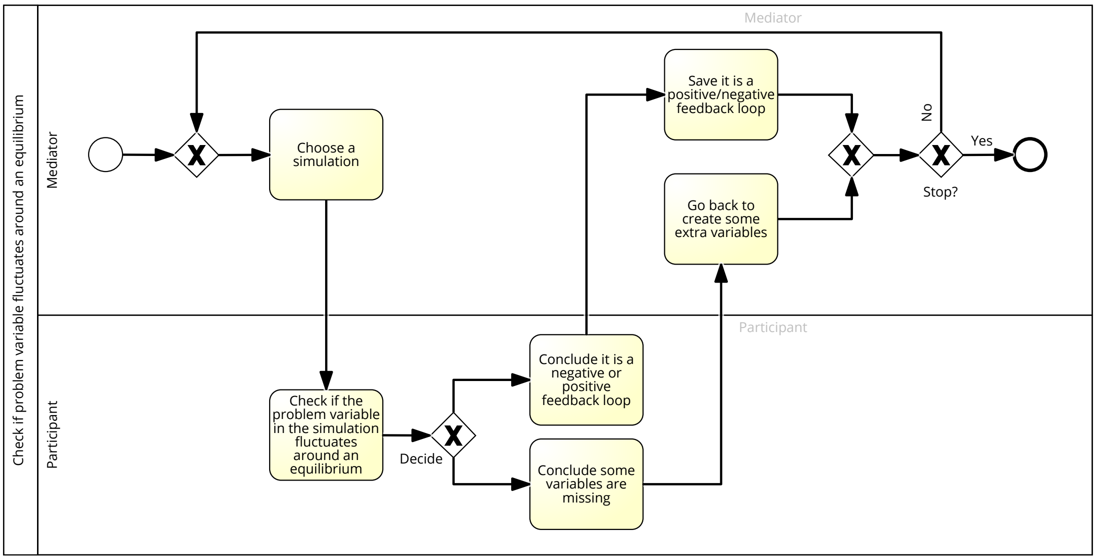

FIGURE 5.72: Check if problem variable fluctuates around an equilibrium - main process.

Check if problem variable fluctuates around an equilibrium consists of six steps, as is shown in figure 5.72, which are looping and split after two steps. The processes are: *Choose a simulation*, *Check if the problem variable in the simulation fluctuates around an equilibrium*, *Conclude it is a negative or positive feedback loops*, *Save it is a positive/negative feedback loop*, *Conclude some variables are missing*, and *Go back to create some extra variables*. We will look at these steps sequentially in the following sections.

At the beginning of *Check if problem variable fluctuates around an equilibrium*, as is shown in figure 5.73, the data looks exactly the same as the post-condition of the last process (*Simulate variable and compare with problem variable*). Therefore, the data model, as shown in figure 5.71, is still accurate here, and the data inside the concepts, is the same as well. For the sake of consistency, this is given again below.

Now we can define the precondition for *Choose a simulation*, which thus is the same as the post-condition for *Simulate variable and compare with problem variable*. Remember that the data requirements, as shown below, have to be met, in order to start with *Choose a simulation*.

[27] Normally a combination of simulations will provide proof, but for the ease of reading, we will keep talking of a single simulation.

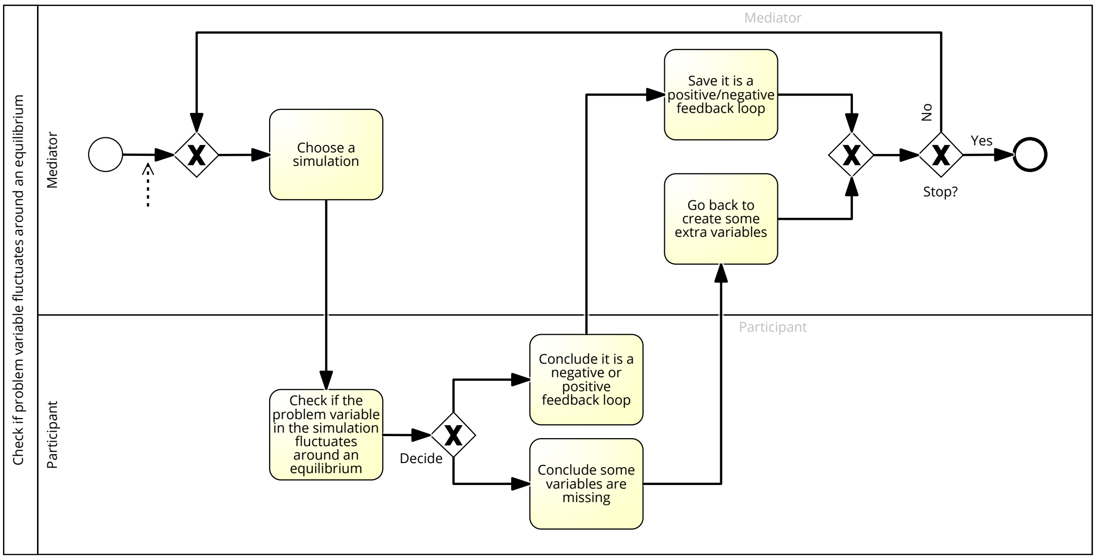

Figure 5.73: Check if problem variable fluctuates around an equilibrium - 1st data position.

Post-condition for *Simulate variable and compare with problem variable* and precondition for *Choose a simulation*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - finds a simulation interesting
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
  - all the feedback loops are understood
  - the mediator asked the participants to remember simulations that looked interesting
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations
- A system dynamics model with causal relations that
  - have a specific strength

- are of a specific type, namely: positive, negative, context-dependent, or not of influence
- are part of a feedback loop that can be positive or negative

Choose a simulation

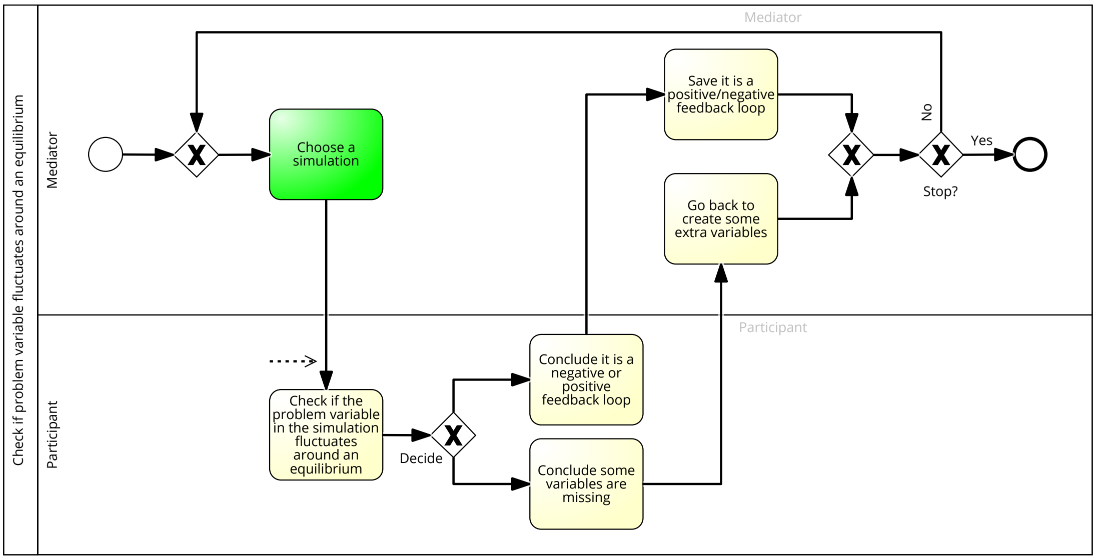

FIGURE 5.74: Check if problem variable fluctuates around an equilibrium - 2nd data position.

Here, the mediator chooses a simulation from the saved simulations, and asks the participants to check if they see that the problem variable is fluctuating around a equilibrium or not. Therefore the only changes in the data, is the information inside the concepts, as there are no new concepts derived. The concept *Process definition* is expanded with the notion that the focus lays on a specific simulation, and the question the mediator asked the participants if they see the fluctuations around the equilibrium.

Therefore we can now define the post-condition for *Choose a simulation*, which is also the precondition for *Check if the problem variable in the simulation fluctuates around an equilibrium.* Remember that the latter can only begin if the data requirements, as shown below, have been met.

Post-condition for *Choose a simulation* and precondition for *Check if the problem variable in the simulation fluctuates around an equilibrium*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - finds a simulation interesting
  - skill, expanded with

    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - all the feedback loops are understood
  - the mediator asked the participants to remember simulations that looked interesting
  - the notion that the focus now lays on a single feedback loop
  - the mediator asked the participants if they see whether the problem variable fluctuates around an equilibrium in the simulation
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Check if the problem variable in the simulation fluctuates around an equilibrium

Now, the participants have to decide if the problem variable fluctuates around an equilibrium, and then they have to decide what this means. How they derive this decision from the simulations, is out of scope of this thesis, as this has to do with quantitative analysis of system dynamics models. Therefore, we assume that they are able to derive a conclusion out of what they see with the fluctuation of the problem variable in the simulations.

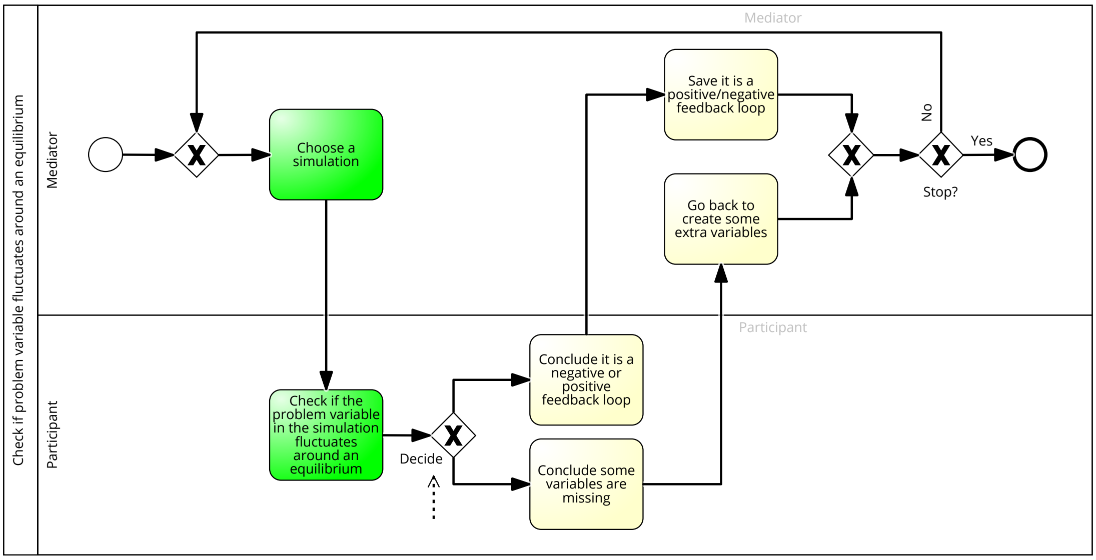

FIGURE 5.75: Check if problem variable fluctuates around an equilibrium - 3rd data position.

So, if we look at the data at the position shown in figure 5.75, we see a small change in the *Process definition* concept. There the decision is being added to the information at that data position. There are no new concepts created, so the data model shown in figure 5.71, is still accurate here. Therefore, we can now conclude the post-condition for *Check if the problem variable in the simulation fluctuates around an equilibrium*, which is also the precondition for *Conclude it is a negative or positive feedback loop, Save it is a positive/negative feedback loop, Conclude some variables are missing, Go back to create some extra variables.* Remember that the following data requirements have to be met, in order for the next process to be processed?

Post-condition for *Check if the problem variable in the simulation fluctuates around an equilibrium* and precondition for *Conclude it is a negative or positive feedback loop, Save it is a positive/negative feedback loop, Conclude some variables are missing, Go back to create some extra variables*:

- Goal
- Participant with
  - name
  - function
  - knowledge with

        * a basic understanding of group model building
        * an understanding of the way participants may interact with each other
        * problem variable
        * a list of detail of the problem variable including the problem variable itself
        * system dynamics model of the messy problem
        * finds a simulation interesting
    - skill, expanded with
        * system dynamics building skills
    - interest

- Process definition defined by rules, and actions
    - all the feedback loops are understood
    - the mediator asked the participants to remember simulations that looked interesting
    - the notion that the focus now lays on a single feedback loop
    - the mediator asked the participants if they see whether the problem variable fluctuates around an equilibrium in the simulation
    - participants decides what to conclude from the simulation
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations
- A system dynamics model with causal relations that
    - have a specific strength
    - are of a specific type, namely: positive, negative, context-dependent, or not of influence
    - are part of a feedback loop that can be positive or negative

Conclude it is a negative or positive feedback loop, Save it is a positive/negative feedback loop, Conclude some variables are missing, Go back to create some extra variables

Here, the participants decide what the fluctuation in the simulation means. There are two possibilities:

- *Conclude it is a negative or positive feedback loop*: When the simulation shows a clear fluctuation around an equilibrium, the simulation confirms that it is a negative feedback loop. When the simulation shoots away from its starting point, it is probably a positive feedback loop. These findings are then saved in the *Save it is a positive/negative feedback loop* step.
- *Conclude some variables are missing*: When the fluctuation is not clearly around an equilibrium, nor it shoots away from its starting point, there are probably still some variables missing in the feedback loop. This means that these variables have to be found in order to get an overview on this messy problem. The step *Go back to create some extra variables*, provides the possibility to go back to the nominal group technique process (section 5.1), to create these variables, and then come back to proceed with *Check if problem variable fluctuates around an equilibrium.*

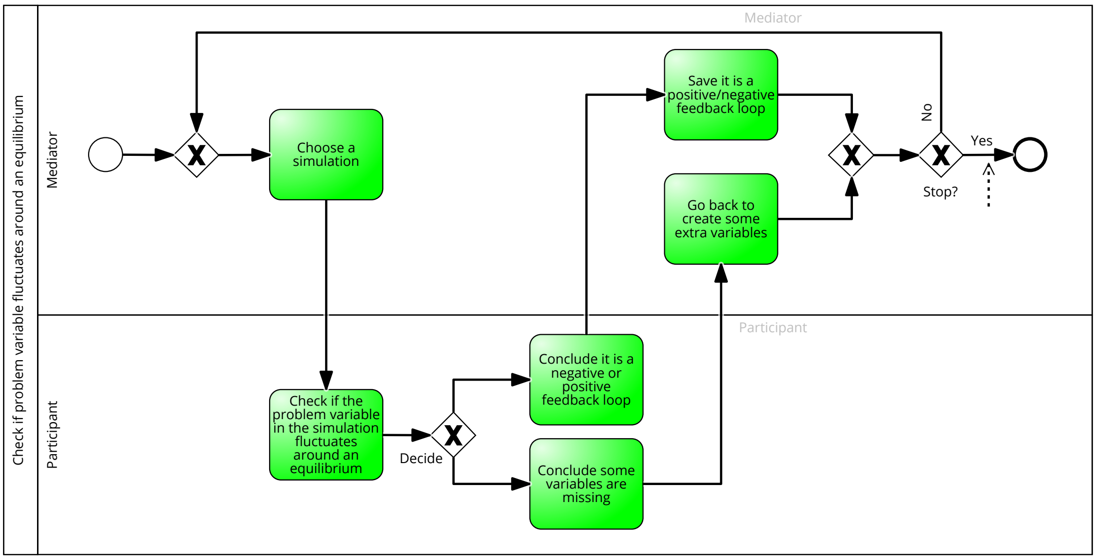

Figure 5.76: Check if problem variable fluctuates around an equilibrium - 4th data position.

When these steps are done, the mediator can choose to stop or go back to choose another simulation. Normally, the mediator goes back to choose another simulation, until all the simulations have been processed. We assume the mediator chooses to stop, which means we are now at the position shown in figure 5.76. As this is the end of *Check if problem variable fluctuates around an equilibrium*, we are also at the position shown in figure 5.77.

If we look at the data model at this position (see figure 5.78, we see a small change. The concept *Saved simulation* can now be of two specific types, namely "represents positive",

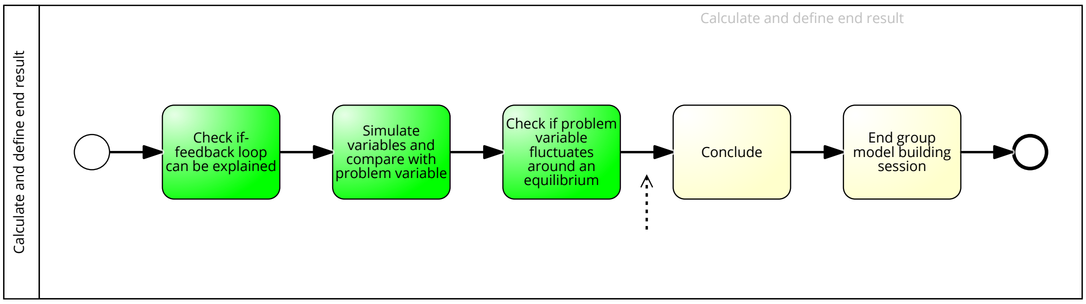

FIGURE 5.77: Calculate and define result - 4th data position.

and ”represents negative” (which are all that do not represent positive). If we look at the data inside the concepts, a lot has changed. Inside the concept *Process definition*, the two questions of the mediator are irrelevant here. Also the notion that all feedback loops are understood, and the notion that the focus now lays on a single feedback loops, are irrelevant. Last, the decision of the participant has become irrelevant, because from now one there is nothing to decide.

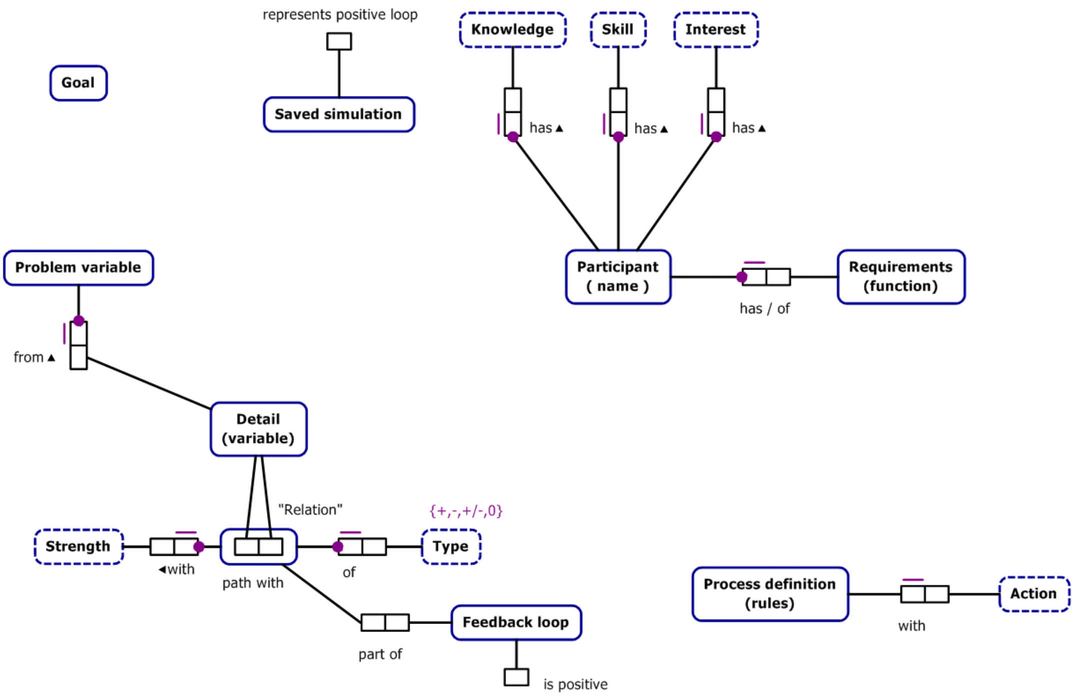

FIGURE 5.78: Calculate and define result - data on the 4th position.

Therefore, we can now define the post-condition for *Conclude it is a negative or positive feedback loop, Save it is a positive/negative feedback loop, Conclude some variables are missing, Go back to create some extra variables*, which is also the precondition for *Conclude*. Remember that the latter can only begin if the data requirements, as shown below, have been met.

Post-condition for *Conclude it is a negative or positive feedback loop, Save it is a positive/negative feedback loop, Conclude some variables are missing, Go back to create some extra variables* and precondition for *Conclude*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - finds a simulation interesting
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations, of which it is know if they simulate a positive or a negative loop
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

5.3.4 Conclude

Now, there is a complete insight in how the system dynamics of the messy problem works, the group is going to look at how to control the messy problem. In *Conclude* (see figure 5.79), the group is going to find *"control- and target variables"*, which will give them a grip in controlling the problem variable. *"Control variables"* are variables, which the organization (that the group represents) can steer its behavior. If we look at the example situation of section 1.2, a control variable might be <number of employees>, as the HRM department can hire or fire employees.

"Target variables" are variables the company want to change, but cannot do directly. These could be variables that have a direct influence on the problem variable. Therefore, if we look at the example situation of section 1.2, a target variable could be <growth> and <cost>, as these directly influence the problem variable <profit>, but can only be controlled indirectly by the organization. For instance, a lower <number of employees> (control variable) results in a lower <cost> (target variable) which results in higher <profits> (problem variable).

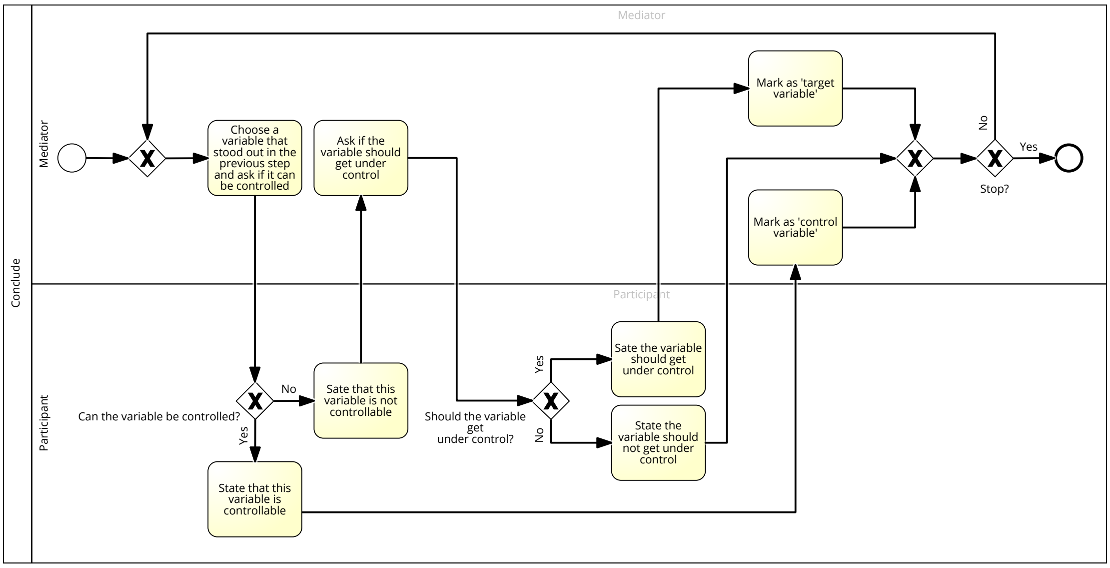

FIGURE 5.79: Conclude - main process.

The identification of the control and target variables, is done in *Conclude*, by following a few steps. *Conclude* contains five steps in total, namely: *Choose a variable that stood out in the previous step and ask if it can be controlled*, *State that this variable is not controllable*, *Ask if the variable should get under control*, *State the variable should get under control*, *Mark as "target variable"*, *State the variable should nog get under control*, *State that this variable is controllable*, and *Mark as "control variable"*.

These steps are looping until all variables have been processed, and within a loop there are three possible routes to go (which will be clearer later on). We start at the position shown in figure 5.80, and the data on this position is identical to the last data position of the previous phase (shown in figure 5.76). Therefore, the data model shown in figure 5.78, is still accurate here, and the data inside these concepts, is as well. For the sake of consistency, we give the list again below, which now not only represents the post-condition for *Check if problem variable fluctuates around an equilibrium*, but also the

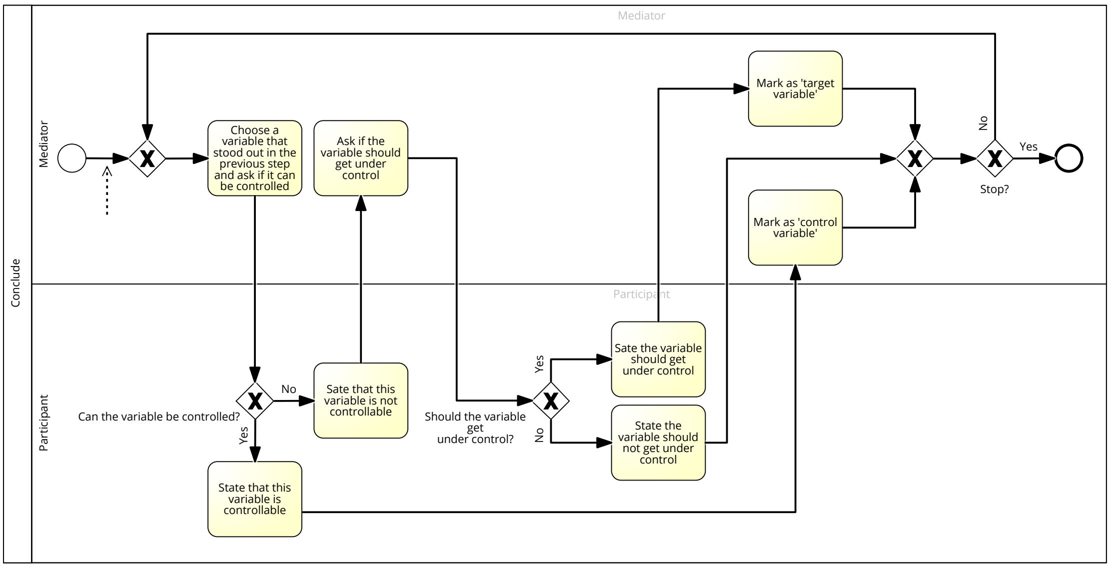

FIGURE 5.80: Conclude - 1st data position.

precondition for *Choose a variable that stood out in the previous step and ask if it can be controlled*. Remember, the latter can only start when the data requirements, as shown below, have been met.

Post-condition for *Check if problem variable fluctuates around an equilibrium* and precondition for *Choose a variable that stood out in the previous step and ask if it can be controlled*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - finds a simulation interesting
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations, of which it is know if they simulate a positive or a negative loop

- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

Choose a variable that stood out in the previous step and ask if it can be controlled

Here, the mediator asks the participants to name a variable that looked interesting in the previous step. Remember that participants had in their knowledge if they found a simulation interesting. This now means that they find the variable that is represented by that simulation, interesting. When the participants agreed on a chosen variable, the mediator asks the participants if they think this variable can be controlled by the organization. Here, the benefits of a group session arises, as normally all the departments of the organization are represented, and therefore, the group must be able to answer that question.

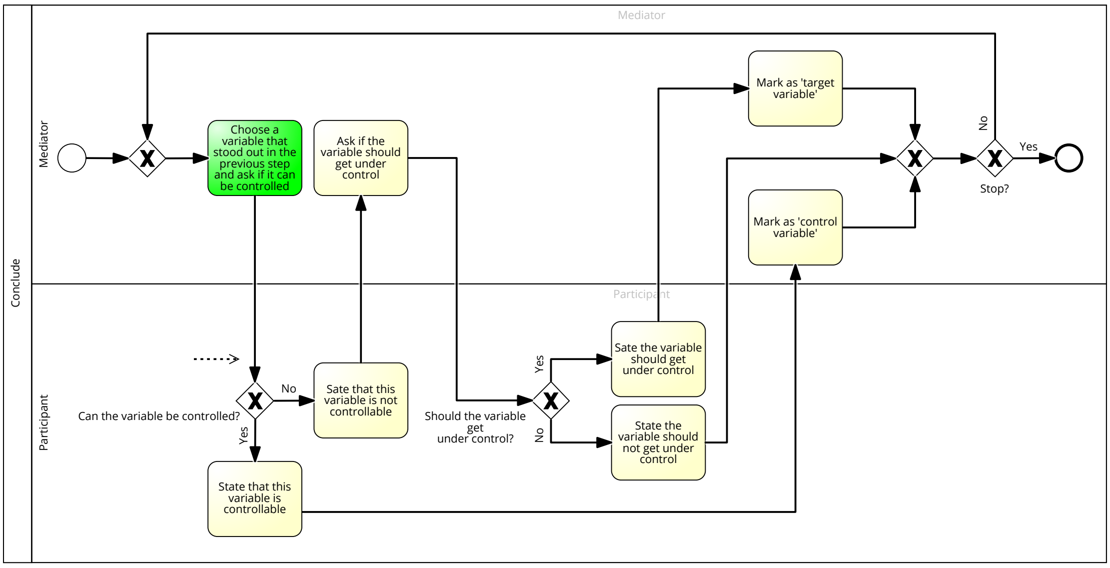

FIGURE 5.81: Conclude - 2nd data position.

When the question is asked, we are now just before the participants decide whether or not the variable can be controlled, as is shown in figure 5.81. If we look at the data on this position, not much has changed. There are no new concepts created, so the data model in figure 5.78, is still accurate here. The only change is inside the concept *Process definition*, since there is now the notion that a variable has been chosen, and that the participants are asked if they think this variable can be controlled.

Therefore, we can now define the post-condition for *Choose a variable that stood out in the previous step and ask if it can be controlled*, which is the same as the precondition for *State that this variable is not controllable*. The latter can only start when the data requirements, as shown below, have been met.

Post-condition for *Choose a variable that stood out in the previous step and ask if it can be controlled* and precondition for *State that this variable is not controllable*:

- Goal
- Participant with
  - name

  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
    * system dynamics model of the messy problem
    * finds a simulation interesting
  - skill, expanded with
    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - the notion that a variable has been chosen, because it looked interesting in the simulation
  - the mediator asked the participants if they think the variable can be controlled
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations, of which it is know if they simulate a positive or a negative loop
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

State that this variable is not controllable

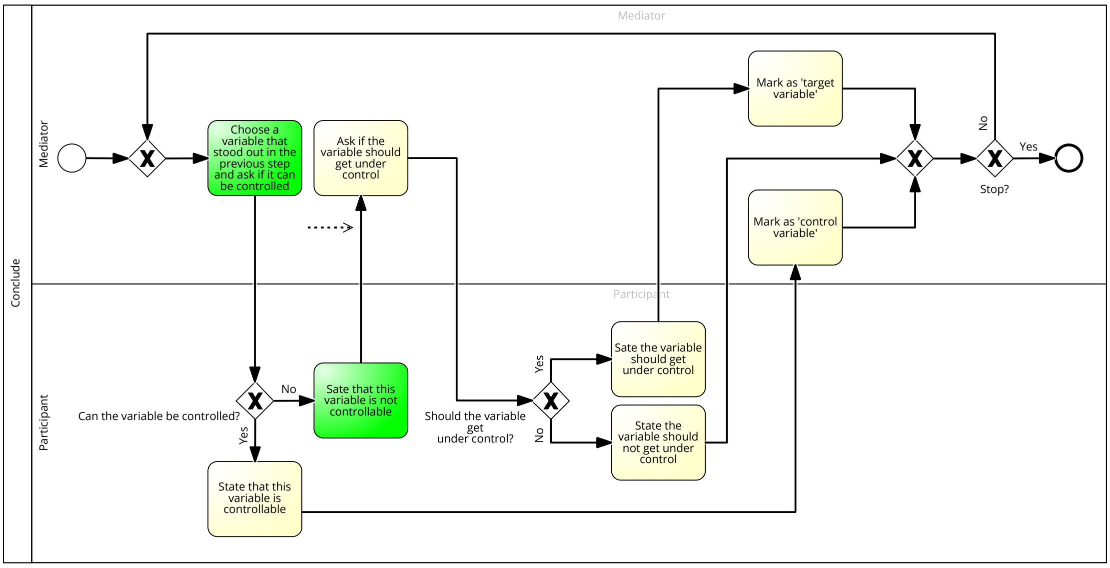

FIGURE 5.82: Conclude - 3rd data position.

If the participants decides that the variable is not controllable, they make it clear to the mediator. That is what happens in *State that this variable is not controllable*, and this results in a small change in the data on the position shown in figure 5.82. There are no new concepts created, so the data model in figure 5.78, is still accurate here. There is only a small change inside the concept *Process definition*, since the statement of the participants is being added here. The question of the mediator has become irrelevant here, since the question has now been answered.

Therefore, we can define the post-condition for *State that this variable is not controllable*, which is also the precondition for *Ask if the variable should get under control*. The latter can only start if the data requirements, as shown below, have been met.

Post-condition for *State that this variable is not controllable* and precondition for *Ask if the variable should get under control*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - finds a simulation interesting
  - skill, expanded with

        * system dynamics building skills
    - interest

- Process definition defined by rules, and actions
    - the notion that a variable has been chosen, because it looked interesting in the simulation
    - the participants stated that the variable is not controllable
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations, of which it is know if they simulate a positive or a negative loop
- A system dynamics model with causal relations that
    - have a specific strength
    - are of a specific type, namely: positive, negative, context-dependent, or not of influence
    - are part of a feedback loop that can be positive or negative

Ask if the variable should get under control

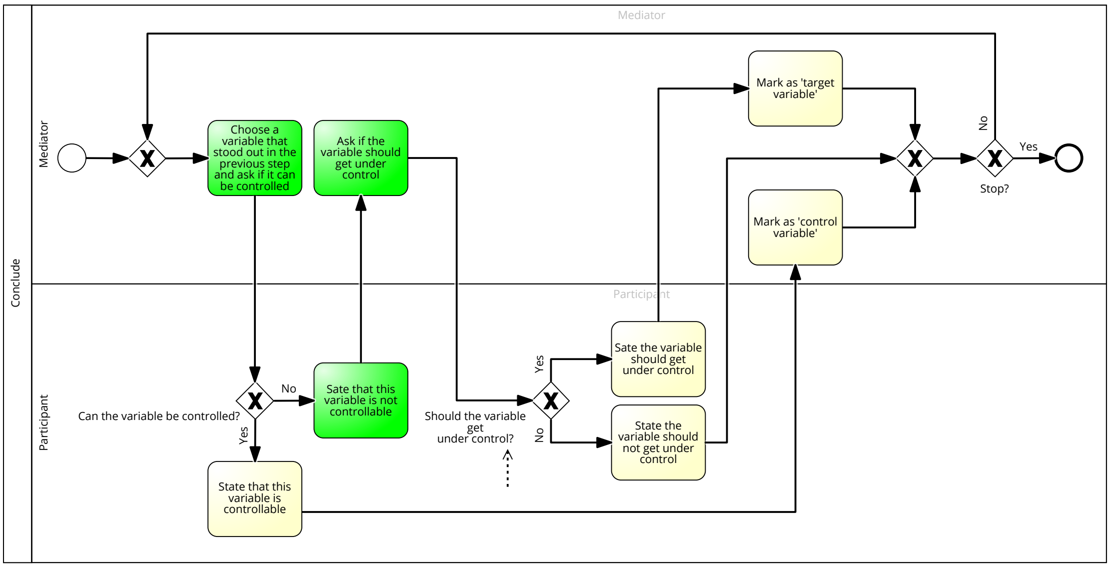

FIGURE 5.83: Conclude - 4th data position.

Since it is now clear that the variable is not controllable, and therefore not a *"control variable"*, it is interesting to see if it is a *"target variable"* (i.e. if it must get under control). In *Ask if the variable should get under control*, the mediator asks the participants just that. When this is done, we are at the data position shown in figure 5.83, just before the participants decides. Therefore, there is only a small change in the data at this position, since no new concepts have been created. The only new thing is the question asked by the mediator, which is kept inside the concept *Process definition*.

Therefore, we can now define the post-condition for *Ask if the variable should get under control*, which is also the precondition for *State the variable should get under control, Mark as 'target variable', State the variable should not get under control*. *State the variable should get under control, Mark as 'target variable', State the variable should not get under control* may only start if the data requirements, as shown below, have been met.

Post-condition for *Ask if the variable should get under control* and precondition for *State the variable should get under control, Mark as 'target variable', State the variable should not get under control*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself

    * system dynamics model of the messy problem
    * finds a simulation interesting
  - skill, expanded with
    * system dynamics building skills
  - interest

- Process definition defined by rules, and actions
  - the notion that a variable has been chosen, because it looked interesting in the simulation
  - the participants stated that the variable is not controllable
- Problem variable
- List of detail of the problem variable including the problem variable itself
- Saved simulations, of which it is know if they simulate a positive or a negative loop
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative

State the variable should get under control, Mark as 'target variable', State the variable should not get under control

To answer the question of the mediator, the participants have to choose between two possibilities:

- *State the variable should get under control*: The participants see the variable as important, as it might influence the problem variable directly or close enough. Therefore, this variable is a target variable which is marked in *Mark as 'target variable'*.
- *State the variable should not get under control*: In this case the variable does not seem close enough to the problem variable to create a major influence on it. Therefore, the changing of the value of the variable would not change the problem variable significantly. Thus, the variable is parked.

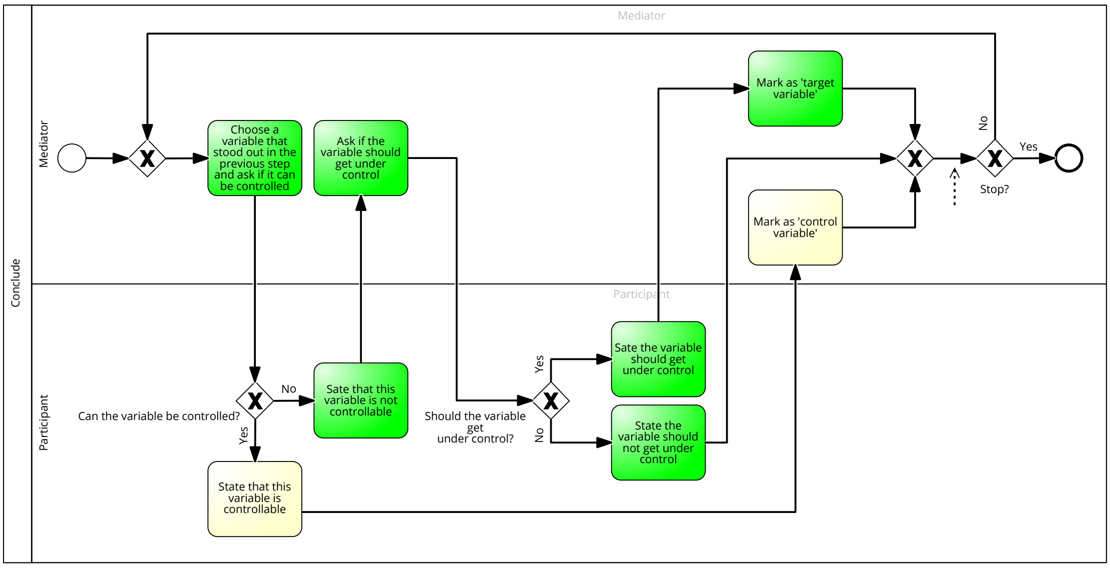

FIGURE 5.84: Conclude - 5th data position.

This means that when these processes finished, we are now at the data position shown in figure 5.84. We assume that target variables have been created, which means that the data model has changed. A new concept *Target variable* has been created, which is a link between *Saved simulation* and *Detail*, as is shown in figure 5.85. Also the data inside these concepts have changed. The simulations are now not seen as saved simulations, but just as simulations.[28]

This means we can define the post-condition for *State the variable should get under control, Mark as 'target variable', State the variable should not get under control.* Since this data position is also reachable after *State that this variable is controllable, Mark as 'control variable'*, this is also the post-condition of this step. For consistency reasons it is given, but a full explanation of this list of data is given in the next section.

[28]The reason for this is that it is not necessary anymore to remember the interesting simulations. They are now pure for reference.

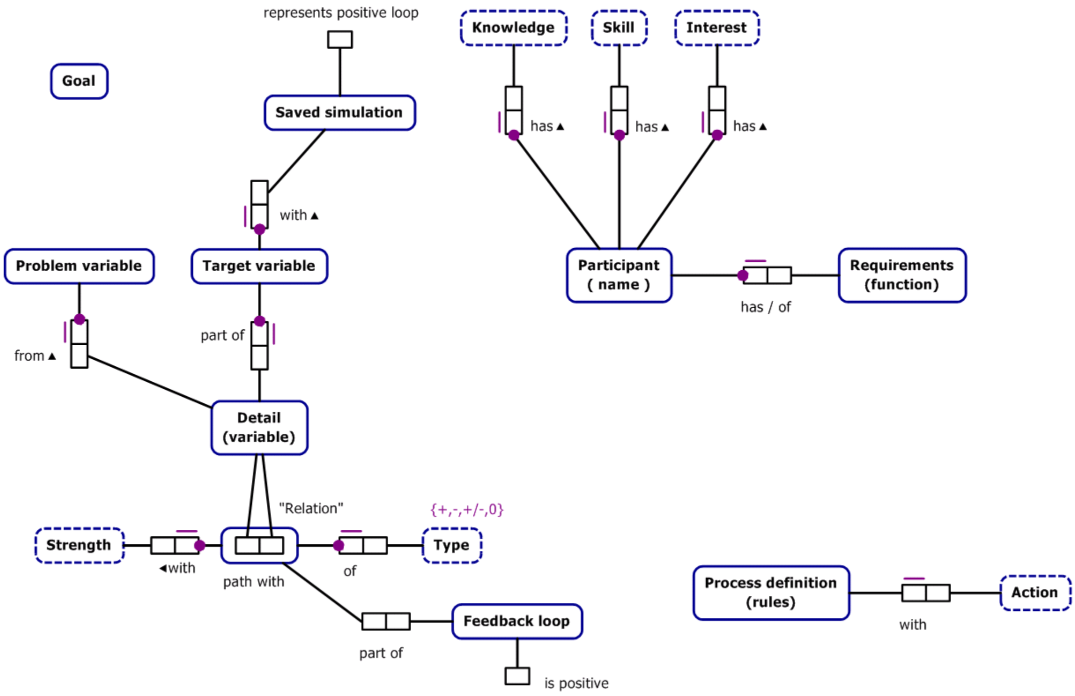

FIGURE 5.85: Calculate and define result - data on the last position.

Post-condition for *State the variable should get under control, Mark as 'target variable', State the variable should not get under control*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - an understanding of the effects of the variables
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength

  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative
  - that are simulated

- target variables
- control variables
- simulations

State that this variable is controllable, Mark as 'control variable'

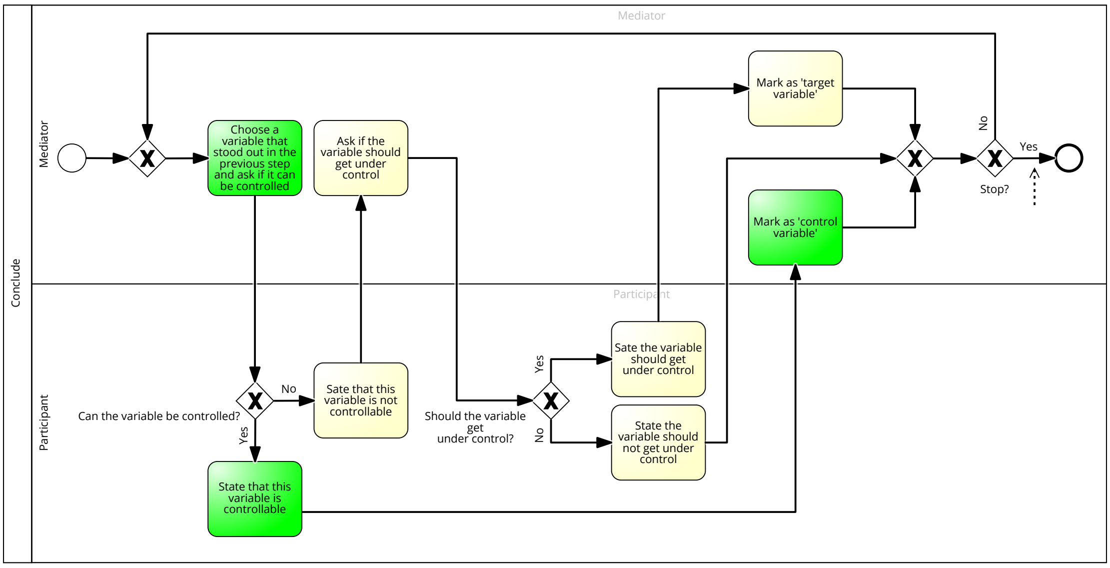

FIGURE 5.86: Conclude - 6th data position.

If the participants decide the chosen variable is controllable, the other possible route is chosen (as is shown in figure 5.86). First they *State that this variable is controllable*, which means it is a control variable, and therefore the step *Mark as 'control variable'* follows. When this is done, it is added to the list of control variables.

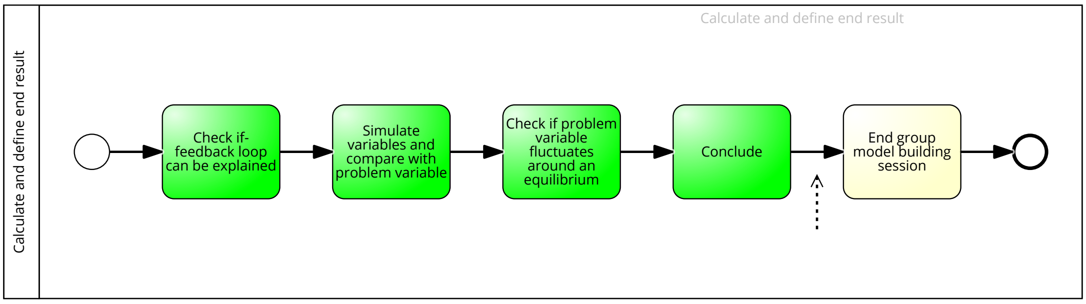

FIGURE 5.87: Calculate and define result - 5th data position.

As said in the last section, we are now at the same position as when the route of "target variables" is followed, which means we are now at the end of *Conclude*, as is shown in figure 5.87. The data model at this position (shown in figure 5.88), is expanded by the addition of the concept *Control variable*, which is also a link between the *Saved simulation*, and the *Detail* concept. This also means the list of data inside the concepts, has been expanded by the addition of control variables.

At the end of *Conclude*, the notions and question that where created during this phase have become irrelevant, since they have been answered. Now the group has a list of control and target variables, which they can use to formulate a solution to the messy problem (which will be explained in section 5.3.5). For now we can define the post-condition for *State that this variable is controllable, Mark as 'control variable'*, which was also the post-condition for *State the variable should get under control, Mark as*

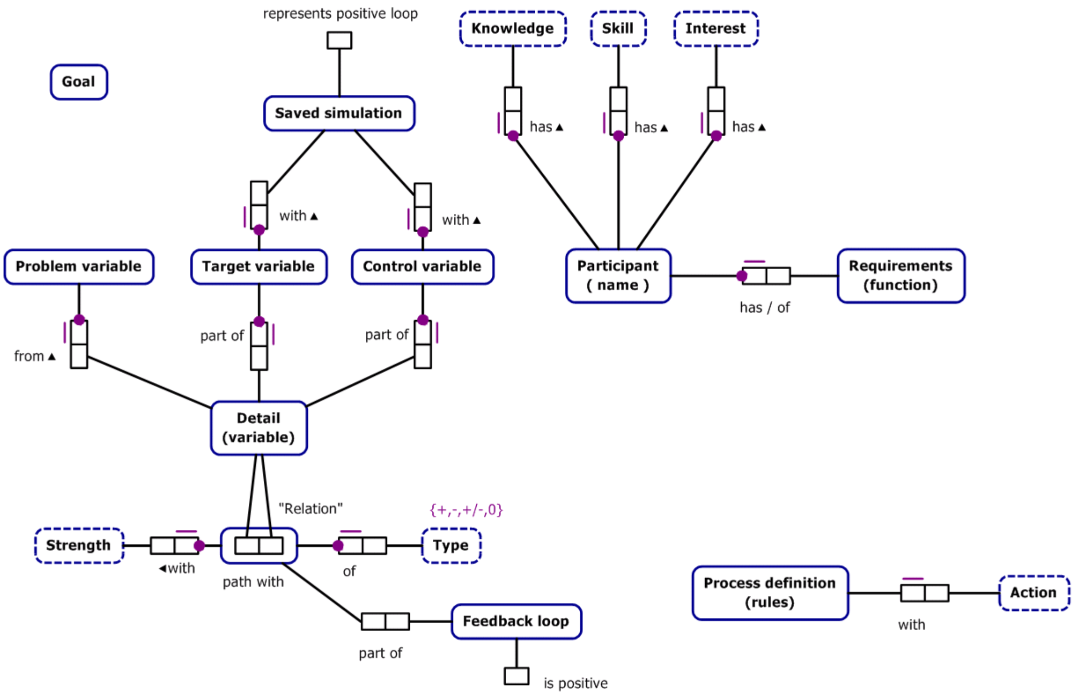

FIGURE 5.88: Calculate and define result - data on the last position.

'target variable', State the variable should not get under control, and is the precondition for *End group model building session*. Remember, the latter can only start if the data requirements, as shown below, have been met.

Post-condition for *State that this variable is controllable, Mark as 'control variable'* and precondition for *End group model building session*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    * a basic understanding of group model building
    * an understanding of the way participants may interact with each other
    * problem variable
    * a list of detail of the problem variable including the problem variable itself
    * system dynamics model of the messy problem
    * an understanding of the effects of the variables
  - skill, expanded with
    * system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable

- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative
  - that are simulated
- target variables
- control variables
- simulations

5.3.5 End group model building session

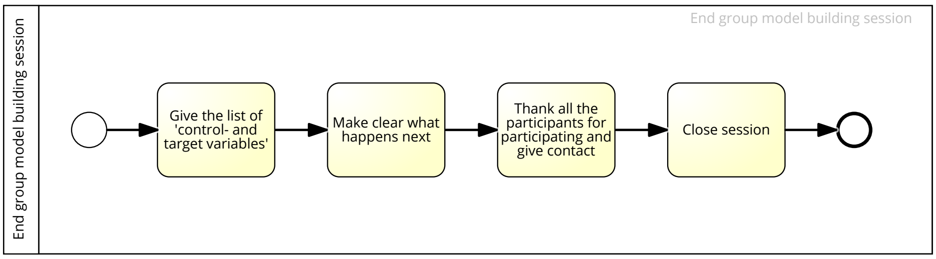

FIGURE 5.89: Conclude - last data position.

Now that the control- and target variables have been defined, it is time to think about a solution. The last step, *End group model building session*, will help the participants in defining a next step in solving the messy problem. This happens with the following steps:

1. *Give the list of 'control- and target variables'*: Here the list of control- and target variables is summed up again. The reason for this is to make clear that this is what the participants have produced during this session. These variables mapped the messy problem, and define the grip in solving it. The target variables as variables that have to be changed in order to create a wanted effected on the problem variable, and the control variables as variables that the organization has to change in order for the target variables to change.
2. *Make clear what happens next*: Now that the list of variables is known. The mediator suggests that the organization should think of a list of actions to change the control variables, in order to change the target variables in the wanted direction. It is not the task of a group model building session to think about these solutions, but it must be made clear that the messy problem has been solved in a sense that it has been mapped in an unbiased way, and is accepted by the group as a whole. Now the group can, with their consensus, create solutions, given that the problem looks like the way it looks after the group model building session. The mediator also makes clear that a full report about this session, will be produced and shared within a few weeks.
3. *Thank all the participants for participating and give contact*: The participants are thanked for their participation. Group model building demands a lot of afford and time from participants, therefore it can work satisfying when being thanked. Also the mediator gives contact information, so the participants can consult if something is not clear about the final report.
4. *Close session*: Last the session is being closed.

After the session is being closed, we are at the end of *Calculate and define end result* (as is shown in figure 5.90), which is also the end of the group model building session as a whole (as is shown in figure 5.91).

The only change in the data model at this position, is the addition of the concept *Contact*, which is the contact information the participants can consult in order to ask question

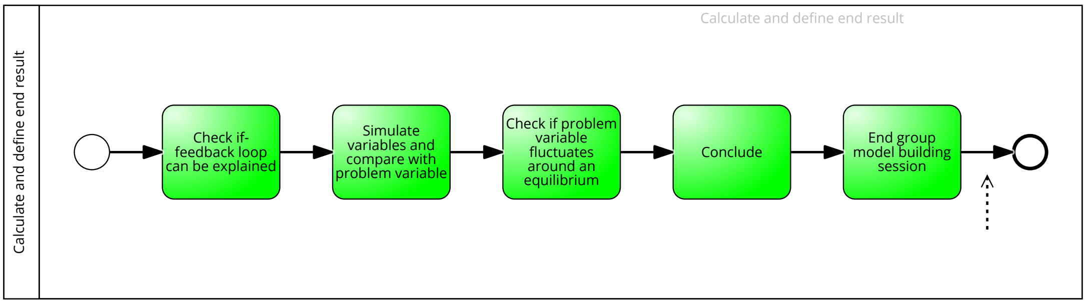

FIGURE 5.90: Calculate and define result - last data position.

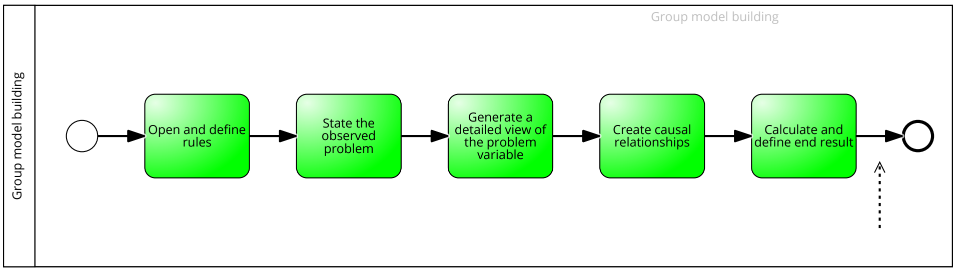

FIGURE 5.91: Group model building - the last data position.

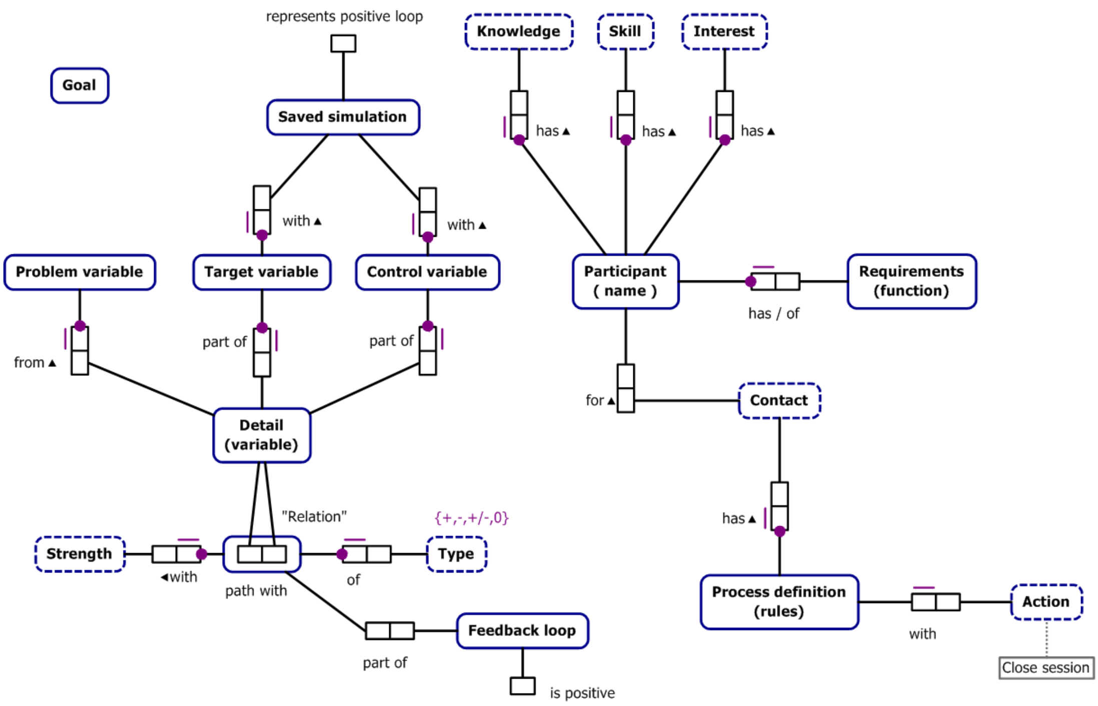

FIGURE 5.92: Calculate and define result - data on the last position.

about the final report, that will be shared in a couple of weeks. This data model is shown in figure 5.92, which is the final data model of the group model building session. Inside the concepts the possible discussion, opinions, notions, actions, and questions have become irrelevant and should not be part of the post-condition here. It would be strange if there is still a discussion going on while the group model building session has ended.

The contact is the only information inside the concepts, that has been added here, therefore, we can now define the post-condition for *End group model building session*, which is also the post-condition for *Calculate and define result*, and the post-condition for the group model building session as a whole. Therefore, this post-condition is defined as the post-condition for *Group model building*, and this is given below.

Post-condition for *Group model building*:

- Goal
- Participant with
  - name
  - function
  - knowledge with
    - a basic understanding of group model building
    - an understanding of the way participants may interact with each other
    - problem variable
    - a list of detail of the problem variable including the problem variable itself
    - system dynamics model of the messy problem
    - an understanding of the effects of the variables
  - skill, expanded with
    - system dynamics building skills
  - interest
- Process definition defined by rules, and actions
- Problem variable
- List of detail of the problem variable including the problem variable itself
- A system dynamics model with causal relations that
  - have a specific strength
  - are of a specific type, namely: positive, negative, context-dependent, or not of influence
  - are part of a feedback loop that can be positive or negative
  - that are simulated
- target variables
- control variables
- simulations
- contact information for question in the future

After the detailed description of group model building

This was the last part of the detailed description of group model building. The process flow has been explained on a low level, and the data that flows through these processes, has been modeled and translated in pre- and post-conditions. Because there were some things left out, or not described in great detail as possible, the next chapter (Future research), will explain what tasks can be done in order to formalize group model building even more. The formalization of chapter 4 and chapter 5 can be seen as the basis for these tasks.

Chapter 6

Further research

The last two chapters showed us the formalization of group model building in great detail, but the process and data models still lack some information. This chapter will give some suggestions in how to formalize group model building even more, by giving some examples in how to research (and therefore formalize) the missing elements of the group model building technique.

First, not only a small recap is given of what has been formalized, but it is also explained what still is missing in this thesis (section 6.1). Second, a further research suggestion concerning the communication of the group model building session is given (section 6.2). Last, a further research suggestion is given concerning the coordination of the group model building (section 6.3).

6.1 What has been formalized?

This thesis looked at group model building as a set of processes, with data flowing through it. This has been formalized by first modeling the processes of group model building, and then by looking at the data that goes into such a process and comes out afterwards. (This has been done in chapter 4) Next, each process was decomposed even further into sub-processes, and the data going through these processes has been modeled as well. (This has been done in chapter 5)

The data was then translated into pre- and post-conditions for each sub-process. These conditions were presented as lists of data, which brings us to the first further research suggestion. Although the data models in ORM, and the process models in BPMN, are formalized with highly structured languages (with formal syntax and semantics), the information representation of the pre- and post-conditions has not been formalized by a highly structured language. As conditions represent rules, it would therefore be more advanced when pre- and post-conditions were presented as logics (e.g. predicate logic).

When these predicate logics have been developed, they can be used to prove the soundness of the formalization process, but can also be used as proof for the soundness of the group model building technique as a whole. It can be very likely that some data is still missing, or implicitly used throughout the thesis. The implicit knowledge, that then will emerge, can be used to enhance the overall quality of the formalization of the group model building technique.

But to excavate the implicit knowledge from the group model building process, it is important to think about the supporting processes that may be involved. For instance, in this thesis the discussion was quite often formalized as a single process, like *Discuss* or *Accompany discussion*. But one can imagine that these are in fact really complicated processes, that do not only have formal communication (e.g. answering a question in a specific way), but also informal communication (e.g. a participant making a point of order, when something suddenly seems unclear. Also the emotions that define how something is said, can be placed in this category).

Therefore, these sub-processes can be divided into two groups, namely to support communication (not only what is said, but also how it has been said), and to support coordination (when to do what). Both are the tasks of the mediator, but in this thesis, the mediator's role and actions have been formalized in very little detail. Therefore, the next sections will give some suggestions in how to formalize the role of the mediator in more detail. Please note that a group model building session most of the time lends its success on the quality of the mediator's actions (Vennix, 1996) (Rouwette and Franco, 2014).

6.2 The communication

Guiding the communication of a group model building session, is probably the hardest part for the mediator. As said before, the success of a group model building session highly depends on the quality of the communication (Vennix, 1996) (Rouwette and Franco, 2014). If communication is not controlled enough, arguments could change into fights. Therefore, good communication is the basis to create consensus within a group (Vennix, 1996) (Rouwette and Franco, 2014). Consensus is the basis for high quality knowledge sharing, and therefore, the basis for an unbiased solution (Stroebe et al., 2010).

As said above, communication can be divided into *"informal"* and *"formal"* communication. The formal communication has already been modeled in detail in this thesis. Formal communication is in essence a question being asked by the mediator, and answered by the participant. The informal communications however has been left out. Therefore a research suggestion would be to start formalizing the processes of possible informal communication, and then model the data that flows through these processes.

Modeling informal communication is probably one of the most complex tasks there is in formalization, as the communication process can be in a lot of states. Humans are masters in communications, as they can decide on gut feeling, which reaction would provoke the most demanded reaction. Computers are much less capable of making these decisions without a full network of possible models and states. This would for now be an unfeasible task to do.[1] Therefore, the modeling of communication should be simplified in a way.

These simplified ways of communication can then be modeled. BPMN as a language is not optimal for models with a lot of states and connections. Therefore the suggestion

[1]Given the technical capabilities of today.

would be to create process models in Petri Nets (Petri, 1966). Here, states can be reached by many other states, which gives a lot more flexibility than with BPMN.

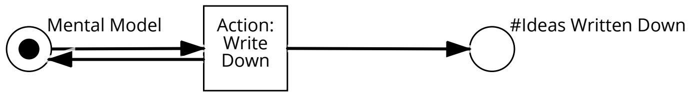

FIGURE 6.1: A communication example with petri nets.

Not only the communication, but also the thinking of the participants can be modeled with Petri Nets. Figure 6.1 gives an example of the thinking process inside the nominal group technique part of group model building. Here, the participants are allowed to think about variables, and write these down on paper. The dot represents something is in that state, which is displayed as a circle. The square is an actions, which will do something with the dots. The firing of the action, means that all the dots that go in the square, leave the states they were in (and therefore can only fire when all the states that go into an action, have a dot). After firing, the states after the action will be filled with a dot. Translated, this means that as long there is an idea for a variable inside the mental model of the participant, the participant can write variables down on paper.

One can imagine the great detail that can be described when using Petri Nets. Therefore, the suggestion would be to use this for the whole group model building process, to describe it in an even greater detail. These processes then form a structural basis for the formalization of the data, because the data is now represented by dots. Therefore the deriving of predicate logic to formally proof the soundness of group model building, is made easier.

6.3 The coordination

Not only the communication is important, also the coordination plays an important role within group model building. In this thesis the group model building process was described as a sequential process. But one can imagine that it is sometimes necessary to go back a few steps, because some parts are still not clear. For instance, if the system dynamics model is being built in the *Create causal relationships* process, it is possible that participants suddenly think of more important variables. Then the process would go back one step to create even more variables. Although this thesis described these steps in a formal sequential way, in a practical situation the sequence of these steps is much more flexible.

Therefore, the Petri Nets that where described in the previous section can not only be used to model the communication processes, but can also be used to model the coordination processes, by defining phases in which the group model building process can be. This would also enhance the formalization of the facilitator role. For instance, when in the group model building process ideas are being created (in the *Create detail of the problem variable* step), there are a few states the mediator can switch between.

Figure 6.2 describes these states. What differs from the description in BPMN is that the processes are now not modeled as a sequential chain. First, the participants go into a write down phase, then into a sharing phase. But, after the first round the sharing phase

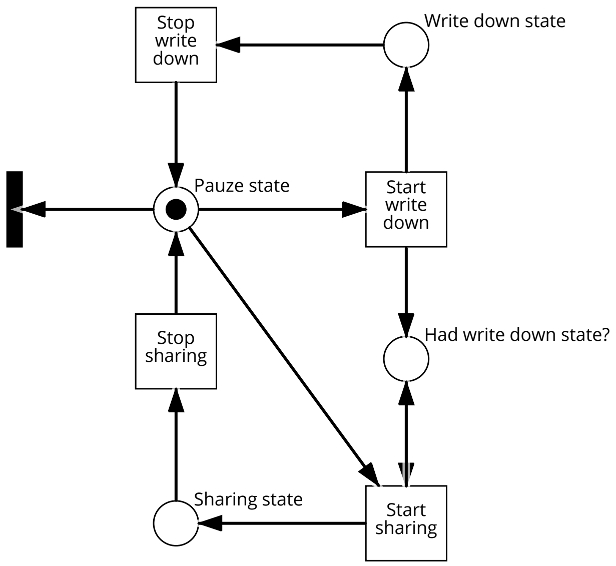

FIGURE 6.2: A coordinator example of the nominal group technique from a mediator perspective.

can start again.[2] But, also the written down phase can start over again, if a participant makes clear he still has some new ideas.

To conclude, this chapter has made a couple suggestions to enhance the formalization of group model building. First, the suggestion was made to translate the lists of information into predicate logic, to create a more formal basis to prove the soundness of the formalization process and of group model building as a whole. Second, the suggestion was made to model the processes of group model building even more, by modeling the communication and coordination, to enhance the formalization of the role of the mediator. It was suggested that these formalization in greater detail could be done using Petri Nets. When the formalization of group model building is done in greater detail, it will enhance the feasibility of creating computer programs that would make group model building easier to use (this will be discussed in the next chapter).

[2]This will happen if the participants still have some variables written down, which were not shared until now.

Chapter 7

Conclusion

This thesis was about formalizing group model building, to create a basis for the creation of a computer program, which would make it possible to enact in group model building from the lazy chair, instead of forcing every participant to be in the same room together. The latter was seen as a downfall of group model building when using in multinational organizations, as it was accompanied by high costs, and therefore made it unfeasible for these type of organizations.

The formalization process was done in a couple of steps. First, chapter 2 looked at the fundamental theory of group model building, by discussing the research that forms the basis to understand messy problems and to understand the methods in solving them. Second, chapter 4 and 5 step wise formalized the group model building process by modeling the processes (in BPMN), and the data flowing through these processes (in ORM). Thereof, the pre- and post-conditions were derived, which gave insight in the necessary information to create formal reports, that could be used as a supporting tool to continue the sessions after it was paused earlier.

Chapter 6 suggested a few research topics that would formalize the group model building process even more. This was done by introducing the Petri Net language, and the predicate logic, which can be seen as instruments to model group model building in much greater detail. Also, the perspective of the mediator was discussed, as the communication and coordination done by the mediator, could be modeled as well.

To conclude, this thesis has founded a basis in solving messy problems in a situation where participants are in great distance of each other. As companies grow, so does the emergence of messy problems. When the number of people trying to solve problems grow, the only way in solving the problem in an unbiased fashion, is to bring all these people together, and let them participate in a structured session (to prevent fighting). As more and more companies operate globally, the bringing together of people comes with great costs, therefore the old group model building technique was not sufficient anymore. Therefore, this thesis has generated a futuristic way of solving messy problems, and thus helps organizations even more, in making difficult decisions.

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