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To cite this version:

P.W.G. Bots, C.E. van Daalen. Designing a project decision making game. ISAGA 2007 Conference. 38th Annual Conference of the The International Simulation and Gaming Association, Jul 2007, Nijmegen, Netherlands. 11 p. hal-00468542

HAL Id: hal-00468542

https://hal.science/hal-00468542v1

Submitted on 31 Mar 2010

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Designing a project decision making game

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Keywords: AIDA; bounded rationality; decision making; experiential learning; game design; project management.

Abstract

This paper presents PRODEMA: a project decision making game that was designed to provide a safe environment for experiential learning by senior project engineers about the tension between structured decision making methods and the way in which humans naturally make decisions. The paper focuses in particular on the game design method, which consists of two phases: (1) decision problem definition and analysis using a multi-stakeholder adaptation of the Analysis of Interconnected Decision Areas method, and (2) development of a storyline around the decision problem, the setting for the players, and the rules for their interaction. The method, supported by the MEDIA tool, has been used to design a specific decision making game for a course for senior project engineers. This game was tested twice, first with faculty staff, then with graduate students, before it was used as a learning aid.

Introduction

The PRODEMA game discussed in this paper was developed for use in a course on project decision making. The audience of this course consists of project engineers and project managers working for a multi-national energy corporation. The purpose of the game is to provide a context for experiential learning (Kolb, 1984) about decision making in the context of large engineering projects. More specifically, it should raise the participants' awareness of the tension that exists between the high rationality that is exerted by formal decision making methods (Goodman & Lawless, 1994) and the bounded rationality that characterises human decision making (Simon, 1990; Todd & Gigerenzer, 2003).

The first parts of the course provide training exercises to enhance the participants' skills in rational decision-making techniques. The PRODEMA game is played during the final day of the course to make the participants realise that when they go back to the workplace, they will have the tendency to default to decision-making heuristics that are typical for bounded rationality.

Although all games involve some form of decision making, they are not all *about* decision making. The type of game discussed in this paper simulates a situation in which a team has to decide on a complex problem, ending with the players justifying the choices they made to a third party. Our particular research interest in designing this game for our client was to develop a generic method for designing games to learn about complex group decisions. It is this method that we will focus on in this paper. The PRODEMA game itself serves merely as an example to illustrate the game design method. For confidentiality reasons, its content (decision situation, roles, etc.) differ from the game we designed for the energy corporation, but it is comparable in structure and complexity.

The remainder of this paper is structured in three sections. First, we will present the three steps of the game design method (decision type selection, problem structure definition, game elaboration) using the PRODEMA game as example. Next, we will present the way in which we tested the game we developed for our client, and discuss some findings obtained in two test runs. We then make some closing remarks on the game design method.

Game design method

When describing the decision making game design method we developed, we will use the same terminology we used in an earlier paper (Bots and van Daalen, 2007): purpose, players, roles, rewards, representation of the physical system, and representation of the inter-actor environment (the P2R4 properties, for short).

The game design method comprises three steps: (1) selecting the type(s) of decision making problem, given the purpose of the game and the people who will be playing it, (2) defining and analysing the decision problem(s) using a multi-stakeholder adaptation of the Analysis of Interconnected Decision Areas method (Morgan, 1971), and (3) development of a storyline around the decision problem(s), the setting for the players, and the rules for their interaction.

Step 1: Selecting the type of decision problem

When designing a game to learn about project decision making processes, the designer should first establish who are the *players* (background, occupation, prior knowledge and experience) and what is the *purpose* of the game (what aspects of decision making and what types of decision situation should the players learn about?). The typology proposed in this section can be helpful in characterising the decision problem(s) the players should be confronted with in the game.

The basic form of a decision problem is that a decision maker has to choose one of several alternative options, where these options have different consequences, some of which are more desirable to the decision maker than others. Decision problems can be characterised along several dimensions, which can be grouped in these three categories:

A. Decision structure:

- *composition*: elementary (the decision problem requires a single choice to be made) or composite (the decision problem may require several choices to be made)
- *interdependence*: when a decision problem comprises several sub-decisions, these sub-decisions may be more or less strongly interdependent. Using the terminology of Thompson (1967), they are ‘pooled’ when the decision problem can be solved without coordinating the sub-decisions, ‘sequential’ when choices made regarding some sub-decisions affect the choices that can be made for other sub-decisions, and ‘reciprocal’ when no sub-decision can be made without taking into account the other sub-decisions
- *objectives*: mono-objective (the options impact only one variable that interests the decision maker) or multi-objective (the options affect several variables, necessitating a trade-off between different stakes)
- *time horizon*: fixed (all decisions are made at one point in time) or rolling (decisions are made over time, and in-between decisions, the decision situation changes as a result of the choices made and/or of external events)

B. Relation between decision problem and decision maker(s):
- *stakeholders*: the objectives may be related to the interests of one stakeholder or those of several stakeholders
- *decision making*: individual (a single decision maker), distributed (several independent decision makers) or collective (several decision makers deciding as a group)
- *availability of information*: complete (all information to solve the decision problem is available) or partial (some 'pieces of the puzzle' are missing)
- *distribution of information* (for multi-actor decision problems): symmetric (all decision makers have the same information), asymmetric (different decision makers have different 'pieces of the puzzle')
- *consistency of information* (when information is distributed asymmetrically): coherent (information is logically sound across information sets) or conflicting (information sets may contain contradicting elements)

C. Decision-making process:
- *frequency*: a decision may be unique (the decision maker has not previously dealt with a similar decision problem, and does not expect to do so in the future) or routine (the decision maker has to make similar decisions regularly, and can develop a standard decision-making routine)
- *group process* (for multi-actor decision problems): collaborative (the decision makers work concertedly to reach a common goal) or competitive (the decision makers seek to maximise their own utility, and stand to gain by non-cooperative behaviour)

Project managers will, at some time or other, have to make decisions with virtually any combination of these characteristics. The purpose of the game we developed for our client was to make project engineers aware that the rational techniques they learned about in the course do not come naturally to them. The decision problem should therefore allow the participants to experience that humans tend to use "recognition processes that largely obviate the need for further information search, heuristics that guide search and determine when it should end, and simple decision rules that make use of the information found" (Todd & Gigerenzer, 2003, p. 148), and to realise that this may cause them to neglect these seven rules for effective decision making (Janis and Mann, 1977, p. 11):

1. complete survey of alternatives
2. complete survey of objectives
3. pondering of all consequences and risks for each alternative
4. intensive search for new information relevant to further evaluation
5. correct assimilation of new information, even when this does not support the preferred choice
6. re-appraisal of *all* alternatives (including those rejected), before making the final choice
7. implementation planning (including contingency plans) for the chosen alternative

The decision problem should therefore comprise a variety of alternatives and objectives that is large enough to provoke heuristic search, but not so large as to be unmanageable with rational techniques. This suggested a composite, reciprocal, multi-objective structure. A rolling time horizon would create a need for risk analysis and contingency planning. Our client preferred the game to be a team activity, which led us to choose for a multi-actor, collective decision with asymmetric information (to increase the need for collaboration) in a unique, collaborative

setting. We decided to provide complete and coherent information to prevent that players would afterwards have an easy excuse for not finding a good solution.

Step 2: Defining the structure of the decision problem

For the PRODEMA game, the decision problem relates to the design of a wind farm: an array of wind turbines that generate electrical power. The method we use for problem definition is based on AIDA (Analysis of Interconnected Decision Areas), developed at the Tavistock Institute of Human Relations (Morgan, 1971). AIDA provides an excellent means to structure and subsequently solve composite decision problems.

A decision problem is defined in terms of decision areas (A), exclusions (X), and criteria (C). More specifically, A is a set of decision areas $\{A_1, \ldots, A_n\}$, where each A_i is a set of mutually excluding decision options $\{o_{i1}, \ldots, o_{im})$ with $m \geq 2$ decision options. The wind farm decision problem is defined with 8 decision areas having 2 or 3 options as shown in Table 1.

Table 1. Decision areas and options for the wind farm decision problem

Decision area	*Decision options*
Location	L1 (onshore), L2 (near-shore), L3 (offshore)
Foundation type	F1 (light), F2 (heavy)
Tower type	T1 (low), T2 (medium), T3 (high)
Rotor type	R1 (small), R2 (large)
Blade material	B1 (aluminium), B2 (glass-reinforced plastic), B3 (carbon fibre)
Blade manufacturer	M1 (blades only), M2 (can manufacture all superstructure parts)
Generator type	G1 (integrated with rotor), G2 (in nacelle, with gear box)
Generator manufacturer	M2 (all superstructure parts), M3 (generators only)

The set of exclusions X contains the 'impossible' combinations of 2 or more decision options for different decision areas. More formally, $X \subset \wp(A_1 \cup \ldots \cup A_n)$, that is, X is a subset of the set of all possible subsets of the union of all sets of decision options, so each $x \in X$ is a set of 2 or more decision options o_{ij} ($1 \leq i \leq n$, $1 \leq j \leq m$), and for each exclusion x holds that $\forall o_{ij}, o_{kl} \in x : j \neq l$. The set of exclusions for the wind farm decision problem has the 18 elements shown in Table 2.

Table 2. Exclusions (impossible combinations of options) for the wind farm decision problem

Combinations	*Reason for exclusion*
L2+B1, L3+B1	salt corrosion
L2+R1	dense bird population; birds get killed due to fast rotation of R1
L1+F2	F2 precludes multi-functional land use
L3+F1, L3+T1	F1 is too light, and T1 too short for offshore use
L2+F1+T2, F1+T3	F1 is too light for T3, and even for T2 near-shore (wind too strong)
R1+B3, R3+B1	material properties / manufacturing process
G1+R2, G1+T3	rotation of R2 is too slow for G1, G1 is too heavy for T3
T1+R2, L3+T2+R2	T1 is too low for R2, and offshore T2 is too low for R2 as well
M2+B1, M2+B3	M2 uses only glass-reinforced plastic for blades
M1+M2, M2+M3 [a]	processes of M2 are incompatible with those of M1 and M3

[a] Note that for these Mi+Mj, Mi and Mj are manufacturer of blades and generator, respectively

The exclusions in X constrain the feasible solution space: if $X = \emptyset$ (no constraints), the number of solutions would be $\#A_1 \cdot \#A_2 \cdot \ldots \cdot \#A_n$, which will be at least 2^n. This 'combinatoric explosion' may prohibit the use of AIDA, but for small values of n the method remains quite useful: the solution space for Table 1 has 864 elements, but this number is reduced to 25 by the exclusions in Table 2.

The set of criteria C serves to decide which of the feasible solutions is best. AIDA assumes that for each feasible solution the total impact on each of the criteria can be calculated. Doing so produces a consequences table that can be used as the basis for multi-criteria decision analysis (Belton & Stewart, 2002; Lootsma, 1999).

Although AIDA can be performed with paper and pencil, constructing a decision tree with branches that stop when a constraint is detected (Figure 1 illustrates how this is done for the first three decision areas of Table 1), the MEDIA tool (Modelling Environment for Design Impact Assessment, see Bots et al., 2004; Bots et al. 2005; Mayer et al., 2005) greatly facilitates the task. The sets of decision areas, options, and constraints can be defined and modified easily, and MEDIA will automatically calculate the number of feasible solutions and generate decision trees. Moreover, the consequences of each decision option can be defined as impact variables, with for each variable an arithmetic expression (as shown in the left-hand window in Figure 2) that is interpreted in a way similar to spreadsheets like Microsoft Excel. MEDIA can then use these expressions to construct a consequences table that aggregates the impacts of different options on the same variable and allows comparison of alternative solutions.

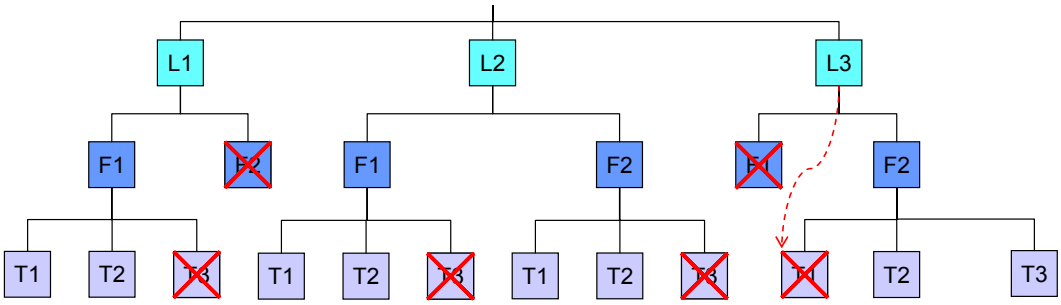

Figure 1. First three levels of the decision tree for the wind farm decision problem

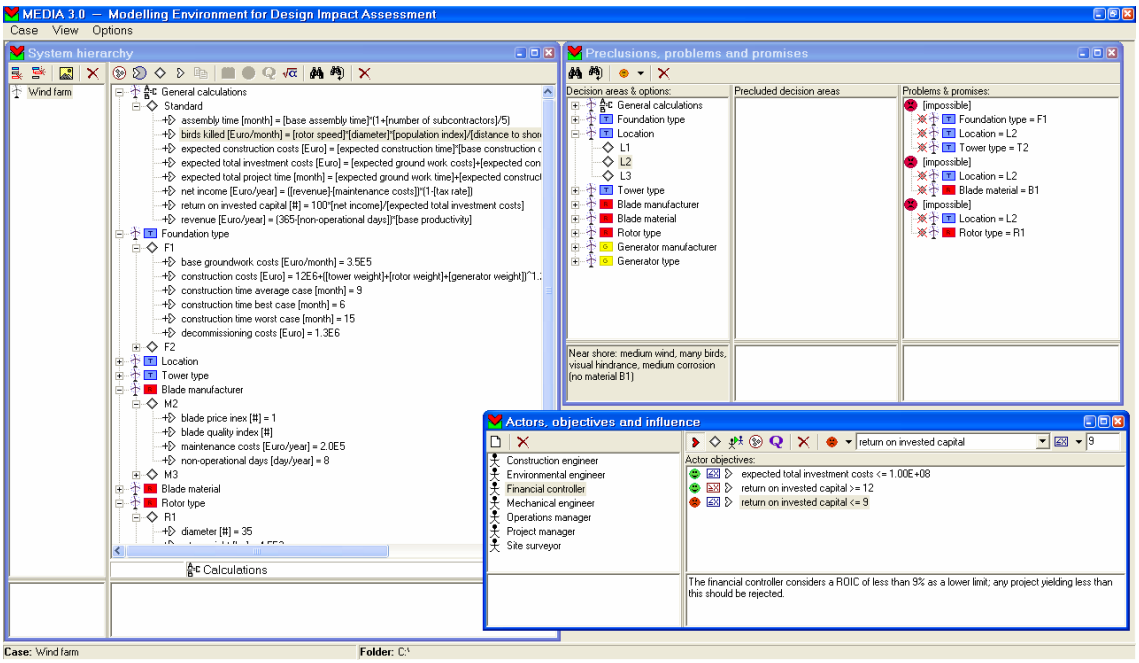

Figure 2. Representation of the wind farm decision problem in MEDIA

MEDIA extends the AIDA method by adding the stakeholder dimension. Stakeholders are represented as actors who prefer or reject particular decision options and/or have objectives with respect to particular variables. Table 3 shows the seven decision makers involved in the wind farm decision problem. In MEDIA, their interests are operationalised as objectives: variables plus specific threshold values, e.g., 'Non-operational days < 20' and 'Return on invested capital > 12%'. This feature allows MEDIA to visualise who stands to gain and who stands to lose when a particular solution is chosen (see the lower right-hand window in Figure 2).

Table 3. Stakeholders for the wind farm decision problem

Actor	*Focal interests*
Project manager	total project time, profitability, manageability
Financial controller	total investment cost, profitability
Site surveyor	available surface, adherence to local regulations
Construction engineer	robustness and durability of foundation & tower
Mechanical engineer	efficiency of wind conversion
Environmental engineer	environmental impact (habitats, noise, visual hindrance)
Operations manager	productivity, safety, reliability

Step 2 thus produces the definition of the decision problem in terms of decision areas, options, exclusions, and criteria. As the MEDIA tool requires that objectives be linked to a stakeholder, the stakeholders are identified as well. This provides the basic structure of the game, but more information is needed to make the game playable.

<u>Step 3: Defining the relation between problem, decision maker(s), and player(s)</u>

In the third step of the game design method, the P2R4 properties are elaborated further:

- *Roles*. As the PRODEMA game is to simulate a collaborative decision making process, the players each assume the role of one of the stakeholders in Table 3. To be able to play their part convincingly, the players need to know not only the 'what', but also the 'why' of their objectives (e.g., why is productivity important to the operations manager). This means that the role description for the players needs to be elaborated with context information that provides a justification for the objectives. To further encourage role-play, the PRODEMA role descriptions also specify some personal objectives, such as a preference for a particular manufacturer, or a passion for birds. In addition, the masking behaviour that is motivated by these personal objectives (Franz & Robey, 1984; O'Connor & Carnevale, 1997) is expected to enhance the potential pitfalls of selective bias and failure to re-appraise alternatives.
- *Rewards*. Players need a personal incentive to really become involved in playing the game. An example of such an incentive may be a scoring system that makes it possible for a player to *win* the game. The reward structure should be consistent with (but may expand on) the objectives which are part of the decision problem definition. If the game involves making a collective decision, there must also be an incentive to work together. During the briefing for the PRODEMA game, the players are informed that for each role the alternative that scores best on their role-specific criteria will count as 100% and that their personal score will be the performance of the proposed alternative relative to this 100%. The collective incentive is that the team decision (the proposed design of the wind farm) needs authorisation of the company's board of directors, and that *all* team members lose out if the team proposal is rejected.

- *Representation of the physical system*. The physical and technical constraints, and the economic consequences of choosing different options are represented in step 2 using MEDIA's exclusions and arithmetic expressions for impact variables. In step 3, it is decided how the information contained in the MEDIA model is distributed among the players (e.g., in PRODEMA, only the environmental engineer knows the environmental impact of rotor types on different locations). As was the case with the roles, the concise, analytical representation in MEDIA is should not be given as such to the players, but be embedded in a more or less extensive explanation (depending on the background of the players) of the workings of the physical system. It may be also be useful to provide the players of the game with some kind of physical model to help them visualise the situation. In the PRODEMA game, players have a map showing the possible locations on which they can place abstract scale models that visualise the combination of parts for the alternatives they consider to be feasible (see Figure 3).
- *Representation of the inter-actor environment*. This is the main game design issue which remains after defining the decision situation, as this is not represented at all in MEDIA. The inter-actor environment entails the design of the plot, the actor network, the task structure, and the rules for interaction.

  The plot is a realistic context which allows the players to identify themselves with the decision making situation. It consists of an explanation of the point of departure, and a description of the decision making task. In PRODEMA, the premise is that a tender has been issued for the design of a wind farm, and the players' task is to come up with a good design proposal, which has to be authorised by the board of directors before submission.

  By actor network we mean the social relations that exist between the roles, for example that the construction engineer and mechanical engineer know and trust each other because they have worked together on a previous project, or that the financial controller is new to the company and wishes to assert him/herself. The extent to which information about these relations between the different roles is included in the role descriptions depends on the purpose of the game. At a minimum, information is needed in order for the players to identify themselves with their role. More elaborate pre-defined social relations may, for example, enhance the game's potential for learning about face-to-face negotiations. However, much depends on the players' capacity to act out their role.

  The structure of the task may be predefined to some extent (e.g. a division into subtasks or a requirement to use certain methods/techniques). The degree to which the game pre-structures this process is a crucial design variable because it strongly affects what the players can learn about decision-making. In the PRODEMA game, the purpose is to reveal the natural tendency to revert to simple decision-making rules and heuristics. This works best if the players are free in how to organise the process of decision making. However, in order for the game to be do-able in the time available, one or more subtasks may be introduced. Adding structure increases the do-ability of proposing an adequate decision on time, but it reduces complexity and realism, and would in the case of PRODEMA detract from the purpose of the game.

  The rules for interaction also largely depend on the purpose of the game and the background of the players. For complex negotiations, the interaction may be structured in different rounds that protocol who gets to speak with whom. For PRODEMA, however, it was not necessary to define an explicit set of rules because a face to face team meeting is a familiar situation for the players. The

only rule that is clearly stated at the beginning of the game is that players are allowed to share information about the contents of the problem, but should keep their character description with their personal objectives to themselves.

Practical experiences

The method discussed above was used to develop a project decision making game for senior project engineers. This game is played during the final day of a course on decision making.

Setup of the game

A team can consist of 6-8 participants who each play a different role. The complete game (including debriefing) takes five hours and consists of two rounds. The first round is the main body of the game in which the team has to come up with a proposed decision. The problem is comparable in complexity to the wind farm decision problem: 9 decision areas define a design space of about a thousand possible combinations, which is constrained to approximately 30 feasible designs. The decision makers each have between 3 and 6 objectives that are largely compatible (they contribute to the overall quality of the design), but pertain to different criteria on a more disaggregate level than, for example, the total investment cost or the return on invested capital that are known to be very important for the board of directors.

At the start of the game, the facilitator explains the situation and hands out the role descriptions. The participants have 15 minutes to read their character description and scan what information they have on the problem. The task structure of the first round of the game is simple and consists of five activities:

- Introductory meeting: the project manager leads a brief team meeting during which the players introduce themselves
- Parallel preparatory work: the team splits up into working groups of 2-3 players who work on a separate part of the problem situation
- Plenary meeting: the project manager leads a team meeting in which the whole team has to come up with a team decision; for this key activity of the game no specific structure or agenda is imposed
- Prepare presentation: the team can use flipcharts to summarise the motivation for their decision
- Presentation: the team presents to the board of directors, who then questions the team on the proposed decision and the quality their decision making process

This is followed by a debriefing during which participants reflect on their decision making process, guided by a questions related to symptoms of defective decision making (Janis and Mann, 1977).

After this initial debriefing, there is a second round to the game. The participants are asked to continue with the game in their original roles, and a significant piece of new information is given to the team. This information is such that it forces the team to rethink their decision and to develop a new proposal. This is again followed by a debriefing during which the participants are asked whether they actually applied the lessons they learnt from the first round, and whether the game experience as a whole has implications for when they return to work after the course.

Setup of test runs with the game

Two test runs of the game were conducted prior to using it in an actual course. In the first test run, the roles were played by university staff and the plot was limited to the first round only. This test was meant to check whether the purpose of the game was achieved and focused especially on the do-ability of the game. The second test run was conducted with graduate students (see Figure 3) and included both rounds.

Figure 3. Testing the game with graduate students

Two representatives from the client organisation (both having extensive project management experience) also took part, assuming the role of board of directors, judging the team's decision. This test was meant to replicate achievement of the purpose of the game, and focused especially on the realism of the decision situation (recognisable for the players? similar enough to real-world projects?) and on the complete flow of the game.

Results of test runs with the game

Both test runs did show that even though participants have knowledge of structured decision making techniques, it is not a natural way of working. At several moments during the game, individual participants suggested doing things more systematically, but their suggestions were not taken up. Occasionally, participants started using a problem structuring method, but then did not follow it through. Several decision making heuristics that characterise bounded rationality were observed during the game, which means that in both test runs the main purpose of the game was achieved. During the debriefing of the second test run, the participants indicated that they should have made a plan for their decision making process in advance. Following this, they carried out the second round of the game, and again they did not structure their process. This demonstrated how deeply rooted this behaviour is, and reinforced the lesson from the first round.

With regard to the do-ability of the game, the first test run showed that the complexity of the game was at the right level, that is, complicated enough to pose a real challenge, but not so complicated that the team could not come up with a feasible design proposal. Considering the authors' experience in teaching and educational game design, this 'one off' success cannot be fully ascribed to the design method. However, without the rigour of step 2 and the analytic support provided by MEDIA, the risk of unbalance or outright mistakes in the structure of the decision problem would have been high.

In the first test run of the game we left the way in which the plenary team meeting was conducted open, imposing no structure on the process. During the test we found that the role of the project manager contained too much content information,

whereas it was not clear how the project manager was to lead the team towards a decision. In the next test run, we asked the project manager to prepare the team meeting as part of his preparatory task. We expected this would lead to a more focused meeting, still without us imposing a specific structure on the process. The test with graduate students showed that it does require some leadership experience from the person playing the project manager role, but that lack thereof can be compensated by some additional guidance by the facilitator. We also found that there needed to be some more balance in the (amount of) information given to the different roles, as well as some small adjustments to be made to the consequences of certain options.

The restricted time available to come to a decision with distributed information seems to lead the players to focus on the decision problem and disregard the information provided on personal objectives and social relations. This focus was even more visible with the graduate students. The graduate students used a more structured approach than the staff members, but the staff members were more involved in their role. The graduate students, possibly being less able to relate to the role descriptions, concentrated more on the task at hand. We decided not to shift the balance in the design from content towards strategic and social behaviour, because the main purpose of the game relates to the substance of the decision situation.

Conclusion

The game design method which has been discussed in this paper worked very well for the project decision making game we developed for our client. Although a single application cannot prove its genericity, the method is not specific to the case which was described in this paper, and can be used in general for designing games related to reciprocal team decision making situations.

The variety in purpose of a decision making game prohibits definition of rules regarding what type of decision problem to use in a game. Nevertheless, the list of characteristics of decision problems proposed for use in step 1 of the method does provide guidance for reflection on this point.

Step 2 of the design method (defining the structure and content of the decision problem) is effectively supported by MEDIA. The tool facilitates problem scaling (adding or removing decision areas, options, and variables to make the problem more or less complicated) while maintaining consistency. This allows the designers to experiment with different choices and constraints, looking for those that will appear most plausible to the players. MEDIA also helps in determining whether there is a ‘dominant alternative’ (one or several decision areas for which one option scores best on all criteria), which would simplify the problem and may, when undetected by the game designer, spoil the game and impair the learning experience.

Step 3 is geared towards defining the decision making process that the players follow. In this step, the way MEDIA links objectives to stakeholders facilitates checking whether the incentives are evenly distributed across the roles, and every player has a possibility to win. While designing the decision making game for our client, it did become apparent that MEDIA currently does not support definition of how the available information is distributed across the roles. Originally developed as a decision analyst’s tool, MEDIA does not consider information asymmetry among roles. This aspect is decided upon in step 3, and it is not easily changed in a consistent manner.

To better support game design, MEDIA could be extended along two dimensions: (1) allowing game designers to specify for each stakeholder (role) which information (not only about decision areas, options, and their consequences, but also about the other stakeholders, their means and ends, and their social relations) is available to them, and (2) enhancing the current facilities for associating free-text comments to specific parts of a MEDIA model (panes at the bottom of the windows in Figure 2) so as to automatically generate role descriptions.

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