SIMULATION IN FACILITATION OF OPERATIONS MANAGEMENT EDUCATION

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ABSTRACT

Traditionally, discrete event simulation is associated with logistic system analysis due to its role as an operations research method. In this article, we consider a multiple case study on the alternative use of simulation for operations management education. When stressing the role of the student or trainee instead of operations—as in operations research—alternative demands on model set up and use arise. Identifying such demands and ways to deal with them extends simulation methodology by showing how to exploit existing simulation knowledge and tools for pedagogic purposes. Our multiple case study evaluates four simulation-based games reflecting operations systems in health care and manufacturing. Respective games target learning activities of a different nature. Outcomes of the evaluation provide insights on modelling requirements, and guidelines and good practices that are supportive in meeting these.

1 INTRODUCTION

In past years, many authors provided examples of simulation-based games facilitating operations management education and training (Lewis and Maylor 2007). Essentially, games allow students or trainees to acquire or improve their decision-making skills in a safe environment, i.e., a model-based setting. Active player involvement, and the possibilities of experiential learning are among the main reasons for advocating gaming, as an alternative for conventional lecturing (Faria and Wellington 2004; Greenblat 1988). Moreover, games' simulation features like visibility, reproducibility, safety, economy, and system availability may give them relevant advantages over trainings-on-the-job (Raser 1969; Ruohomaki 1995).

Surprisingly, whereas potential of simulation-based games for operations management education is clear, their development and use is hardly supported by simulation modelling methodology. Current methodology is dominantly focused on simulation use for logistic systems analysis. Simulation literature tends not to consider a pedagogic perspective in model building and use. In recognition of this observation, in our previous work, we address specific demands pedagogical purposes may set on model development and use (Van der Zee and Slomp 2009). Insights obtained stressed relevance of including the notions of player decision-making and game plots in simulation modelling. Starting from these insights, we defined a modelling framework for simulation-based gaming (Van der Zee et al. 2012). The proposed framework extends the framework by Robinson (2008b) which addresses simulation use for logistical analysis purposes. The extended framework provides a stepwise approach for specifying the simulation conceptual model serving as a blueprint for the simulation coded model - to be built using simulation software tools. The simulation conceptual model entails specifications of modelling objectives, and model inputs, outputs and content.

This article extends our previous work by seeking empirical evidence on (i) the way specifics of the learning environment and constraints on resources (for example, staff, domain experts, hardware, software) may inform decision making on alternative modelling choices by setting specific requirements for model

development and use, and (ii) guidelines and good practices for meeting these requirements. We found how such evidence is largely lacking (Van der Zee et al. 2012; Van der Zee and Sloot 2014). Requirements are linked to four essential model qualities, i.e., validity, credibility, utility and feasibility (Robinson 2008b). Being guided by our previous work (Van der Zee et al. 2012), we consider the following research issues concerning model development (1-4), model use (5-7), and process of model development and use (8):

- 1. How to derive modelling objectives from pedagogic purposes?
- 2. How to choose model content, inputs and outputs reflecting subject matter?
- 3. How to measure student accomplishments in meeting pedagogic purposes?
- 4. How to relate user roles to model interface design and operation?
- 5. How to define alternative scenarios and user roles constituting a game session?
- 6. How to evaluate player accomplishments in meeting pedagogic purposes?
- 7. Which supplemental materials are required for facilitating model use?
- 8. How do resource constraints influence model development and use? How to resolve issues?

To answer research questions we perform a multiple case study involving four simulation-based games successfully being used in operations management education by the authors.

The remainder of this article is organized as follows. Literature related to methodological support on conceptual modelling for simulation-based serious gaming is reviewed in Section 2. In Section 3, we discuss the research methodology underlying our multiple case study. In Section 4, essential features of the games under study will be considered. Next, we evaluate game set-up and –use (Section 5). Section 6 and 7 discuss and summarize main research findings.

2 GUIDANCE ON CONCEPTUAL MODELLING FOR SIMULATION-BASED GAMING

Three basic approaches may be distinguished for guiding the modeler in specifying a simulation conceptual model (Robinson 2008a): principles of modelling, methods of simplification and modelling frameworks. Principles of modelling stress relevance of simple models for enhancing their utility and feasibility. They advocate an evolutionary approach towards model development, i.e. start with a simple model and add detail in an incremental way. Simplification methods work the other way around by seeking to reduce model detail (Innis and Rexstad 1983).

Modelling frameworks go beyond aforementioned principles and methods by suggesting a stepwise approach towards conceptual model creation, in terms of model components, their attributes and their relationships. They offer support for executing modelling steps, by suggesting guidelines, methods and good practices. Modelling frameworks may differ on their scope. Some frameworks address the general case, i.e., discrete event dynamic systems (Arbez and Birta 2011). Other frameworks somewhat specialize to broad fields of interest like operations systems (Robinson 2008b), the military (Pace 2000), and health (Kotiadis 2007). Guru and Savory (2004), and Monks et al. (2017) further refine scope by considering specific domains, i.e., physical security systems and stroke care logistics, thereby trading off the benefits of more refined support and the demand for suchlike modelling services. See Robinson (2008a), and Van der Zee et al. (2011) for overviews of modelling frameworks.

So far, guidance for the modeler as mentioned above is largely tailored towards simulation use for logistic analysis purposes. Literature on simulation modelling methodology tends not to consider a pedagogic perspective in model building and use. In recognition of this fact, in our previous work, we explore specific demands set for model development and use of simulation-based games (Van der Zee and Slomp 2009). We found how the notion of gaming requires a perspective on model users, their roles and the way those roles (model operators, players) are facilitated by the model – representing some referent system in line with the choice of subject matter. Furthermore, the experimental frame is to be linked to a series of game scenarios serving as vehicles for the learning experiences – following from player interaction with the model – that are aimed for. Typically, the experimental frame is multi-layered as players' logistic performance within the game setting has to be related to their accomplishments with respect to pedagogic

purposes underlying the game. Insights obtained are used as starting points for developing a conceptual modelling framework for simulation-based serious gaming (Van der Zee et al. 2012). The proposed framework extends the existing framework by Robinson (2008b) which addresses simulation use of logistical analysis purposes. The extended framework provides a stepwise approach for specifying modelling objectives, model inputs, outputs and content, starting from a pedagogical perspective. For each modelling activity it is clarified (i) what is to be specified (ii) what alternative modelling choices may exist, and (iii) how to specify choices made.

In this article we extend our previous work by seeking empirical evidence on (i) how specifics of the learning environment and resource constraints inform decision making on alternative modelling choices by setting specific requirements to model development and use, and (ii) good practices in meeting these requirements. Note how such evidence is largely lacking: while many examples of simulation-based games are provided in literature (Lewis and Maylor 2007) they tend not to provide details on modelling methodology underlying game design and use.

3 METHODOLOGY

In this section we address main phases in the set-up of the multiple-case study. The first phase concerns the selection of simulation-based games being part of the study, by identifying the population and specifying selection criteria (Voss 2009). A first criterion for selecting the games concerns characteristics of the learning environment in terms of the context of use (lecture, computer practical, assignment, in-company training), pedagogical purposes (level, coverage of alternative pedagogical purposes according to the revised taxonomy of Bloom (Anderson et al. 2001), and model users (teacher, student, trainee). We strove for a wide coverage of alternative characteristics, such that possible differences in modelling choices will be highlighted. Resource availability for game development and use is taken as a second criterion by considering games facing low or high resource availability. Unfortunately, despite the fact that many simulation-based games for operations management education have been proposed in literature, modelling issues in their development and use are hardly accounted for. Although this is not surprising, as methodology is weakly developed, see Section 2, it hinders their use within this study. In addition, proposed games tend not to be easily accessible for further study. Therefore, we chose to evaluate games that are familiar to and readily accessible by the authors.

In the second phase each selected game is characterized for its learning environment, model development and use (Table 1). Choice of aspects is largely motivated by earlier research on a framework for conceptual model specification for simulation-based gaming (Van der Zee et al. 2012), see Section 2. To reflect the requirements on the process of modelling and model use we add aspects concerning resource use.

Learning environment	Model development	Model use	Process
 Subject matter Context of use Prospective students or trainees Pedagogic purpose(s) 	 Modelling objectives Model content Model inputs and outputs User interface Model user roles Model visualization Modes of user interaction Model responsiveness 	 Scenarios User roles Evaluation of learning effects Supplemental materials 	 Resources for model development Resources for model use

Table 1: Game characteristics.

Our choice of aspects reflects the pedagogic purposes underlying simulation model development and use. Contrary to simulation models being used for logistic analysis purposes – that are typically being demonstrated by the model builder, development of game models requires clarification of the user

perspective in terms of the learning environment, user roles and their specific needs for interacting with the model (Van der Zee and Slomp 2009). Main user roles are the game operator and the player. The first role is typically associated with the teacher and/or teaching assistant, whereas students or trainees are considered players. Subject matter is reflected in the choice of model content representing a referent operations system. Model inputs underlie alternative game scenarios facilitating player-learning activities contributing to pedagogic purposes set. Model visualization and outputs provide players with information on system status that may serve as (i) an input for their decision making that is to be implemented as a net effect of their interaction with the model, and (ii) indicate their accomplishments. In turn, the latter information may also be used by the game operator to evaluate learning effects. Supplemental materials like manuals and instruction videos facilitate model use.

In the final phase, starting from the description of game characteristics, we evaluate how choices made with respect to model development and use relate to specifics of the learning environment, and resource constraints by seeking answers to the research questions posed. Outcomes of the evaluation are meant to provide insights on modelling requirements, and guidelines and good practices that are supportive in meeting these. We distinguish between 4 classes of requirements concerning model validity, credibility, utility and feasibility respectively (Robinson 2008a).

4 SELECTION AND DESCRIPTION OF GAMES

4.1 Game Selection

We selected four games for our multiple-case study, see Figure 1:

- 1. FMS DEMO (Aesop 1997): addresses workings and design of a Flexible Manufacturing System (FMS). The model is part of teaching material, i.e., a tutorial on the simulation tool Simple++TM. It is used within a MSc course on Asset Management.
- 2. Acute stroke pathway design: addresses design of the acute stroke pathway. The model is adapted from a model proposed by Lahr et al. (2013). It is used in a BSc course on Design Methodology.
- 3. Operational control of assembly lines (Van der Zee and Slomp 2009): considers design of rules for assembly line control. Models are based on two research projects in practice (Kalk 2005; Wind 2006). It is used in two BSc courses within the Industrial Engineering program.
- 4. ED game (Sloot 2013; Van der Zee and Sloot 2014): considers set-up and workings of an ED. The game is developed from scratch: a regional mid-size ED served as a referent system. It is used in an elective MSc course on Health Care Operations Management.

Author DJZ served as a teacher in all courses hosting the respective games. Author SS served as a teacher hosting game 4. Author DJZ acted as a main developer for games B and C, and as a co-developer for game 4. Author SS acted as a main developer for game 4. Both authors had access to all relevant course and game materials.

4.2 Game Selection

Each game is described according to the aspects defined in Section 3, see Table 2.

5 EVALUATION OF GAME DEVELOPMENT AND USE

In this section we discuss games' evaluation outcomes, also see Table 3.



Figure 1: Game selection: A-FMS Demo (Aesop 1997), B-Acute stroke pathway design C-Operational control of assembly lines (Van der Zee and Slomp 2009), D-ED Game (Sloot 2013).

5.1 How to Derive Modelling Objectives from Pedagogic Purposes?

Essentially, the definition of modelling objectives requires the identification and understanding of a referent logistic system (that is to be modelled), and model purpose(s) that should be supported by the model. Whereas classic use of simulation links models to either existing or would be systems, such linkage may be different in case of game-use. In principle, subject matter and pedagogic purposes guide the choice of model, which may relate to a fictitious (game 1) or an existing referent system (for example, in-company training on the use of new equipment) or a combination of both (game 2,3,4), also see Section 5.2.

Mapping of pedagogic purposes to modelling objectives assumes a tailoring towards (i) the choice of referent system, (ii) alternative modes of learning that may be supported by simulation, and (iii) model user roles. Key modes of learning suggested by the games under study concern (a) understanding of system setup and workings, which is typically supported by a visual display of the model, and means for model interaction, (b) system analysis, facilitated by the development of an experimental frame, and (c) system engineering, thereby using the model as a testbed. These findings are in agreement with Laurrillard (2002), who suggests that adaptive media forms – such as simulation – facilitate students in clarifying internal relations, experimenting, and relating theory to practice. Modes of learning may be linked to a specific choice of user roles, in terms of their interaction with the model. For example, in game 3, students act as a line manager. As such, they are an active part of the game model. Alternatively, for games 2, and 3 students take a role a logistic manager or consultant, thereby acting as observers – taking notice of model workings and accomplishments – starting from their choice of model inputs. Finally, for game 1 the teacher is in charge of model use, and thereby guiding the students' learning experience in a direct way.

	Aspe	ects	A: FMS DEMO	B: Acute stroke pathway design
ent	Subject matter Context of use		Design and use of Flexible Manufacturing Systems MSc Course Asset Management; Part of lecture: 20-30min	Operations system design BSc Course Design Methodology; Assignment (self- study, 1.5 week)
ning environm	Prospective students or trainees		Students programs Industrial Engineering, Technology Management	Students program Business with little engineering background
	Pedagogic purpose(s)		1. Understanding set-up and workings of a flexible manufacturing system	 Understand relevance of quantitative models for operations system design
Lean			 Recognizing relevance of logistic analysis for systems (re)design Identify key elements in doing logistic analysis 	 Understand key steps in defining an experimental design for evaluating alternative solutions
	Modelling objectives		ad 1. Understanding of FMS set-up and workings ad 2,3. Learn how to improve FMS throughput	ad 1. Understand workings of simulation model ad 2. Learn how to define simulation experiments
		Choice of model	Example model tutorial Simple++ [Aesop 1997]	Model re-use: Adapted from Lahr et al. [2013]
nt	Model conteni	Main Components	Shop control, conveyor, transport system, 2 lathes, 2 milling machines, drilling machine, quality assurance	First response (GP, 911), Transportation by Emergency Medical Services, Intra-hospital diagnostics and treatment
	Inputs	Factors	10 preselected measures for improving FMS performance (may be combined, 10! experiments)	Predefined measures influencing patient response, delays associated with care and logistic services and quality of diagnostic tests (may be combined, 8! experiments).
eme		Levels	-	-
eloc		Achievements	Throughput, Profit	Patient treatment rates
dev		Logistic analysis	Queue length, waiting time per station	Patient lead times, delays
Model c	Outputs	Format	Numerical; Spreadsheet format clarifying how measures (investments) impact on profit by allowing for higher throughputs	Numerical (averages; individual patient data)
		Precision	Low	High
		Measure learning effects	-	-
	a)	Model user	Teacher, students	Students
	lser interface	Model visualization	2D, simple schematic	2D, icons
		Modes of user interaction	Predefined menu structure for operating the model and choosing among alternative measures	Predefined menu structure for operating the model (Event control) and global variables for choosing among alternative solutions
	ſ	Model responsiveness	High, around 10 sec/experiment	High, around 5 sec/experiment
	Scenarios		Effects of single measures, and combined measures	Effects of single measures, and combined measures
	roles	Roles	Teacher executes the model using a menu structure; Students may suggest measures for improving FMS performance - to be implemented by the teacher	Student performs experiments one by one by changing model parameters
ŋ		Interaction	ad 1. Demonstrate model of FMS for its set-up and workings	ad 1. Perform experiments with the model: adjust model parameters, execute model
Model use	User		ad 2. QU2: Allow students to choose from 10 alternative measures for improving system performance (throughput, profit) ad 3. Link FMS model operations to model outputs; implement measures by experimenting with the model; interpret model outputs for experiments	ad 2. Interpret model outputs
	Evaluation of learning effects		Questioning students during lecture	Scoring of report for assignment
	Supplemental materials		None	 Student manual Instruction videos on model operation and performing of experiments
cess	Resou	urces for model development	Teacher - embedding existing game in course	Teacher - modify existing model for game use, produce supplementary materials
Pro	Resources for model use		Teacher, Teacher computer	Student computer

Table 2: Games description – FMS DEMO, Acute stroke pathway design.

	Aspects		C: Control of assembly lines	D: ED Game
ť	Subject matter Context of use		Effective control of assembly lines I Company training, II BSc Courses Industrial Engineering: Practical: 2hrs	Design of health care logistic systems MSc course Health Care Operations Management
Learning environmen	Prospective students or trainees		Students programs Industrial Engineering, Technology Management; Assembly line workers	Students from a broad range of programs, like Operations Research, Supply Chain Management, Human Resource Management, Marketing, Medicine.
	Pedagogic purpose(s)		ad I: Understand effects of current and proposed control rules on performance of the assembly line ad II: Train skills in engineering and evaluating alternative rules for shop control	 Understand workings of a typical health care system, and the way variability may influence its responses Train skills in analyzing health care systems for their logistics performance, and providing decision support.
	Modelling objectives		ad I. Understand effects of current and proposed control rules on performance of the assembly line ad II: Learn how to improve rules for assembly line control with respect to line throughput	ad I. Understanding set-up and workings of an ED, and the way variability may influence its responses ad II. Learn how to improve ED performance by addressing variability
an	odel ntent	Choice of model	New model: Van der Zee & Slomp [2009], based on thesis projects.	New model: Van der Zee & Sloot (2014), using existing ED as a referent system
	MC	Main Components	of workers <= number of stations.	Observatory, Fast-Track
	its	Factors	Control rules; settings for worker and job attributes	Sources of variability, number of treatment rooms, availability of observatory or fast track
	nduj	Levels	Control rules: 2; Worker and job attributes: 2	Variability: yes/no, Number of treatment rooms: 5, Observatory: yes/no, Fast track: yes/no
		Achievements Logistic analysis	Throughput Lead times	Length of Stay, Utilization, Waiting Time
el set-		Format	Numerical (real-time averages), bar, pie chart	Numerical
Mode	Outputs	Measure learning effects	Decision trace: capturing decisions made by the line manager, allowing for operator and self- evaluation (including possibility of undoing decisions)	Moderate
		Model user	ad I: Assembly line workers, ad II: Students	Students
	erface	Modes of user interaction	Decisions of users are implemented by dragging workers to stations.	Decisions of the operations manager are put to the test by performing simulation experiments using building block from default library. The respective building block allows for a menu-supported definition of experiments.
	User im	Model responsiveness	Dragging workers is instantaneous; completing experiments takes around 20-25minutes (delay is caused by real-time player decision making).	Individual experiments take around 30 seconds.
	Scenarios		Basic scenario (simple control rule); advanced scenarios (alternative control rule, alternative settings for worker and job attributes)	Default scenario used as base line scenario
Model use		Roles	Users play the role of the line manager that may assign workers to stations after they completed their job. Teacher acts as game operator.	Users play the role of the operations manager of the emergency department
	User roles	Interaction	ad I,II Perform experiments with the model, i.e. test various control rules in assigning workers by acting as a line manager. Each experiment involves a series of decisions of the line manager.	ad 1,2 Perform experiments with the model to find out how system variability may influence performance, and how it may be addressed by changing the design of the Emergency Department. Experiments may be executed batch wise.
	Evalu	ation of learning effects	Evaluation of user scores, and decision trace.	Questioning students during computer practical, scoring of assignment
	Supplemental materials		Introductory slides on model workings and operation	 Student manual: introduction of domain, model set-up and workings, model operation Introductory lecture by ED-manager, Instruction videos on model operation and experimenting
cess	Resou	irces for model development	Teacher - develop model, produce supplementary materials	Student (thesis project), teacher - develop model, produce supplementary materials, student test- panel
Pro	Resources for model use		ad I: Laptops, Instructor; II: Computer lab, Instructor, Teaching Assistant	Teacher, ED-manager, Teaching Assistant, Lecture room, Computer lab, Student computers

Table 2 continued: Games description - Control of assembly lines, ED Game.

5.2 How to Choose Model Content Reflecting Subject Matter?

Various requirements guided the choice of model content for each of the games. Subject matter and pedagogic purposes may set various degrees of freedom in choosing the referent model. Whereas design of game 3 was restricted to exactly one referent system – as it was to be used for training operators on the control of an existing assembly line, subject matter associated with game 2 gave a lot of freedom to the game developer in choosing the referent system and model – as long as it was representing an operations system and met pedagogic purposes. In principle, a simple model is favored, as long as it contributes to the pedagogic purposes. Apart from reduced modelling efforts, simpler models may benefit their transparency, and – hence – the learning effect.

In case freedom exists in choosing model content availability of existing games or logistic models that may be extended towards games may be considered, compare games 1,2. Clear advantages in terms of resource use are associated with choice of model content for games 1,2. This is even more true if the game developer is familiar with the respective domain or system, compare game 2. Choice of model content for game 4 took some more efforts, as specific requirements were put forward for the course hosting the game. Literature review, consultation of domain experts and site visits were undertaken to motivate choice of system and scenarios, and validate model content.

5.3 How to Measure Student Accomplishments in Meeting Pedagogic Purposes?

Model outputs may serve as indicators of student accomplishments (all games). While outputs linking to achievements give a first impression, outputs revealing reasons for good or poor accomplishments may allow for more in-depth analysis. Output analysis for game 3 goes beyond this. The latter game assumes model users to play a role as a line manager. Their decision-making is captured by means of a decision trace. Data recorded may be used for in-depth evaluation of student accomplishments, see Section 5.5. Note that the need for such a trace is absent for the other games for which decision making is related to the choice of alternative system configurations – as defined in an experimental frame.

5.4 How to Meet User Requirements on Model Interface Design and Operation?

All games use simple means for visualization in terms of iconic or schematic displays. Having used and evaluated all games many times for relatively large groups of students (up to over 300), we found no indication that more elaborate visualization would imply great benefit for the games. Student interaction is facilitated by (i) default tool menus for defining the experimental frame (game 4), or model execution (game 1,2,4), and (ii) dedicated menus or global variables for choosing among alternative system configurations (game 1,2).

For game 3 student interaction (taking a role as a line manager) is restricted to decisions on worker assignments, while they are being informed on shop status. Respective decisions are made, i.e., implemented, by simply dragging workers to stations. Game 3 allows the teacher (acting as a game operator) to make changes to the system configuration and consider detailed recordings on student accomplishments via a dedicated menu. Important criteria for facilitating model interaction for the student or trainee were to allow for their (i) decision making by simple means (menus, dragging), (ii) easy model access providing few entries to the model (ideally one) – thereby acknowledging that many users are not familiar with simulation models, and (iii) prompt model responses.

5.5 How to Define Alternative Scenarios and User Roles Constituting a Game Session?

In setting up simulation-based game sessions, we found that a few specific requirements tend to influence choice of scenarios. Foremost, time constraints may have a large impact on the number of scenarios to be considered. For example, game 1, being part of a regular lecture, is played in no more than half an hour, including an introductory part. Furthermore, game 2 lasts for two hours, allowing for only 4 scenarios to be executed. Clearly, this puts pressure on the game operator for choosing the right scenarios. In doing so, one

may also have to consider game sequencing, ideally serving the build-up of knowledge and understanding - also in mastering a simulation model that may not be familiar to model users. On the other hand games 2 and 4 challenge students skills in defining their own scenarios efficiently, by allowing for a great many alternative scenarios – and being less restrictive on time for game play.

5.6 How to Evaluate Student Accomplishments in Meeting Pedagogic Purposes?

In principle, model outputs offer an important means to evaluate student accomplishments, see Section 5.3. Typically, this is supplemented by questioning students (games 1,3,4), or scoring assignments related to respective games (games 2,4), in order to assess their understanding and build-up of skills. By asking students to articulate their observations and conclusions, their understanding of the subject matter and acquired skills may be more thoroughly assessed than just considering model outputs.

5.7 Which Supplemental Materials are Required for Facilitating Model Use?

In developing and using the games, we acknowledged the need for making users familiar with the referent system and the use and workings of the simulation game model. Students are made familiar with the referent system by introductory slides, case descriptions, or interviews of or presentation made by managers, i.e., domain experts. Manuals and instruction videos are used to explain and demonstrate model workings. Note that respective materials also benefited supportive staff – being non game developers.

5.8 How Do Resource Constraints Influence Model Development and Use?

Simulation-based game development comes at a price. Games 3 and 4 that are largely build from scratch took many months of development time. Re-use of models used for logistic analysis purposes (games 1, 2) proved to be much cheaper, reducing the development efforts to minor model modifications, and building a game around the model. We noted that simulation-based game development entails a cross-disciplinary effort requiring designer skills concerning simulation, gaming and education (Van der Zee and Sloot 2014). Fluency in either skill may make a difference in game development lead-time.

Time may not only imply a constraint in model development, it may also influence model use. Teaching formats or student availability may set relevant restrictions on time available for game use, compare games 1 and 3. In turn, this may set restrictions on the number of game scenarios in a session and game responsiveness, see Section 5.5. Finally, we found how the availability of computer labs may be a relevant constraint, compare games 3,4.

6 DISCUSSION – FACILITATING SIMULATION-BASED GAMING

From our evaluation of four simulation-based games we distilled several guidelines and good practices for model development and use. Apart from their meaning for simulation based gaming above guidelines hint at the specific features of simulation game models: they are tools that facilitate players by allowing for their learning experiences, whereas classic simulation models often boil down to single-use vehicles operated by analysts for decision support. Its status as a tool that may be re-used, its use, and its users make the difference by putting forward alternative requirements.

Future studies may allow for refinements and extensions of guidelines and good practices for game model development and use found in this research by strengthening the educational perspective. For example, they may be linked to the specific nature of educational goals, thereby following a well-defined taxonomy, or the need to facilitate game debriefing – to make sure that "the learning starts when the game stops".

Table 3: Evaluation outcomes.

	Issue	Requirements	Support: Guidelines, Good Practices
	How to derive modelling objectives from pedagogic purposes?	Validity/credibility: Correct mapping of pedagogic purposes on modelling objectives	 Consider alternative modes of learning that may be supported by simulation, especially understanding of system workings, system analysis and system engineering. Link respective modes to user roles.
	How to choose model content, inputs and outputs reflecting subject matter?	Validity/credibility: Fit with subject matter.	- Consider degrees of freedom on model scope and detail set by modelling objectives (pedagogic purposes). Model complexity (scope, detail) should be sufficient to meet pedagogic purposes, no more. Validate content by literature, site visits, and/or domain ovnorte
		Feasibility: Availability of resources for model development and use	 Explore possibilities for re-use of existing models developed as a net result of research, industrial projects, or readily available as teaching material
Model development	How to measure student accomplishments in meeting pedagogic purposes?	Validity/credibility: Selection of model outputs being representative for player accomplishments in meeting pedagogic purposes	- Model outputs may be extended by including a decision trace, in case players have an active role in game execution.
	How to relate user roles to model interface design and operation?	Utility: Ease of understanding how to play the game, ease of interpreting model display and outputs, ease of determining what is needed to improve performance, high model responsiveness.	 In serving players: Keep it simple - strive for simple self-explaining displays capturing essence of the referent system, use single model entries. Teachers may be served by dedicated menu's allowing them to define the experimental frame, and evaluate player accomplishments. Trade-off accuracy of model outputs and model responsiveness. Usually, high responsiveness is welcomed, if not demanded. Provide supplemental materials, see Model use
		Feasibility: Availability of resources for model development and use	 Trade-off gains of more refined interface design for model utility vs. resource needs (which are typically high and/or may require specific modelling skills). Make sure model responsiveness is in accordance with the time frame set for game execution.
Model use	How to define alternative scenarios and user roles constituting a game session?	Feasibility: Availability of players, and resources.	 Identify critical resources for executing the game, especially, teaching staff, and computer labs. Check availability of players given course/working schedules and time available for doing the game.
	How to evaluate player accomplishments in meeting pedagogic purposes?	Validity/credibility: Use of game findings being representative for player accomplishments in meeting pedagogic purposes	 To improve assessment of student accomplishments evaluation of model outputs may be supplemented by player questioning, and scoring of assignments associated with the game.
	Which supplemental materials are required for facilitating model use?	Utility: Ease of understanding how to play the game, ease of interpreting model display and outputs, ease of determining what is needed to improve performance	 Provide supplemental materials: case material for explaining scenarios and player roles, manual and video instructions on how to operate the model)
Process	How do resource constraints influence model development and use? How to resolve issues?	Feasibility: Resource availability for model development and use.	 Assess resource availability with respect to staff (possibly from multiple disciplines), and domain experts. Be greedy with respect to possibilities for model re- use, see Model development (model content). Safeguard player access to simulation tools required for model execution outside teaching hours.

Clearly, resource constraints may have a significant impact on simulation use for gaming purposes. Typically, little funding in higher education is available for course development. In addition, staff may be more focused on research opportunities than their educational jobs. Furthermore, simulation-based game development typically relies on the successful cooperation of staff from various disciplines, including education, gaming and simulation. Providing modelling frameworks for simulation based game design, and their enrichment by adding guidelines and good practices based on empirical evidence is assumed to contribute to overcoming barriers sketched by showing how to do it and what it takes.

7 CONCLUSION

In this article, we consider a multiple case study on the alternative use of simulation for operations management education. By evaluating games' development and use, we provide insights on modelling requirements, and guidelines and good practices that are supportive in meeting these. Future work is directed towards domain specific modelling frameworks specializing towards specific areas within operations management.

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