Proceedings of the 2010 Winter Simulation Conference
B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yücesan, eds.

CONCEPTUAL MODELLING FOR SIMULATION-BASED SERIOUS GAMING

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ABSTRACT

In recent years several simulation-based serious games have been developed for mastering new business concepts in operations management. This indicates the high potential of simulation use for pedagogical purposes. Unfortunately, this potential is hardly reflected in simulation methodology. We consider this issue by identifying alternative demands game use of simulation sets for model building and application. Moreover, we propose a framework for conceptual modelling for simulation-based serious gaming, which addresses relevant issues in a systematic, step-wise manner. Use of the framework is illustrated by two case examples, highlighting simulation use for training and education respectively.

1 INTRODUCTION

Many researchers indicate the high potential of serious simulation games for mastering new business concepts in operations management, see, for example, Chapman and Martin (1995), Ruohomaki (1995, 2003), Chwif and Barretto (2003), Smeds (2003), and Lainema and Hilmola (2005). Essential strengths of gaming are in the active involvement of trainees, the possibility to experience the topic as a whole, and its suitability to convey system characteristics (Greenblat, 1988; Faria and Wellington 2004). These characteristics give it a decisive advantage over conventional lecturing. Furthermore, factors such as visibility, reproducibility, safety, economy, and system availability make gaming a viable alternative for training-on-the-job (Raser, 1969; Ruohomaki, 1995).

Clearly, the basic notion of discrete event dynamic systems, together with the availability of simulation tools present a welcome starting point for building game models – allowing for an efficient representation of operations systems in (service) industry. This potential is acknowledged in literature by several authors, who adopt discrete event simulation models for use in serious games, see, for example, Angelides and Paul (1993), Chapman and Martin (1995), Ruohomaki (1995, 2003), Haapasalo and Hyvonen (2001), Chwif and Barretto (2003), Smeds (2003), and Lainema and Hilmola (2005).

While there seems to be a clear potential and interest for simulation-based serious gaming, questions on simulation methodology for game use receive little attention. Simulation text books and tools typically start from the idea of simulation being just a methodology to analyse "hard" design decisions (Robinson 2001). In this view stakeholder interaction largely follows from the analyst's demonstration of simulation results. Other, "soft" uses, like serious gaming, which stress active stakeholder (player) involvement in model use, in terms of their understanding, learning, co-engineering etc., are at best scarcely addressed. This finding is also reflected in the work of the aforementioned authors addressing serious games for education and training in operations management. They hardly address methodological issues – as they would arise from the use of simulation – in setting up and using their game models.

In a recent case study we explored three issues concerning use of simulation for serious gaming, i.e., the modelling and coding of player decision-making, the design of valid game scenarios, and the analysis and presentation of player scores (Van der Zee and Slomp 2009). In this article we extend our previous research by proposing a framework for conceptual modelling of simulation-based games. Essentially, the framework adds to our existing work by:

- Supplying an *ordered sequence of activities* to undertake for model specification – fit for model coding.
- Including activities concerning *learning needs*, and the *definition of modelling objectives*.
- Further *detailing of activities* concerned with describing model contents, inputs and outputs.
- Addressing *requirements* for a conceptual model.

The framework results from an adaption and extension of the framework by Robinson (2008b). The primary focus underlying their framework is the use of simulation for modelling and analyzing operations systems in business. We modify the framework to facilitate simulation use for serious gaming by reconsidering the modelling objectives, and users, i.e., players, needs. Modifications follow from the framework for game design introduced by Greenblat and Duke (1981). Use of the framework is illustrated by two case examples, addressing serious gaming for training and educational purposes respectively.

The remainder of the paper is organised as follows. In section 2 we will introduce the methodology for developing the new framework for conceptual modelling for simulation-based gaming. Next, in Section 3, two case examples are introduced. In Sections 4 and 5 we discuss the new modelling framework and the requirements for conceptual modelling. They serve to illustrate the application of the framework. The paper concludes with a summary of the major findings.

2 METHODOLOGY

Basically, the use of simulation models for serious gaming, instead of system analysis, implies a shift with respect to:

- Modelling objectives: the model is meant to support learning instead of analysis.
- Users: players and game leaders are added to analyst and other stakeholders.
- Interaction: on-line user interaction with the model is intrinsic to game runs.
- Model re-use: games are typically used to serve distinct groups of players.

To reflect the aforementioned changes we propose to adapt the dominant cycle of activities for a simulation project, by integrating relevant elements underlying game design, see Figure 1. Figure 1 clarifies how our prime focus is on the conceptual modelling step. This step should result in a blueprint for coding, i.e., the conceptual model, and a statement on the coded model's intended use.

Unfortunately, there is little agreement on the notion of conceptual modelling, apart from having relevance for the early stages of the simulation study, linking somehow problem situation and model coding (Robinson 2008a). In this article we relate conceptual modelling activities to the framework defined by Robinson (2008b). Robinson's framework is built on a recent and thorough literature review. It is meant to support conceptual model definition by identifying and detailing five sequential, but iterative, key activities:

- Understanding the problem situation,
- Determining the modelling and general project objectives,
- Identifying the model outputs,
- Identify the model inputs,
- Determining the model contents (scope and level of detail).

Furthermore, Robinson specifies requirements on the quality of a conceptual model for later phases in the simulation study, see Section 5.

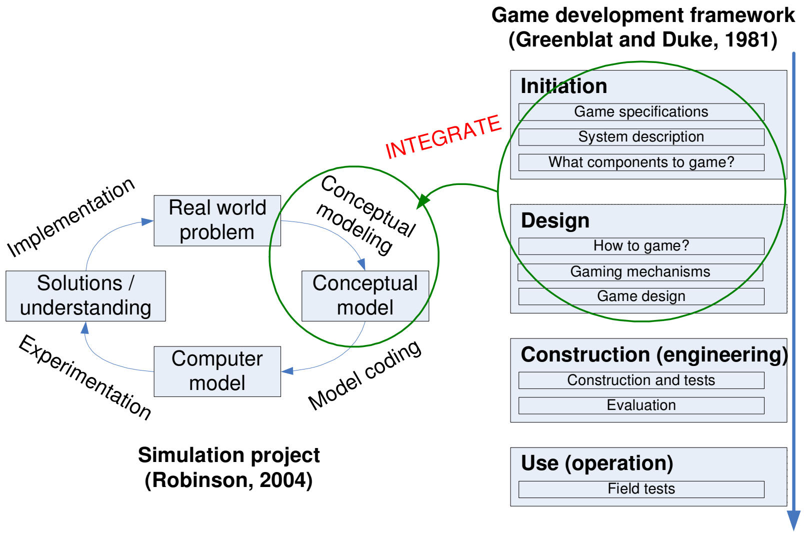

Figure 1: Adapting simulation models for game use

Essentially, our approach foresees in adapting Robinson's framework for game use by including relevant game elements. Such elements are found by considering a framework for game development, as proposed by Duke and Greenblat (1981). Remark how their framework has been enriched by Riis et al. (1995) building on their extensive experience in game design and use. The choice of framework is motivated by the structured way it describes the design process, and its role as a reference model for simulation and gaming – being much referenced by simulation game designers, cf. Angelides and Paul (1993), Crookall (1995), Smeds (2003).

Greenblat and Duke (1981) describe the overall game design process in four phases: Initialization, Design, Construction, and Use of the game, see Figure 1. We only summarise essential elements for each phase here. For a more detailed discussion we refer to Greenblat and Duke (1981), and Riis et al. (1995). The outcome of the initial phase in game design should be a clear focus on objectives and scope of the game, see Figure 1. Important issues are concerned with the appropriateness of the game relative to alternative approaches, purpose of the game and its constituting elements. The actual game design covers two phases: the development of a game concept, and the implementation of this game concept in terms of construction. The final phase is concerned with the actual operation of the game.

3 CASE EXAMPLES

In order to illustrate the use of our new framework we will consider two case examples. The first case addresses operator *training* for assembly line operation, whereas the second example concerns retail managers being *educated* on in-season price promotion. Both cases consider simulation-based games which have been used and tested in practice (Van der Zee and Slomp 2009, Holkenborg 2009). Remark how education and training concern two important uses of serious games. Training tends to be more tailored to the (daily) operation of a (company) specific system. Education may have a wider focus by encouraging, for example, critical thinking, the formulation of good questions, and creativity in solution finding, thereby building on the notion of a tailored "imaginary" system, see Jones (1995), Corsun (2000), Klabbers (2003). Section 4 will clarify how these differences may matter in conceptual modelling.

3.1 Training Assembly Line Operators

Recently a manufacturer of mail inserting systems (cf. Figure 2) changed its concept underlying the design and operation of its manual assembly lines. Consequently, operators had to be trained for the new working procedures (Van der Zee and Slomp 2009).

Figure 2: Mail Inserting System (Van der Zee and Slomp 2009)

New working procedures concerned among others the operation of the line according to the takt-time principle (Baudin 2002). Essentially, the takt-time principle realises line pacing by considering a fixed time frame – the takt-time – in which each team should complete assembly operations for one product. The respective product is to be placed in a buffer and serves as an input for a successor segment of the line. The setting of the takt-time is based on demand figures. Basically, it relates planning period and its associated demand. Ideally, implementation of the takt-time principle should contribute to a regular product flow for the line, and reduce the effects of blocking and starvation.

The design of the assembly line assumes each station to be operated by at most one worker. To guarantee volume flexibility for the assembly line, the number of stations is chosen such that it exceeds the number of operators under "normal" work loads. Elementary operator decisions within the takt-time concept concern the selection of a next station to work on. Job variety and worker differences should be considered in solving this problem. Another issue that has to be solved, is concerned with the acceptance of the proposed control solution by the workers The takt-time control concept evokes a natural resistance among workers, as working according to takt-time can easily be associated with working-like-robots.

3.2 Educating Retail Managers – In-Season Price Promotion for Fashion Merchandise

A supplier of software for retail management seeks to further exploit its knowledge of business processes in retail. One of the opportunities considered is the design of serious games for educational purposes. Typically, retail managers are educated by training on the job. The use of serious games may present an attractive, alternative way in educating managers in making better founded decisions, and speeding up their learning processes (cf. Section 1).

As a first initiative the company started a pilot project (Holkenborg 2009, Van der Zee and Holkenborg 2010). The pilot project addressed the design, testing and use of a serious game for educating managers in fashion retail on in season pricing decisions. Essentially, pricing decisions may be used to influence consumer behaviour in their willingness of buying products. In turn this may help to improve shops' profits by increasing turnover and reducing unsold stock.

More in particular, the game concerns the sale of jeans – being considered as an appealing example setting. The sale of jeans is assumed to follow a seasonal pattern – as is common in fashion retail. This implies that the selling and wearing of jeans is restricted to specific periods of a year. Pricing decisions are typically made either on a seasonal or on a week-by-week basis. Note how the latter setting assumes that recent information on sales may be included in decision-making. Hence better informed decisions may be made.

4 A FRAMEWORK FOR CONCEPTUAL MODELLING

In this section we propose a framework for simulation-based serious gaming. The framework results from adapting and extending Robinson's framework (Robinson, 2008b), which addresses conceptual modelling for simulation and analysis of operations systems in business. Each step will be illustrated by the aforementioned case examples, see Section 3.

4.1 Understanding the learning needs

Whereas "analysis" is driven by a perceived need to improve a problem situation linked to a system - either existing or foreseen, "learning" builds on a *pedagogic purpose* linked to a (possibly imaginary) system and a target group of students (trainees). Pedagogic purposes may be (Ments, 1983, Riis et al., 1995):

- To describe – illustrate or demonstrate an issue, a situation or a process.
- To demonstrate – a method or a technique.
- To practice – training and education.
- To reflect – experiment and obtain response.
- To prepare – increase or direct attention towards a specific situation.

Learning needs typically follow from the context and problem being studied, as well as the educational backgrounds and interests of the students (trainees). Similar to Robinson's idea of distinguishing between levels of understanding the problem situation, three levels of understanding the learning needs may be considered, i.e., they are (i) clearly understood and expressed, (ii) apparently well understood and expressed, although they are not, (iii) neither well understood nor expressed. The respective level of understanding relates to the efforts of the game designer in clarifying matters. Relevant suggestions made by Robinson concern contacting the right people, dealing with different views of stakeholders, or applying methods for problem structuring. Furthermore, for serious gaming, one may also consider the use of literature and educational resources and materials.

After gaining a basic understanding of learning needs, the appropriateness of a game for meeting them should be considered (Riis et al., 1995). Key questions are:

- Is the game appropriate at all? This assumes a justification of development costs. Alternative solutions may be, for example, lecturing, and training on the job.
- What damage may be caused by a poor game? Risks may be in the way the game model matches reality, and the quality of its execution – especially with respect to the choice of the game leader.
- How important is the behaviour of the simulation game leader? Clearly, the game leader may have a big impact on the game process, and players' learning.
- What will be reactions to variations in the benefits obtained by the participants? Background and roles of participants may heavily influence their experiences.
- What about participants who dislike games? Typically, this refers to participants who have been ordered to participate, and show a lack of interest in the game.
- Can simulation gaming be overdone? This refers to the fit of game and learning needs.

Case example: training assembly line operators

Operator learning needs follow from the redesign of the manual assembly line. Relevant pedagogic purposes are *to practice* the control rules for operating the line, and *to reflect on* the way a takt-time rule may influence their working conditions and system performance.

The purpose of reflecting on the new control system is rather soon identified. It takes some more time to realize the operators' need for practicing. This is reflected in the fact that the initial choice to support learning by lecturing does not work out well for the operators. Their experience is limited – being allowed to watch model behaviour but not influence it. Hence, only a limited contribution is made to their confidence and insights in solution quality.

Appropriateness of the game has been justified by comparing it with alternative solutions, see above. Game size and simplicity imply limited efforts in game design and execution, and reduced risks involved. Variations in game outcomes due to player backgrounds (educational background, experience) are expected, and fostered as a way to force insightful and convincing discussion among players. Only well-motivated participants are invited for the game.

Case example: educating retail managers

The starting point for this project implies the a-priori use and testing of a game for facilitating learning of retail managers. The choice of subject addressed by the game follows from interviews of several interested retail managers. Essentially, the game should educate retail managers on pricing decisions for in-season promotion. Here education is meant to create awareness and insights on the way pricing decisions influence customer behaviour, and – next – shop performance.

Appropriateness of the game is considered in terms of risks involved in case of a poor game setup, and execution. Given its status as a pilot project it is crucial to guarantee a successful experience for game attendants.

4.2 Determining the modelling and general project objectives

Modelling objectives determine the starting point and check point for model development. Robinson suggests to define modelling objectives in terms of achievements, performance, and constraints. This assumes a clear definition of performance measures, and goals, and the restrictions set to solution finding and testing, like, for example, the available budget, time constraints, and design options.

Serious gaming relates achievements to pedagogic purposes, see Section 4.1. Performance measures may be used to indicate success in answering to the pedagogic purposes. Furthermore, in many cases the notion of the factors explaining performance – causes and effects – may be more important, see Section 4.4. Restrictions on game design and use typically reflect limitations in resource availability, player interests and availability, context of use and design options. The latter options may for example refer to requirements on instructions, and the use of specific materials (Riis et al., 1995).

General project objectives supplement the modelling objectives by linking model development to a time scale, and by considering model nature and its use. Robinson details the latter aspect by distinguishing between model flexibility in accommodating changes, run-speed, visual display, ease of use, model/component reuse.

Game model nature and use follow from the identification of users, i.e., game leader and players, and the way their model interaction should be facilitated. This sets high demands to model understanding and ease of model interfacing – as model users are typically not familiar with simulation model set up and its underlying logic. Note how this differs from the case where simulation is used for analysis purposes – here model builders often are the (sole) model users. Demands are typically reflected in the way models are to (i) be visualized, in terms of what to display (all, relevant parts of the system), and how to display (2D, 3D, schematic, mathematic etc.), (ii) be used by characterizing facilities for interaction (dragging, pop ups, menus etc.), (iii) respond to player decisions – in terms of execution times, and (iv) distinguish among roles of the game leader and player(s) (access to model elements, i.e., inputs, outputs, model details).

Case example: training assembly line operators

Operator achievements are in their understanding, and practicing of the takt-time control concept, see Section 4.1. The performance measure that serves as an indication of their understanding concerns the throughput realized within a certain time frame. Most relevant resource restriction in game design is the availability of the operators, as their absence implies production losses.

As far as general project objectives are concerned especially model visualization and interaction received due notice. Basically, operators should be able to relate their working environment to the model. A simple 2D visualization would suffice as long as assembly line stations, operators, operations and their dynamics are clearly distinguished. Interactions means should be simple, as operators are not familiar with simulation tools.

Case example: educating retail managers
Achievements of retail managers are related to their ability in making good and founded pricing decisions for in-season promotion, see Section 4.1. Key performance indicator is the profit margin, as it results from sales, purchase prices and unsold inventory. Just like for the other case example the most important restriction for game design concerns the availability of the players, i.e., retail managers.

Whereas the aforementioned operators require a visual display of shop floor operations for making their decisions, retail managers typically do not require such detail for their pricing decisions. They rely on summaries of customers´ behaviour in terms of expected sales figures. Visualization should reflect their reality in terms of relevant graphs. Again, interaction means should be simple, as retail managers are not familiar with simulation tools.

4.3 Identify the model inputs

Just like the classic use of simulation game use starts from the notion of experimental factors, i.e., model elements which may be adapted for characterizing a scenario. For gaming a certain ordering of scenarios may be a requisite, in order to familiarize players with the game and "build up" their skills and knowledge. Choice of experimental factors and their range may be decoupled from the actual choice of scenarios for a specific game session. Note how restrictions on resources, player interests and availability may force a careful choice of a limited set of scenarios for a specific session. (Re)use of the game for players with alternative educational backgrounds may make it worthwhile to extend available scenarios.

Case example: training assembly line operators
Two experimental factors are considered: operator efficiency, and control concept. In this way players experience the differences between the current control policy and the takt-time rule, as well as the influence of operator differences on system operation and performance.

Case example: educating retail managers
The game is rather flexible with respect to the choice of experimental factors, allowing to define numerous scenarios. Actual game use assumes a tailoring towards the respective target group of retail managers, considering their background, branche of trade, interests etc. For example, a pilot game considered alternative pricing strategies in terms of decision-making on a weekly or on seasonal basis.

4.4 Identify the model outputs

Model outputs are meant to serve two purposes (Robinson 2008b):

- To identify whether the modelling objectives have been achieved.
- To point to the reasons why the objectives are not being achieved, if they are not.

For game use simulation modelling objectives are related to pedagogic purposes, see Sections 4.1, 4.2. Outputs may serve as an indicator of players' success in answering to these purposes. Furthermore, outputs may serve as the starting point for player decision-making within the game context, and game leader evaluation of players' progress. An important means in this respect may be a "decision trace" (Van der Zee and Slomp 2009) highlighting the (sequence of) decisions made by a player. Note how such a trace may be both of relevance for the player (also during game execution) and the game leader (evaluation).

Case example: training assembly line operators
Players are supported in decision-making by indicators, representing, for example, the time remaining until the start of a new takt-time period, throughput realized so far, and visual observations of the line.

Outputs considered by the game leader are the decision trace concerning operator assignments, and throughput figures, next to intermediate observations on player progress, and performance.

Case example: educating retail managers

Retail managers are supported in their gaming decisions by outputs on their price strategy implemented so far (decision trace), and related developments of costs, sales, profits and inventory levels. In turn the decision trace and figures on overall net profit allows the game leader to judge on players' progress and learning.

4.5 Determining the model contents

Determining model contents entails two activities, i.e., deciding on model scope and its detail. Robinson (2008b) suggests to specify model scope by identifying the entities, activities, queues and resources that are to be included in the model. The choice for these types of components follows from abstracting operations systems as queueing systems. Decisions on model detail boil down to defining component attributes.

Decisions on model contents are not easy and may involve the sound judgement of domain experts and stakeholders. Judgement should include a careful balancing of conceptual model requirements, see Section 5. For further hints on defining model contents – which are also valid for simulation games – see Robinson (2008b).

A specific issue concerning game use of simulation is in the specification of players' roles and interactions with the game model. In line with Van der Zee and Slomp (2009) we propose to specify player details in terms of intelligent agents. Intelligent agents are defined according to a reference architecture (Van der Zee and Van der Vorst, 2005; Van der Zee, 2007). Essential elements are:

- Decision makers are modelled as *intelligent agents* who carry out *decision jobs*, just like machines carry out physical jobs.
- The definition of a common *internal structure for agents*, which specifies basic elements and operations. Elements concern:
- Buffers for storing data, goods, and resources.
- A job queue containing job definitions issued by a higher-level agent.
- A transformer reflecting jobs being processed.
- Local intelligence, specifying the control logic applied by the agent in job execution.
- Handling of incoming and outgoing flows of goods, resources, data, and job definitions are realised by input and output operations.
- Model dynamics is linked to *job dynamics* as activities only start if both a job definition, and its required input, i.e., goods, data and/or resources, are present.

Case example: training assembly line operators

Figure 3 shows how player details have been specified for the game model by means of object diagrams (Booch 1994), cf. Van der Zee and Slomp (2009). The figure shows how a player is related to the role of a line manager, i.e., an intelligent agent. His decision jobs are triggered by events, i.e., product arrivals and the completions of operations. Decision output is concerned with job definitions specifying assignments of workers to stations.

Case example: educating retail managers

Figure 4 shows the scope for the game. It highlights key entities and their relationships. Further detailing – including player roles, i.e. retail managers – is possible, similar to the operator training game.

5 REQUIREMENTS OF A CONCEPTUAL MODEL FOR SIMULATION-BASED GAMING

Robinson (2008b) considers 4 requirements to judge on the *quality of the conceptual model for later phases in the simulation study:*

- Validity refers to "a perception, on behalf of the modeller, that the conceptual model can be developed into a computer model that is sufficiently accurate for the purpose at hand".
- Credibility is defined as "a perception, on behalf of the clients, that the conceptual model can be developed into a computer model that is sufficiently accurate for the purpose at hand".
- The utility of the conceptual model is "a perception, on behalf of the modeller and the clients, that the conceptual model can be developed into a computer model that is useful as an aid to decision-making within the specified context".
- Feasibility, is "a perception, on behalf of the modeller and the clients, that the conceptual model can be developed into a computer model with the time, resource and data available".

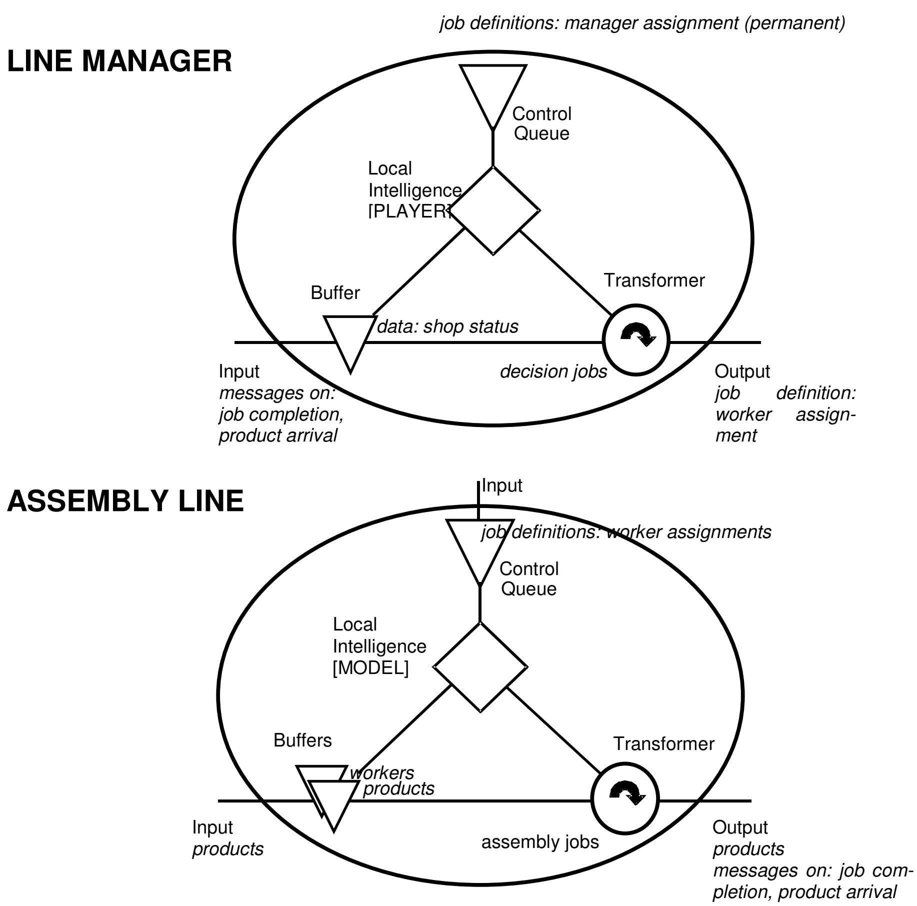

Figure 3: Conceptual model contents – line manager and assembly line (Van der Zee and Slomp 2009)

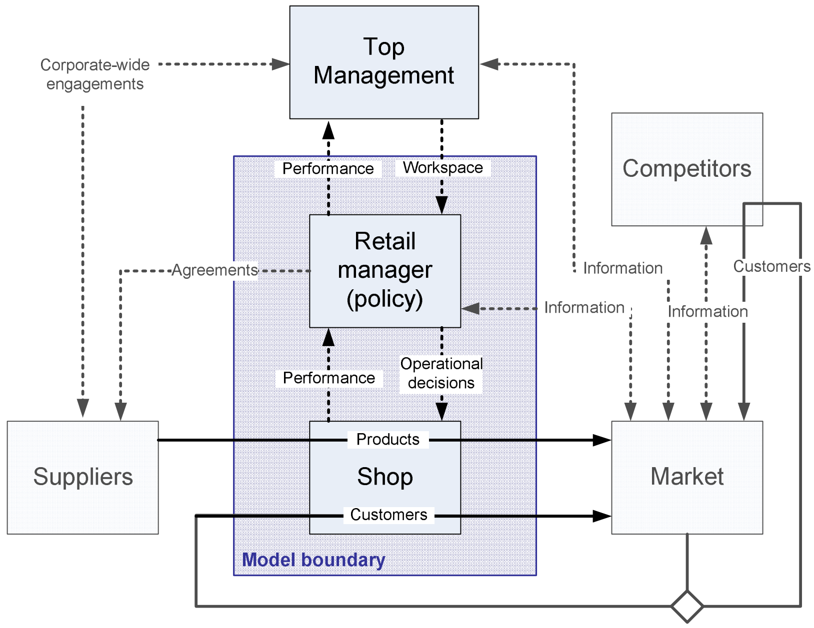

Figure 4: Determining game scope for retail game (Holkenborg 2009).

In principle the above criterions are also valid for the conceptual model of a serious game. However, subtle differences may be in explaining their definitions. Whereas the notion of accuracy (validity, credibility) in system analysis starts from the existing or foreseen system, in serious gaming accuracy may (also) be subject to the underlying pedagogic purposes, see Sections 4.1, 4.2. An important facet of accuracy may be "realism", i.e., the extent to which game users perceive the simulation to be reflective of life situations. Adobor and Daneshfar (2006) show how this may positively influence player learning.

For simulation and gaming utility should be linked to the player learning needs and game leader requirements. An important moderator of utility may be the "simplicity of model use". Ease of use would include (a) ease of understanding how to play the game, (b) ease of understanding the results returned, and (c) ease of determining what is needed to improve performance (Faria et al., 2009). Adobor and Daneshfar (2006) demonstrated that ease of use by the participants positively affected learning in the simulation.

Simulation models for gaming purposes are typically re-used to facilitate distinct groups of players (Section 2). Re-usability should therefore be added to the above list of requirements. Here re-usability may refer to "a perception, on behalf of the modeller and the clients, that the conceptual model adequately addresses learning needs for target groups of players". Remark, how this definition stresses model contents rather than modelling efficiency – in terms of efforts to be put in building/adapting the coded model model. We associate this "technical" notion with feasibility.

Case example: training assembly line operators
Simplicity of use as explained above is of high relevance for the game utility. Here simplicity is related to an insightful visualization of the shop floor (identifying operators, stations, and operations), ease of making decisions ("dragging" operators to stations), and the on line display of relevant model outputs.

Case example: educating retail managers
The pilot game provoked an interesting discussion on the realism of the game among the players. Some players argued that more factors should be included in the game. Others argued that this may hinder transparency of the game outcomes, and validity of the game – as the inclusion of new factors may imply

a shift of field being addressed. The discussion made clear how realism is an issue to be addressed, and should be carefully linked to a clear definition of the pedagogic purposes of the game.

6 CONCLUDING REMARKS

In this article we consider the alternative demands game use of simulation sets for model set up and application. Basically, the use of simulation models for serious gaming instead of system analysis, implies a shift with respect to:

- Modelling objectives: the model is meant to support learning instead of analysis.
- Users: players and game leaders are added to analyst and other stakeholders.
- Interaction: on-line user interaction with the model is intrinsic to game runs.
- Model re-use: games are typically used to serve distinct groups of players.

We highlight the impact of this shift in simulation model use by linking game elements to conceptual modelling activities. We do so starting from the existing modelling framework of Robinson (2008b). As a net effect of our efforts an adapted framework is defined, which is tailored to the use of simulation models for seroius gaming. The framework is illustrated by two case examples, addressing serious gaming for training and educational purposes.

Apart from its direct contribution to simulation and gaming, the development of the new framework, stresses the relevance of more research into conceptual modelling – which is still very much in his infancy. This is true even in case of classic simulation approaches (Robinson et al. 2010). Building simulation methodology in this respect also helps to disclose other high potential uses of simulation – as is attempted to illustrate by this paper.

ACKNOWLEDGEMENTS

The authors like to thank Cees Boon for his project involvement, and Stewart Robinson for his helpful comments.

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