Proceedings of the 2014 Winter Simulation Conference
A. Tolk, S. Y. Diallo, I. O. Ryzhov, L. Yilmaz, S. Buckley, and J. A. Miller, eds.

TOWARDS A CONCEPTUAL MODEL AND FRAMEWORK FOR MANAGEMENT GAMES

Oana Nicolae
Gerd Wagner

Brandenburg University of Technology
Institute of Informatics
P. O. Box 101344
03013 Cottbus, GERMANY

ABSTRACT

Management games have a long history in management and social science education, and a large number of such games has been developed and is being used in university education and in professional training. With the increasing use of computers in recent decades, most of them have been developed in computerized form. However, typically, these games are being developed in isolation, without (re-)using any general model, or methodology, or simulation engineering framework. In this paper we propose a basic conceptual model for business management games based on the classical *Lemonade Stand Game* and we show how to construct incremental extensions of this model and how to implement them as web-based simulations using standard web technologies.

1 INTRODUCTION

According to (Keys and Wolfe 1990), management games became popular in the late 1950s due to the combined impact of success stories about applying war gaming and operations research techniques in World War II and new developments in education theory and computer technology.

We use a general development approach for simulation games that has been proposed in (Wagner 2013). According to this approach, a simulation game can be obtained according to the following symbolic equation:

simulation game = participatory simulation model + gaming motivation

where a *participatory simulation model* can be obtained by extending a multi-agent simulation (MAS) model by adding a *participation model* and an *agent control user interface* according to the following symbolic equation:

participatory simulation model = MAS model + participation model + agent control UI

with the following symbolic equation for defining an *agent control user interface*:

agent control UI = output panels + user action forms + user action event listeners

This approach suggests that a game can be developed incrementally by first defining a multi-agent simulation model, then adding a participation model and an agent control UI, and finally adding motivational elements in the form of goals, tasks and rewards for the player.

In this paper we are only discussing the multi-agent simulation model that forms the main building block of the game, while the participation model, the agent control user interface, the gaming motivation and the game pedagogy will be discussed in a follow-up paper.

2 THE LEMONADE STAND GAME

The *Lemonade Stand Game* is a business management game that was developed in 1973 by Bob Jamison of the Minnesota Educational Computing Consortium and was later ported to the Apple II platform in 1979 and distributed by Apple throughout the 1980s (Wikipedia:LS 2014). It simulates a monopoly market in the form of a lemonade stand selling lemonade made from lemons, sugar and ice cubes. An extended version of the game has been released in 2002 under the name "Lemonade Tycoon".

In the version we consider, each business day consists of the following process steps and phases:

1. The business day starts with
   a. making five planning decisions:
      i. decide about advertising options for attracting more customers
      ii. decide if and how the lemonade recipe is to be changed based on the weather forecast
      iii. estimate the customer demand and plan how many pitchers of lemonade is to be produced based on the weather forecast and previous sales experience,
      iv. plan the replenishment order quantities for paper cups, lemons, sugar and ice cubes based on the planned production quantity, the chosen recipe and the current inventory,
      v. plan the sales price for a cup of lemonade based on the weather forecast;
   b. and then placing replenishment orders for paper cups, lemons, sugar and ice cubes.
2. Some time later, the ordered paper cups, lemons, sugar and ice cubes are delivered, so the planned quantity of lemonade can be manufactured and the sales stand can be opened.
3. After the stand has been opened, customers pass by and order lemonade based on their price acceptance and on their customer satisfaction. As long as the produced lemonade is still available, customer orders are served.
4. When all lemonade has been sold, or at the end of the day, the lemonade stand is closed and the remaining lemonade and ice cubes as well as those lemons that are 3 days old are dumped, while the sugar and the paper cups are stored for being used on the next day.

The process defined by these steps can also be described visually in the form of a *Conceptual Process Model* using the *Business Process Modeling Notation (BPMN)*, as shown in Figure 1.

Although such a lemonade stand, as a business enterprise, is simple and can be operated by kids without any prior management training, the underlying business process is already non-trivial and contains several basic elements of management science, in particular: demand forecasting and production planning, product quality management, price planning, inventory management, and marketing. We can describe the process in a more generic manner such that it applies to a larger class of *single-product make-to-stock manufacturing enterprises* in the following way:

1. The business day starts with
   a. making five planning decisions:
      i. decide about advertising options for attracting more customers
      ii. consider to improve the product quality (e.g., by adapting its composition) based on current market conditions (such as changing customer preferences)
      iii. estimate the customer demand and plan the production quantity (in batches) based on current market conditions,
      iv. plan the replenishment order quantities based on the planned production quantity, the bill of materials and the current inventory,
      v. plan the product sales price based on current market conditions;
   b. and then placing replenishment orders with the input materials suppliers.
2. Some time later, the ordered input materials are delivered, the planned product quantity is manufactured and the sales office is opened.

3. During the sales office hours customer orders arrive. As long as there are still products in stock, customer orders are served.
4. At the end of the office hours, the expired product items and input items in stock are depreciated.

Notice that in the case of the Lemonade Stand Game, changing market conditions are modeled in the simple form of weather conditions, while such a simple model of market conditions is not available for a generic manufacturing company.

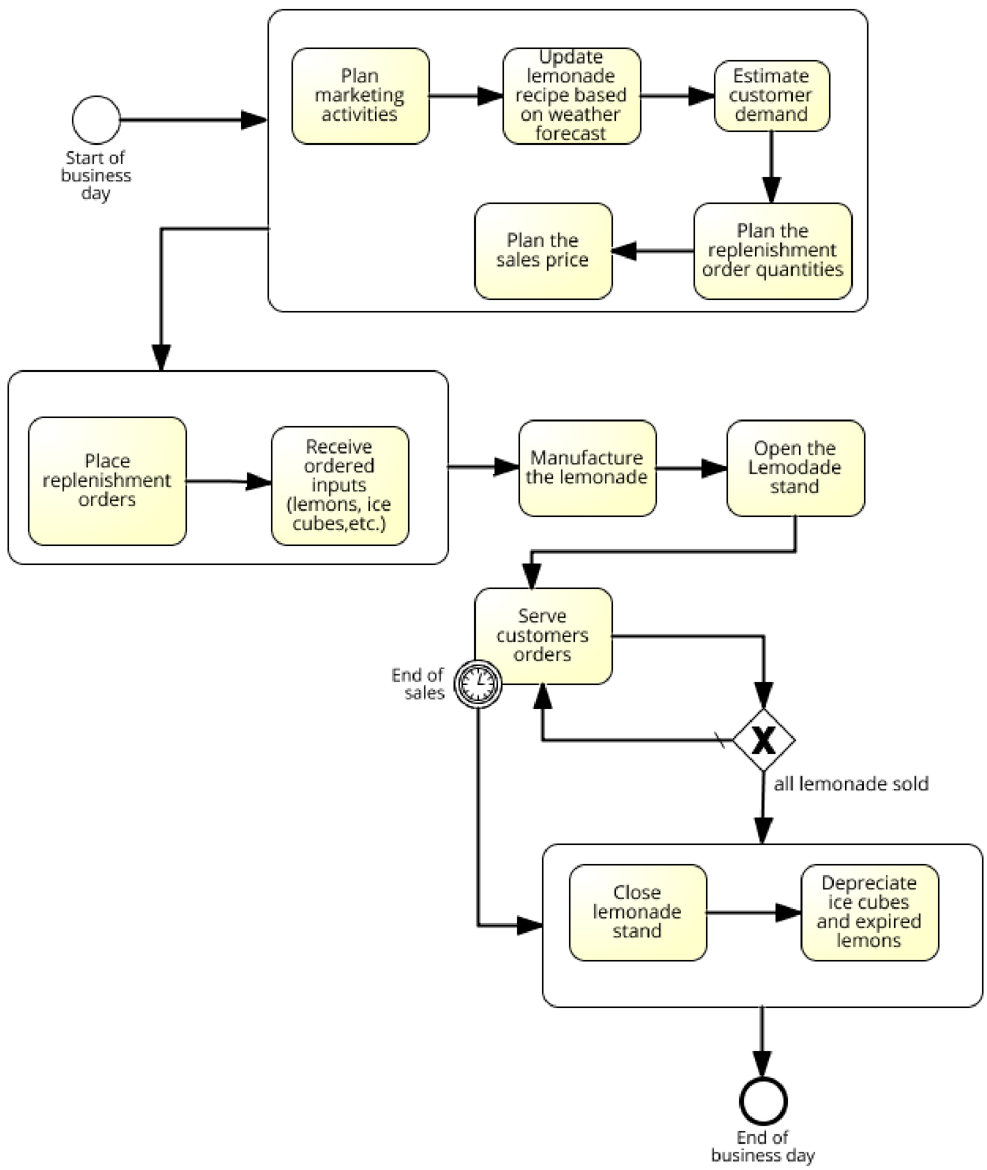

Figure 1: A conceptual process model of the Lemonade Stand Game

3 MANAGEMENT METHODS USED IN THE LEMONADE STAND GAME

3.1 Demand Forecasting Model

In the first LSG model we describe the micro behavior of a monopoly. A single lemonade stand represents the single business company on the market. Due to the uncompetitive behavior, it is difficult in a monopolistic competition to increase the firm budget on the long run. Therefore, in the last version of our simulation scenario we envision an oligopoly which comprises three sellers, aka the lemonade stands. We show that the demand curve it is influenced by the prices of the lemonade offered by the other lemonade stands, which represent perfect substitutes, in the sense that the demand curve is shifted to the right i.e. when the lemonade price from no matter which lemonade stand increases, the overall quantity demanded still increases.

3.1.1 Change in expected future price and demand

We further discuss the forecasted demand model or the estimated relationship between price and the quantity demanded. For estimating the customer demand curve, the method of simple moving averages is used (in the final version with exponential smoothing for capturing trends). Simple moving average is a well known method used in time series forecasting. It uses a certain number of consecutive, historical data points in order to compute a forecasting data point. The formula is the following:

$$\text{simple moving average} = \sum \text{values in previous } \mathbf{n} \text{ periods} \,/\, \mathbf{n}$$

In our particular case, the forecast of the daily demand is computed starting with the fourth day, based on the formula:

$$\text{estimated daily demand} = \sum \text{daily demands in the previous } \mathbf{3} \text{ days} \,/\, \mathbf{3}$$

A drawback of the simple moving average method is that it can be too sensitive when n is small, like in our situation. Moreover, the simple moving average method should only be employed when the data points are relatively stable over time, which is not the case in our scenario as the customer demand may vary greatly over time due to weather changes.

Therefore, a more suitable approach would consider the more recent data to have a greater weight on the forecast than the past data, such as in the *moving average with exponential smoothing* method:

$$\text{new forecast} = \text{last forecast} + \alpha * (\text{last period actual data} - \text{last forecast})$$

where α is a smoothing constant with $0 < \alpha < 1$, and initially the last period actual data is equal to last forecast. The closer the smoothing constant α gets to 1, the more weight is given to the recent demands. In the considered scenario we restrict the smoothing constant interval to [0.05, 0.5] and considerate the $\alpha = 0.5$.

3.1.2 Change in population or consumers preferences

The factors which influence the demand curve are: (1) the price expectations for the lemonade, (2) the increase in the population of consumers, and (3) the consumers preferences. We suppose the consumers income constant and therefore the afferent budget for buying lemonade will fluctuate in the same pre-defined interval, keeping the demand curve constant.

3.2 Production Planning

The production quantity is planned based on the demand forecast. In order to avoid the risk of getting bankrupt in case of unexpected depreciation due to unfavorable market conditions (e.g. caused by unfavorable weather conditions), not all available cash is invested in production. As shown in the previous section, the planned production is determined using the moving average method. Still, the simulation is taking into consideration an upper limit of the planned production quantity, which represents the maximum quantity that can be bought by investing the maximum daily percent ratio (= 80%) from the available amount of cash.

For materials such as lemons and sugar, the maximum production quantity is computed so that its volume is not exceeding the available quantity in stock divided by the input quantities per batch e.g.

maximum production quantity <= quantity in stock / input quantities per batch

while in case of the ice cubes and paper bags, the formula is the following:

maximum production quantity <= quantity in stock / input quantities per supply unit * product batch size

The purchase cost is computed every day, by taking into account all needed materials e.g. lemons, sugar, ice cubes and paper cups, as shown in the following formula:

purchase cost = Σ material quantity to be bought * material purchase price + transaction cost per order

The maximum production quantity is computed so that the purchase cost is not using more than the 80% from the available amount of money.

3.3 Replenishment Planning

We take a simple approach where:

replenishment order quantity = reorderUpToLevel – quantity in stock,

where

reorderUpToLevel = reorderPeriod (in days) * expected daily production quantity.

We want to determine the optimal number of units to order so that we minimize the total cost associated with the purchase, delivery and storage of the product. The required parameters to the solution are the total demand for the year, the purchase cost for each item, the fixed cost to place the order and the storage cost for each item per year.

3.4 Product Sales Price Planning

Finding the right pricing strategy is an important element in running a successful business. The price can be set to maximize profitability for each unit sold or from the market overall. It can be used to defend an existing market from new entrants, to increase market share within a market or to enter a new market. Businesses may benefit from lowering or raising prices, depending on the needs and behaviors of customers and clients in the particular market (Wikipedia:Pri 2014).

In most cases price planning is based on full product costs, which are computed as fixed cost (e.g., depreciation on assets, marketing costs) plus variable costs (e.g., input materials and labor).

One of the simplest and most common strategies is ***cost-plus pricing***, where a company first determines the break-even price as being equal to the product cost c (based either on full cost or marginal cost) and plans a profit rate r, such that the cost-plus price is obtained as $p = c * (1+r)$. During favorable market conditions, full costs would be used for cost-plus pricing, while during periods of poor sales, marginal costs may be used.

Another method of adaptive cost-plus pricing in a dynamic market would be to adapt the profit rate when the *Price Elasticity of Demand (PED)* is changing. This method can be used by the lemonade stand when the weather conditions are sunny and warm, because under such conditions the otherwise quite elastic demand for lemonade gets more inelastic, thus allowing for price increases without affecting the demand.

The PED is a measure used to show the responsiveness, or elasticity, of the quantity demanded of a good or service to a change in its price. More precisely, it gives the percentage change in quantity demanded in response to a one percent change in price (ceteris paribus, i.e. holding constant all the other determinants of demand, such as income). In general, the demand for a good is said to be *inelastic* when the PED is less than one (in absolute value): that is, changes in price have a relatively small effect on the quantity of the good demanded. The demand for a good is said to be elastic when its PED is greater than one (in absolute value): that is, changes in price have a relatively large effect on the quantity of a good demanded (Wikipedia:PED 2014).

4 BASIC MODEL OF A SINGLE MANUFACTURING COMPANY

In the basic version of our *Simple Manufacturing Company* (SMC) model we do not model

- customers and suppliers; instead of individual customer orders, we model only an aggregated demand; instead of considering individual suppliers, we model an aggregated replenishment order, which is always carried out;
- any marketing activities (e.g. advertising),
- market conditions and their forecasting (in the case of LSG, market conditions are largely determined by weather conditions),
- deliveries with delivery dates for determining the age and depreciation of specific input materials (such as lemons),
- competition by other companies.

So, we get the following basic version of the generic process of a simple *single-product make-to-stock manufacturing enterprise*:

1. The business day starts with
    a. making three planning decisions:
        i. estimate the customer demand based on previous sales experience (using the moving average method) and plan how many product batches are to be produced,
        ii. plan the replenishment order quantities for all input materials (using a periodic replenishment policy) based on the planned production quantity, the fixed bill of materials and the current inventory,
        iii. compute the sales price for a product unit using a full-cost-plus formula with a fixed profit rate
    b. and then placing replenishment orders for all input materials.
2. Some time later, the ordered input materials are delivered, so the planned production quantity can be manufactured and the sales office can be opened.
3. During the sales office hours, a bulk order representing the aggregated customer demand arrives. As long as products are still in stock, this bulk order is processed either fully or partially.
4. When all products have been sold, or at the end of the day, the sales office is closed and the remaining products, if they are perishable, as well as all expired input items on stock, are dumped and depreciated, while all other items are kept for being used on the next day.

This process corresponds to the conceptual information model shown in Figure 2 below. An implementation of this basic model is available as a web-based simulation from the Simurena online library under http://alpha.simulario.com/public/194/.

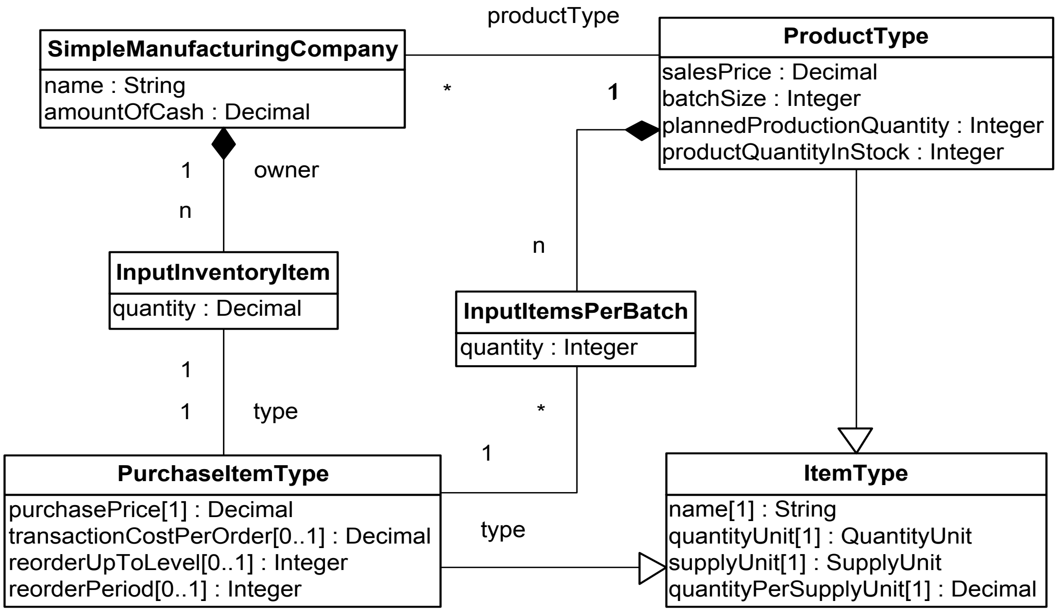

Figure 2: A basic conceptual information model of a manufacturing company

5 EXTENDED MODEL OF A SINGLE MANUFACTURING COMPANY

In the second version of our SMC model we do still not model

- suppliers: instead of considering individual suppliers, we model only one aggregated replenishment order, which is always carried out;
- any marketing activities (e.g. advertising);
- competition by other companies.

So, in the second version of our model, each day consists of the following process steps and phases:

1. The business day starts with
    a. making four planning decisions:
        i. consider to improve the product quality (e.g., by adapting its composition) based on current market conditions (such as changing customer preferences)
        ii. estimate the customer demand and plan the production quantity (in batches) based on current market conditions,
        iii. plan the replenishment order quantities based on the planned production quantity, the bill of materials and the current inventory,
        iv. plan the product sales price based on current market conditions;
    b. and then placing replenishment orders with the input materials suppliers.
2. Some time later, the ordered input materials are delivered, the planned product quantity is manufactured and the sales office is opened.
3. During the sales office hours individual customer orders arrive. As long as there are still products in stock, customer orders are served.
4. At the end of the office hours, the expired product items and input items in stock are depreciated.

Extending the conceptual information model of Figure 2 by adding a model of deliveries and the expiration of items results in the model shown in Figure 3 below.

An implementation of this extended model is available as a web-based simulation from the Simurena online library under http://alpha.simulario.com/public/195/.

5.1 Modeling Customer Behavior

Customer behavior can be modeled in terms of the maximally accepted price, the preferred recipe and customer satisfaction. Both the maximally accepted price and the preferred recipe depend on the weather conditions and the air temperature, while customer satisfaction depends on the ratio between perceived product quality and price. When a customer does not yet have any experience with vendors, she normally chooses the vendor based only on a lower price.

After consuming lemonade bought from a vendor, the customer evaluates the lemonade quality by comparing the vendor's recipe with her preferred recipe and measuring the distance between them. The customer motivation to drink lemonade is influenced by the air temperature and so is the formula of the customer expected lemonade recipe i.e. the higher temperature is, the colder the lemonade is expected to be. But the temperature is not directly influencing the consumer satisfaction which is depending on the production planning i.e. after consuming the lemonade the customer is evaluating the composition of the lemonade versus the expected lemonade recipe.

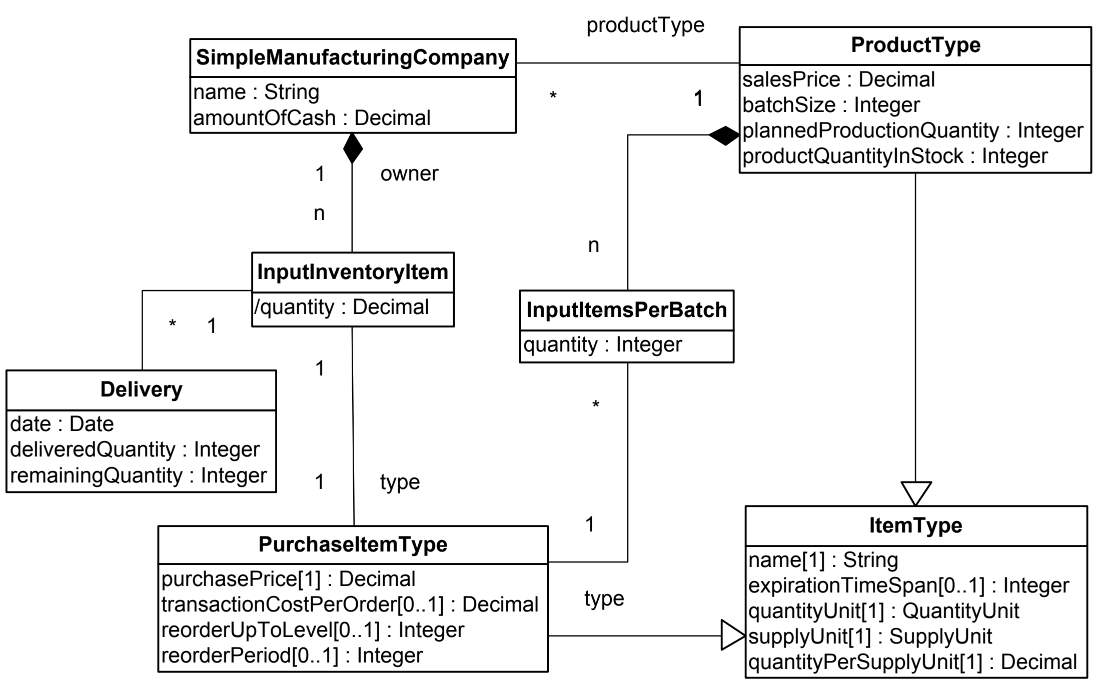

Figure 3: A conceptual model of a manufacturing company with deliveries and expiration of items

5.2 Modeling the Weather-Dependency of the Lemonade Market

The influence of the weather on the lemonade market is modeled with two factors: the average temperature and the weather conditions. The latter are modeled as a set of five different states of affairs with an associated percentage of the people living in the area passing by the lemonade stand, as shown in Table 1:

Table 1: State of affairs with associated percentages

Weather conditions	1	2	3	4	5
	sunny	partly cloudy without rain	cloudy without rain	cloudy with some rain	cloudy with lots of rain
Potential customers	100%	90%	75%	60%	30%

Table 2: Weather forecast and corresponding realized weather

Weather forecast	sunny	partly cloudy without rain	cloudy without rain	cloudy with low rain probability	cloudy with high rain probability
Realized weather conditions	1: 75%, 2: 25%	1: 25%, 2: 50%, 3: 25%	2: 25%, 3: 50%, 4: 25%	3: 25%, 4: 50%, 5: 25%	4: 25%, 5: 75%

On the start of the day, when all planning decisions have to be made, the lemonade stand knows only the weather forecast for the day, which bears some uncertainty. The weather forecast may be: sunny, partly cloudy without rain, cloudy without rain, cloudy with low rain probability and cloudy with high rain probability. It translates into realized weather conditions according to Table 2 displayed above.

The daily demand per person is modeled as a function of the average air temperature as shown in Table 3:

Table 3: Daily demand as a function of average air temperature

Average temperature	> 30	20-30	10-20	0-10
Consumption probability	95%	85%	70%	50%

Also the customer preferences concerning the number of ice cubes to be added to the lemonade (determining its temperature) depends on the air temperature. This means that the warmer it is the more ice cubes have to be added to a cup of lemonade.

6 A MODEL OF A COMPETITIVE MANUFACTURING PRODUCT MARKET

In the third version of our *Simple Manufacturing Company* (SMC) model we do still not model suppliers: instead of considering individual suppliers, we model only one aggregated replenishment order, which is always carried out. In this version, we get the process that is described in the second section of the paper. The market is an oligopoly consisting of three lemonade stands, each of them offering lemonade at a different price. The lemonade stands compete through marketing activities such as advertising the lemonade price.

The lemonade stands do not know the sales prices of their competitors, and therefore their sales price planning is not directly influenced by the prices of the other lemonade stands. But a certain price pressure is created by the competition for customer orders. An implementation of this final model is available as a web-based simulation from the Simurena online library under http://alpha.simulario.com/public/196/.

The customers are modeled in such way that they may have a preferred lemonade stand from where they buy the lemonade. Consequently, a customer will always try first to buy the lemonade from the preferred lemonade stand, if the price is acceptable for her. If the the lemonade price is higher than the customer is willing to pay, she will not buy the lemonade, but she will choose another lemonade stand with a lower price. The customer maintains a list with all prices announced by the lemonade stands.

After buying and consuming lemonade, the customer takes a decision if she is satisfied with its quality or not. If the customer is satisfied with the lemonade quality, she will memorize the lemonade stand as her preferred one for the next day. Otherwise, she will again choose the lemonade stand that sells lemonade at the minimum price.

7 RELATED WORK

Cohen et al (1961) provide a survey on educational management games discussing the relevance of management games for education and research, and the factors that influence their development. The paper predicts the possibility to incorporate a strikingly high degree of realism in the management games, which may eventually boost the educational and learning capabilities of these games.

Giannakos (2013) conducts experiments for proving the learning value of educational games and observes that games demonstrate good performance as compared with traditional instruction. Baptista et al (2014) present an example of a management game similar to the lemonade stand game, in a form of a multi-agent business simulation, and argue for the relevant role of multi-agent simulation for enhancing the learning process with business simulations. Also Cleophas (2012) proposes to use multi-agent simulations for educational management games.

There is not much research on using the lemonade stand game as a concept for general management gaming. In Noy et al (2006), the lemonade stand game has been used as a research tool for investigating the subjective value of information. A management game in the style of the lemonade stand game has been used in Barzilai and Blau (2014) for investigating the impact of scaffolding game-based learning.

Neef et al (2011) identify a set of relevant requirements that an educational business simulation must conform with, and propose a general architectural design for developing business simulation games. According to their proposal, the lemonade stand game qualifies as an educational business simulation game, since its game-play can be mapped to basic business activities such as: acquisition, production, management and control. Moreover, the lemonade stand game instantiates their proposed architecture by complying with all requirements: iterates the simulation process during a number of business days, provides a scoring manager and a feedback based on customer satisfaction and the number of satisfied customers, manages the simulation events and the business activities, simulates the consequences of actions based on the employed economical models, manages the interaction with the player, manages the player experience in forecasting the demand and adjusting the price and the formula of the lemonade.

8 CONCLUSIONS

Although the lemonade stand game is quite simple, the underlying simulation model is non-trivial and contains several elements of management science that can be used for educational purposes. We have developed a conceptual model that allows to design and to implement various extensions of the lemonade stand game for simulating various types of single-product make-to-stock manufacturing companies.

REFERENCES

Baptista, M., Roque M., A. Santos, P. and Prendinger, Helmut. 2014. "Improving Learning in Business Simulations with an Agent-Based Approach." *Journal of Artificial Societies and Social Simulation,* Vol. 17, No. 3, July 2014.

Barzilai, S. and Ina Blau. 2014. "Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences." *Computers & Education,* Vol. 70, pp. 65-79.

Cleophas C., 2012. "Designing serious games for revenue management training and strategy development." In *Proceedings of the 2012 Winter Simulation Conference*, edited by C. Laroque, J.

Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, 1-12. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Cohen, K., J. and Rhenman E. 1961. "The Role of Management Games in Education and Research." *Management Science*, Vol. 7, No. 2 (Jan. 1961), pp. 131-166.

Giannakos, M., N., 2013. "Enjoy and Learn with educational games: examining factors affecting learning performance." *Journal of Computers and Education*, Vol. 68, pp. 429-439.

Neef, A., Maciuszek, D., and Martens, Alke. 2011. "Mapping business simulation games to a component architecture." In *Proceedings of the 2011 11th IEEE International Conference on Advanced Learning Technologies* (ICALT 2011), edited by J. Michael Spector und Kinshuk, 366-368.

Noy, A., Daphne R. Raban and Gilad Ravid. 2006. "Testing social theories in computer-mediated communication through gaming and simulation." *Simulation & Gaming*, Vol. 37 No. 2, June 2006 174-194.

Keys, B. and Joseph Wolfe. 1990. "The Role of Management Games and Simulations in Education and Research." *Journal of Management*, Vol. 16 No. 2, 307-336.

Wagner, G. 2013. "Exploratory and Participatory Simulation." In *Proceedings of the 2013 Winter Simulation Conference*, edited by R. Pasupathy, S.-H. Kim, A. Tolk, R. Hill, and M. E. Kuhl, 1327−1334. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Wikipedia:LS. 2014. "Lemonade Stand". accessed May 22, 2014. http://en.wikipedia.org/wiki/Lemonade_Stand

Wikipedia:Pri. 2014. "Pricing." accessed May 22, 2014. http://en.wikipedia.org/wiki/Pricing

Wikipedia:PED. 2014. Price elasticity of demand. Accessed May 22, 2014. http://en.wikipedia.org/wiki/Lemonade_Stand.

AUTHOR BIOGRAPHIES

OANA NICOLAE is currently a PhD student and an academic staff member within the Department of Informatics, Brandenburg University of Technology, Germany. Her research interests comprise: Modeling and Simulation of Business Processes inside of Organizations, Conceptual Modeling with UML and BPMN. Her email address is oana.nicolae@b-tu.de.

GERD WAGNER is Professor of Internet Technology at Brandenburg University of Technology, Germany. His research interests include (agent-based) modeling and simulation, foundational ontologies, knowledge representation and web engineering. His email address is G.Wagner@b-tu.de.