Demand function and its role in a business simulator

Vymetal, Dominik and Ježek, Filip

Silesian Univerzity in Opava, School of Business Administration in Karviná

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Dominik Vymětal, Filip Ježek
Silesian University in Opava, School of Business Administration in Karviná, Czech Republic
vymetal@opf.slu.cz, jezek@opf.slu.cz

Abstract

Business simulations are useful tools due to the fact that it eases management decision making. No doubt there are many processes which must be considered and simulated. Therefore, such business simulator is often composed of many processes and contains many agents and interrelations as well. Since the business simulator based on multi-agent system is characterized by many interrelations within, this article deals with a specific part of the business simulator only – a demand function and its modeling. The aim of this partial research is to suggest demand function which would be most suitable for the business simulation. In this paper a new approach for customer decision function in business process simulation was presented. The decision of the customer is based on Marshallian demand function and customer utility function using Cobb-Douglas preferences. The results obtained by means of the MAREA simulation environment proved that this approach yields correct simulation results.

Keywords: business simulator, multi-agent system, demand function, MAREA

JEL: C63, C88, D40

Introduction

Currently there are many business transactions all over the world. Recently, the number of domestic and international business transactions increased rapidly. But economy openness, globalization, minimizing price and simultaneously maximizing product quality and other trends lead to a keen competition. In order to sustain the competition management has to take the best decisions as possible. Unsurprisingly the situations in which management has no relevant data to support the decision are not rare. And just here may help sophisticated business simulation which operates with randomly generated parameters. One of the approaches how to support management decisions is Agent Based Modeling and Simulations (ABMS). In our recent works (e.g. Vymětal, Spišák and Šperka, 2012, Vymětal and Šperka, 2011) we presented simulation experiments with a generic business company model. In such model following agents are assumed: customers, sales representatives, purchase representatives, vendors and company management. One of the core functions of a business company is its trading function. The trading function is simulated by means of sales requests, price negotiations and sales orders. Hence, the customer decision whether accept sales quote or decline the proposal has to be modeled.

From our point of view, there are two possible approaches to model the customer decision. The first one is based on the company point of view and market balance of the product quoted by the sales representative. (See e.g. ibid) The other perspective is the customer point of view. For this perspective another approach is needed, namely the customer demand based on the utility gained by the purchase of the product. This utility can be derived from the customer preferences.

The motivation of our research is to derive customer decision function based on the microeconomic theory of utility and to build it in the simulation model. The paper is structured as follows. First, the related work in demand function domain is briefly described. Then the derivation of the decision function is presented. In the next section the MAREA simulation environment is shortly presented and excerpts from the simulation model are shown with a presentation of the modeled company outputs in MAREA simulation environment. In conclusion we present some discussion on the results and further research steps.

Related work

Speaking of demand function economists usually assume utility must be taken into account. According to the economic theory, the maximizing utility is considered to be the main aim of each consumer, no matter if we are talking about cardinalistic or ordinalistic approach.

Zaratiegui (2002) mentioned the demand function was firstly derived from and utility function by well-known L. Walras (1966) and the utility function was under a budgetary restriction maximized. Original analysis of demand function by A. Marshall (1920) shows that the utility function is not the same but varies. The variety of utility function is a result of consumer preferences. In contrast the modern theory considers that the demand function depends not only on consumer’s preferences but income (respectively budget) and prices as well.

Barnett and Serletis (2008) claim the demand is affected by many other (non-income) variables such as demographic variables, welfare comparisons or aggregation across consumer and distinguish between several approaches to the demand issue:

- Demand system without direct reference to the utility function – it is expressed in a budgetary form and can be used especially in case of low price variation and less income variation, otherwise the system must be extended.
- Neoclassical consumer theory – demand system is expressed in a budgetary form and the approach either works with utility function that predetermines the demand system (maximizing demanded quantity – Marshallian demands) or with expenditures (minimizing the costs which must be paid to obtain a particular level of utility – Hicksian demands).
- Specific demand systems – are used especially in order to estimate income or price elasticities.
- Demand systems based on Engel curves - are used in order to estimate income elasticity and compare welfare across households which contributes to the discussion concerning income inequalities and behavior of various income groups.

Huang et al (2011) adds that there are also some other factors which enter demand models and provide a survey of the demand models which contain price factors, rebate, delivery lead time, space allocation decision, product quality and advertising. The survey shows that in spite of the fact that the specific literature deals with all the factors, there are many issues which are challenge for further research. The similar statement can be found in work of Gold and Pray (1984). Authors analyzed the non-price factors of demand which are modeled in computer business simulations and concluded the most demand functions in the models are not flexible enough. In addition to this, Soon () noticed that pricing models, which are most commonly used, deal with only single product while multi-product pricing models are very rare. Krishnan (2010) points out that modeling demand function with uncertainty can be even more complicated and it causes troubles when analyzing contracting practice and welfare.

In our business simulation we apply the neoclassical approach and implement the factor of advertising (respectively an ability of sales representatives).

Derivation of the decision function

For the derivation of the customer decision function following considerations have been taken use of:

- The customer tries to reach the highest utility with a sum of money at his disposal.

- The sum of money at customer's disposal represents his budget limit - *I* financial units allocated for the period of simulation.
- The customer tries to maximize his purchase utility using market basket (x_1, x_2). According to the utility reached with the purchase of the goods x_1 he adjusts his demand for the goods x_1 and accepts or rejects the proposed price.
- We are using Marshallian demand function.

A generalized solution was presented in e.g. Barnet and Serletis (ibid). It is based on idea that consumer (respectively individuals or households) has to solve the problem of maximizing utility function subject to budgetary limitation:

$$max\, u\,(x_1 \dots x_n), subject\ to\ \sum_{i=1}^{n} p_i x_i = I \qquad (1)$$

where:

x = nx1 vector of products

p = vector of prices

I = total income of consumer

To express the customer preferences we use Cobb-Douglas utility function (see e.g. Voorneveld, 2008):

The Cobb-Douglas utility function has the following form:

$$u(x_1, x_2, \dots x_n) = x_1^{\alpha 1} * x_2^{\alpha 2} * \dots x_n^{\alpha n} \qquad (2)$$

There exist several methods of solution, such as preferred Lagrangian method or various methods of substitutions. However, all methods lead to the same final solution (see e.g. Varian, 1995, p. 92 – 95, or Barnet and Serletis, (ibid).

In this way we obtain Marshallian demand function:

$$x_i = \alpha_i \frac{I}{p_i}, i = 1 \dots n \qquad (3)$$

The Marshallian demand function can be used for our simulation purposes assuming following:

Firstly, any consumer has decisions based on budget limitations (denoted by I), preferences which are connected to each particular product (measured as market share of particular product) and price (consumer examines if the price which offers sales representative enables to obtain requested number of products with respect to preferences and budget limitations).

Secondly, the Cobb-Douglas preferences and utility function are taken into account and all products are normal (no substitutes or complements).

Thirdly, using the generalization and concept of composite products the formula of budget line can be expressed as follows:

$$P_x * x + Y = I \qquad (4)$$

Finally, using the neoclassical consumer theory and formula:

$$x = \frac{\alpha_1}{\alpha_1 + \alpha_2} * \frac{I}{Px} = \alpha * \frac{I}{Px} \qquad (5)$$

where α denotes market share of particular product.

As mentioned above, some other non-price variables shall be taken into account. In our case we use two variables – the ability of the sales representative to persuade the customer to buy (ρ) and the advertising factor (γ). The changed formula for customer decision is the expressed as

$$x = \alpha^* * \frac{I}{Px} \qquad (6)$$

where

$$\propto^* = \propto * \ \rho * \ \gamma \tag{7}$$

For simulation purposes formula (7) still needs some refinement.

First, the customer cannot use all his income for purchases. In this case he plans some *budget.* Simulation uses this budget in simulation steps. But there cannot be one budget for the whole simulation. Each customer has its own budget and after each purchase the budget has to be diminished. Hence, for simulation purpose, there has to be one *global budget* defined for all customers and this global budget has to be randomized for each customer in the initialization of the customer at the simulation start as follows:

$$m_i = random(\quad) * GB \tag{8}$$

where

m_i – budgeted the i-th customer

GB – global budget (global simulation parameter)

$random(\quad)$ - randomization function of the uniform distribution.

Second, the customer preference for the product - α differs from customer to customer. In this case we need to simulate

$$\alpha_i^* = random(\quad) * \alpha^* \tag{9}$$

where α_i^* - preferences of i-th customer.

These refinements yield final formula

$$x_i \quad = \alpha_i^* * \frac{m_i}{Px} \tag{10}$$

Table 1: Simulated outputs from formula 10

Product market share	Global budget	Quality of service	Competition		Price
0.15	100000	1	1		250

Customer	Randomization coefficient	Randomized customer budget	Calculated quantity	Randomization coefficient	Randomized market share	Calculated quantity
1	0.360545671	36055	22	0.160588397	0.02	3
2	0.299844356	29984	18	0.539780877	0.08	10
3	0.676747948	67675	41	0.168858913	0.03	7
4	0.37919248	37919	23	0.369914853	0.06	8
5	0.019989624	1999	1	0.837305826	0.13	1
6	0.610431227	61043	37	0.717307047	0.11	26
7	0.528580584	52858	32	0.249855037	0.04	8
8	0.521713919	52171	31	0.577379681	0.09	18
9	0.35175634	35176	21	0.990630818	0.15	21
10	0.776665548	77667	47	0.549302652	0.08	26

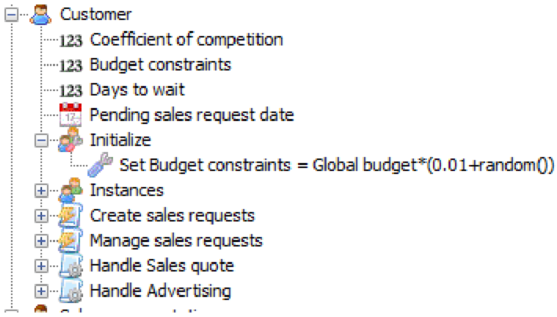
Table 1 provides simulated results from Formula 10. We can see that randomized parameters yield various differences in comparison with “static” parameters used in Formula 7 even if the other two parameters in Formula 10 were not randomized. This has important effects and bring challenges for further research.

In simulation, if quantity x_i < quantity demanded by customer, the customer realizes the quantity x_i is not high enough with respect to his preferences and budget. The proposed price and quantity is rejected by customer and the negotiation with sales representative starts. The sales representative proposes new price in the next simulation step. If the negotiation does not come to conclusion in defined period the sales request is revoked. In other words, the consumer decides not to buy anything and his turn is over. On the contrary, the condition x_i >= quantity demanded by customer], leads to meeting customer’s request and the sales order is generated. In this case the consumer budget is decreased by the value of this realized purchase.

Simulation environment.

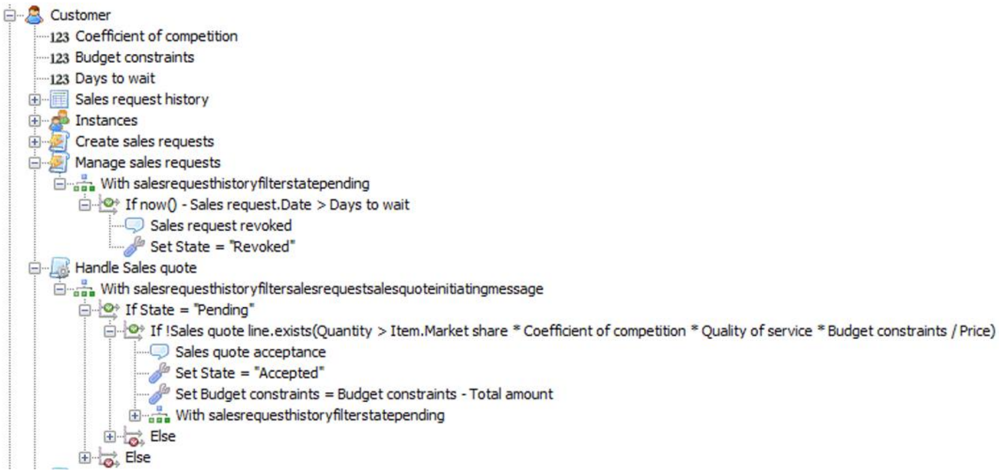
For our simulation we use the MAREA (Multi-Agent REA-Based) simulation environment presented in several papers such as e.g. (Vymětal and Schoeller, 2012, Šperka and Vymětal, 2013). The MAREA environment is based on a generic business company with the REA based ERP system for registration of business events and using multi-agent principle for the dynamic part of the simulation. The customer demand function is realized in the Customer agent script as follows:

- In Figure 1 the initialization function for the budget restriction is shown. The budget restriction is derived by means of randomization of the global budget – the simulation global parameter.
- In Figure 2 the decision condition of the customer based on the preference is presented. Here, first the state of pending sales request is tested and then the decision function is executed. In this function the variables Item.Market share, Coefficient of competition and Quality of service represent the terms of formula 10.



```
Customer
    123 Coefficient of competition
    123 Budget constraints
    123 Days to wait
    Pending sales request date
    Initialize
        Set Budget constraints = Global budget*(0.01+random())
    Instances
    Create sales requests
    Manage sales requests
    Handle Sales quote
    Handle Advertising
```

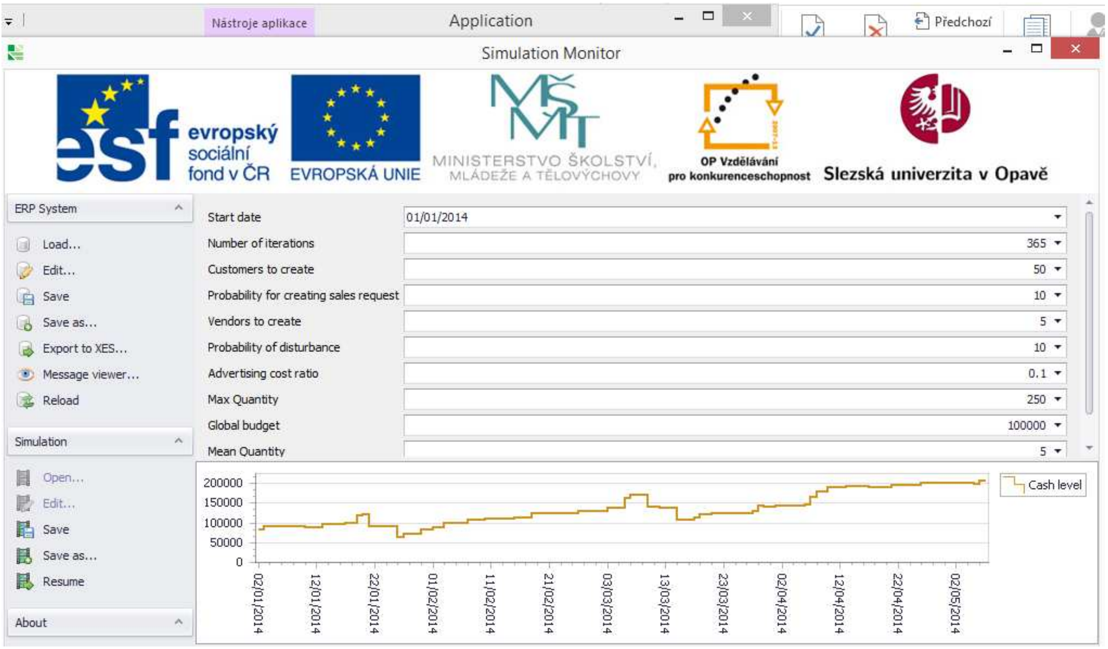
Figure 1: The customer initialization



```
Customer
    123 Coefficient of competition
    123 Budget constraints
    123 Days to wait
    Sales request history
    Instances
    Create sales requests
    Manage sales requests
        With salesrequesthistoryfilterstatepending
            If now() - Sales request.Date > Days to wait
                Sales request revoked
                Set State = "Revoked"
    Handle Sales quote
        With salesrequesthistoryfiltersalesrequestsalesquoteinitiatingmessage
            If State = "Pending"
                If !Sales quote line.exists(Quantity > Item.Market share * Coefficient of competition * Quality of service * Budget constraints / Price)
                    Sales quote acceptance
                    Set State = "Accepted"
                    Set Budget constraints = Budget constraints - Total amount
                    With salesrequesthistoryfilterstatepending
                Else
            Else
```

Figure 2: The customer decision function script

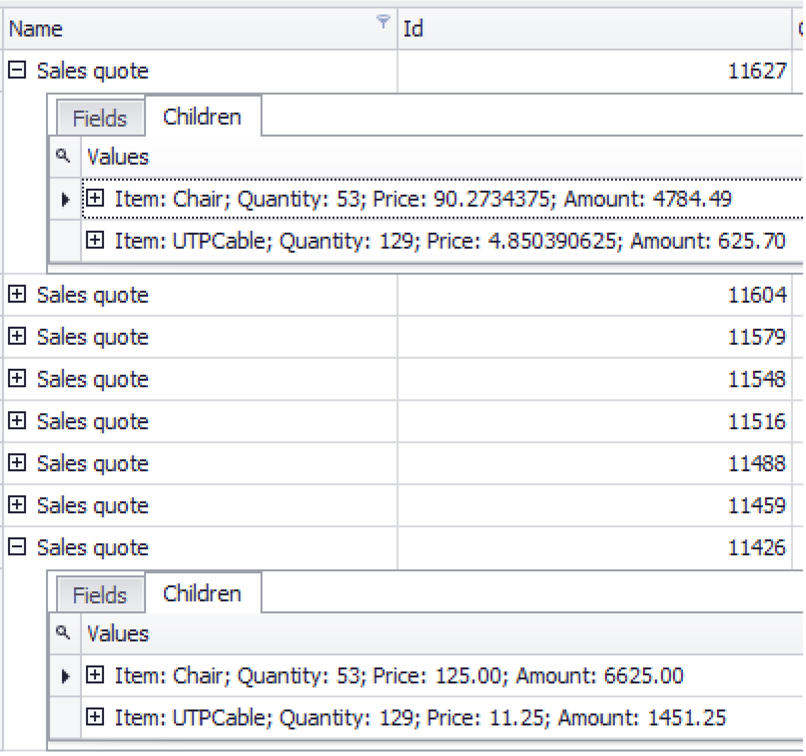
A typical run of the simulation is shown in Figure 3.



Start date: 01/01/2014
Number of iterations: 365
Customers to create: 50
Probability for creating sales request: 10
Vendors to create: 5
Probability of disturbance: 10
Advertising cost ratio: 0.1
Max Quantity: 250
Global budget: 100000
Mean Quantity: 5

Figure 3: Typical simulation run

Here, in the lower the cash flow of the company is shown during the simulation run of 365 steps (one year). The upper pane shows the simulation parameters. The left column shows the ERP system menu and the agent simulation editor tool.



Name	Id
⊟ Sales quote	11627
⊞ Item: Chair; Quantity: 53; Price: 90.2734375; Amount: 4784.49	
⊞ Item: UTPCable; Quantity: 129; Price: 4.850390625; Amount: 625.70	
⊞ Sales quote	11604
⊞ Sales quote	11579
⊞ Sales quote	11548
⊞ Sales quote	11516
⊞ Sales quote	11488
⊞ Sales quote	11459
⊟ Sales quote	11426
⊞ Item: Chair; Quantity: 53; Price: 125.00; Amount: 6625.00	
⊞ Item: UTPCable; Quantity: 129; Price: 11.25; Amount: 1451.25	

Figure 4: The process of customer decision and negotiation in MAREA simulation environment

The process of customer decision and following negotiation is shown in Figure 4. Here we can see the change of the originally proposed price (the lower part) down to the successful quote (the upper part).

In this sense, we have shown that the proposed decision function based on the customer preferences and demand function can be used for the company simulations.

Conclusion

In this paper a new approach for customer decision function in business process simulation was presented. The decision of the customer is based on Marshallian demand function and customer utility function using Cobb-Douglas preferences. The decision function was introduced as a new feature into MAREA simulation environment. The results show that such decision function, when appropriately introduced in simulation can help to improve customer decision support by means of multi-agent simulation tools. The proposed approach will now be subject of further research. First, the customer preferences will be studied more in detail in order to improve the flexibility of the model taking "dynamic" properties of decision formula terms in consideration. Second, similar decision function will be prepared and realized on the company purchase side.

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