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Applying the agent-based modeling technique to business games

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Resumo

Um jogo de negócio pode ser definido numa frase como um jogo que simula uma indústria competitiva em que os participantes controlam empresas num ambiente controlado. O jogo de negócio é um tipo particular de jogo que foi criado em resposta à necessidade de existência de ambientes virtuais onde os participantes pudessem ser expostos a variados desafios de gestão presentes no mundo real.

O objectivo principal de um jogo de negócio consiste na simulação o mais próxima possível da realidade como forma de garantir a eficácia dos processos de aprendizagem que daí decorrem. Estudos experimentais constantaram no entanto que os jogos de negócio são percepcionados como pouco realistas e dificeis de compreender. Este estudo propôs-se assim a resolver estes dois problemas intrinsecamente relacionados.

Este estudo apresenta um novo modelo de jogo de negócio usando a técnica de modelação por agentes para simular o comportamento dos consumidores finais. O modelo baseou-se em teoria económica clássica, na teoria do comportamento de Hull e nalguns conceitos de inteligência artificial.

Foi desenvolvido em parelo com o modelo conceptual um jogo de negócio. O jogo tinha como principal objectivo apresentar informação adicional aos participantes de forma a contribuir para uma melhor compreensão das relações de causa e efeito subjacentes ao modelo.

O modelo desenvolvido usando a abordagem por agentes originou comportamento emergente que ia de encontro ao comportamento esperado de um modelo deste tipo. Para além disso, o modelo permitiu maior flexibilidade e resolveu alguns dos dilemas não resolvidos dos modelos anteriores. Os resultados experimentais demonstraram também que o modelo por agentes, comparado com modelos anteriores, podia disponibilizar informação adicional como forma de melhorar a compreensão dos participantes do jogo de negócio.

Palavras-chave: Jogo de negócio, realismo, transparência, modelação por agentes, modelo de procura, modelo de comportamento do consumidor

Abstract

A simple definition for a business game is that it is a game which simulates a competitive industry where participants manage business firms. Business games continue to be neither perceived as realistic nor understandable. This essay proposes the application of agent-based modeling to help solve these two correlated problems.

This study presents an agent-based model of consumer behavior for business games whose inter-disciplinary foundations were drawn from the neoclassical theory of choice, Hull's drive theory and artificial intelligence. In parallel with the development of the model a business game was developed. The game intended to provide additional informative elements which could enhance the understanding of the participants, thus creating a transparent business game.

In terms of theoretical results, the agent-based model developed in this study originated an emergent behavior similar to the one expected from standard models. Moreover the agent-based model provided additional flexibility and solved some of the dilemmas presented by standard models. The results of the experiments provided some evidence to sustain the hypothesis that an agent-based model can provide additional information enhancing the understanding of the participants.

Keywords: Business game, realism, transparency, agent-based approach, demand model, neoclassical theory of choice, drive theory.

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Chapter 1

Introduction

> *"Business is a game, the greatest game in the world, if you know how to play it."*
> Thomas Watson

A simple definition for a *business game* is that it is a game which simulates a competitive industry where participants manage business firms (Summers 2004). Business games were created in response to the need of virtual environments, where managers or aspiring managers, could be exposed to many of the challenges present in the real-world. The purpose of such games was to provide an accurate replication of the real-world so that training and teaching processes could be developed.

This chapter provides an introduction to business games, the problem domain of this study. To clarify any ambiguity concerning the terminology, section 1.1 describes the terminology used. The following section describes briefly the historical context of business games − the intent is to provide the reader with an insight into the evolution of business games throughout history. Prior to the presentation of the main problem of the study, section 1.3 analyzes in detail the structural elements of a computerized business game.

The main problem of this study is introduced in section 1.4 − the black-box nature of business games and the negative impact this fact has had upon the experience of participants and game sophistication is discussed. To conclude, section 1.5 presents the proposal of applying the agent-based modeling technique to solve the problem and provides an overall view of the structure of the essay.

1.1 Terminology

The development of business games has taken place in a number of widely distinct research areas such as business administration theory, mathematics and game design. Generally, these areas have been far enough from one another for little contact to be made between them. As Shiratori et al. (2005, pg. 4) put it: "the present situation is this: i know what i am researching, but i do not know anything about what others are researching".

Over the years, each research area developed its own terminology, according to its needs, which led to the existence of a large collection of overlapping, sometimes distinct, jargon terms. As a result, terminology has been pointed as a major problem of the field of business games (see Wolfe 2004, Maier and Groessler 2000). This section provides a clarification of the terms used in this essay.

Among the terms with fewer consensus in the area of business games, is the designation of the game genre itself. Maier and Groessler (2000) explained how the marketing campaigns of business games contributed to the confusion surrounding the designation of these games, since advertisers preferred to promote the most captivating terms instead of the most accurate genre designations. A myriad of terms, sometimes awkward, have been used, such as, for instance, *management simulator*, *business simulation game*, *microworld* and *flight management simulator*. In this study, the term *business game* was the preferred designation for the games studied. The explanation of such choice is detailed next (for an overview of the referred concepts see Figure 1.1).

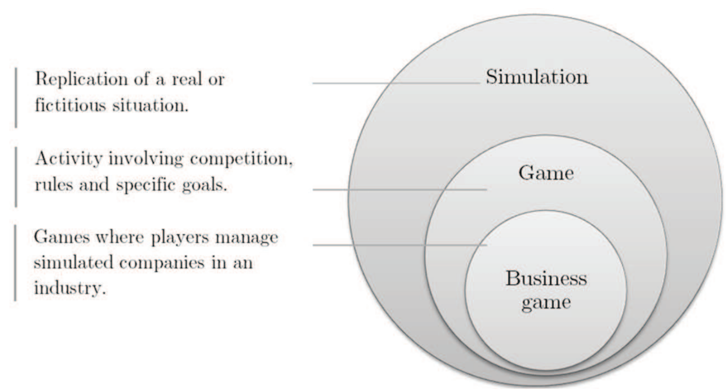


Figure 1.1: Stacked Venn diagram of the relationship between simulations, games and business games.

The term *simulation* has been used by some authors (see Summers 2004, Faria 1998) in the designation of business games − as in the term *business simulation game*. A *simulation* is by definition, a replication of the essential features of a real world or fictitious situation (Thavikulwat 2004). A business game is a simulation as it attempts to simulate a real world situation − the environment of a competitive industry. However, the use of the double word, *simulation game*, can be considered redundant.

According to Narayanasamy et al. (2006) *game* is in fact a narrower concept than simulation since games include features as competition and rules not obligatory present in *simulations*. Therefore, in this study, the term game was chosen instead of the alternative use of the terms simulation when referring to the genre.

Some authors prefer to use the terms strategy and management instead of *business* when referring to business games (see Keys 1997). However, the terms management and strategy can be considered too general to accurately define business games. War games, for example, also develop management skills and strategic reasoning. Therefore the use of the term business was considered the most suitable alternative in the context of business games.

1.2 Historical perspective

Management skills are among the most difficult soft-skills to acquire. This follows from the fact that competence in management is usually acquired without formal practice. As Keys et al. (1998) noted, the absence of a “rehearsal space” is especially critical in management, since learning is considered the only long-run competitive advantage of a business organization. According to the same authors, it was in response to this need that a new generation of “practice fields” was created − the business games.

According to Meier et al. (1969) the first business game, the Top Management Simulation Decision Simulation, was developed by the American Management Association (AMA)[1] in 1956. The game, as stated in AMA’s statements (Cohen and Rhenman 1961) was directly influenced by military war-games.

The idea of creating the game came across after an exploratory visit by an AMA’s research group to the Naval War College. From the observations of how the military practiced their officers decision making skills, using simulation and

[1] The American Management Association (AMA) is a non-profit organization whose purpose was to provide training/teaching development in management (www.amanet.org).

gaming techniques, grew the idea of a "business war-game". The idea was to replace the concepts of victory/defeat used in war games with the analysis of the behavior of competing companies, expressed as economical results over a given period of time (Laurindo et al. 2006, chap. 11). The idea was soon put into practice, and in the following years the game was being widely used in management seminars held by AMA.

Although business games grew out of experience with military war-games, its growth in the subsequent years was also dependent upon progress in computer science (Cohen and Rhenman 1961). The use of computers opened the possibility to create more realistic games. Advances in computer science allied with the "enthusiastic" response that the early games received, made the notion of business games become widespread both in academia and industry. Educational and business organizations created a myriad of offshoot games, more than one hundred games in the USA alone (Cohen and Rhenman 1961).

During the 50s and 60s several games had to be extensively altered to meet the specific needs of its users. As Nebenzahl (1984) described, the alteration processes were especially predominant in the academic world, since games were often transferred from one college to another − as games were transferred the degree of required realism and complexity tended to increase.

The extent to which business games were used was only quantitatively registered in the late 80s. Faria (1987) was the first to accomplish a scientific estimation of game usage in academia and business in the USA. Business games were extensively based on the various disciplines of business administration theory such as finance, marketing and accounting (Goosen et al. 2001). The advanced subjects taught in these disciplines made this type of games more appropriate for graduate and MBAs courses (Keys 1997). Faria registered an overall 95% usage rate at college level with strategic management and marketing courses registering the highest usage rates and found that about 55% of America's larger business firms used business games.

The microcomputer revolution during the 80s was considered by Wolfe (1993) as a turning point in the history of business games. Only a number of the games introduced in the late 50s and 60s, specially the more realistic and complex, were reprogrammed for use in personal computers. Although the microcomputer revolution represented a major transformation of the game scene, business games continued to be widely used. Faria (1998) reported usage rates of 98% and 60% in academia and business in late 90s.

In 2001, Goosen et al. analyzed the industry of business games and documented that the majority of games in use were updated versions of late 60s and early 70s games with minor changes. The content and structure of business games remained the same since the 70s, meaning that the trend of game evolution of the former decades apparently has stopped. However, this was not accompanied by a decrease in game usage, as documented by a number of surveys in China (Chang et al. 2003), UK (Burgess 1991), and in the USA (Faria and Wellington 2004). Although stating different pace rates, all surveys concluded that the usage of business games was a growing phenomenon.

Summers (2004) also analyzed the industry of business games in the same period and, from his review, two important conclusions emerged. First, the author concluded that the industry would grow at an even faster rate during the next decade. Second, that technologies coming from research in computational fields presented the potential to improve the capabilities of business games. These were the two main reasons motivating this study.

1.3 Computerized business games in detail

According to Elgood (1996, chap. 6) the majority of computerized business games have followed the model-based structure usually applied in economic modeling, which earned the games the designation of *model-based games*. A model-based game is, as defined by Elgood (1996, chap. 6), a repetitive decision/result cycle moving onward through time − each cycle simulating a period of real time, such as a month, quarter or a year.

As model-based games, business games can be divided in three major components: the decisions, the model which processes the decisions, and the results which derive from the model execution (see Figure 1.2).

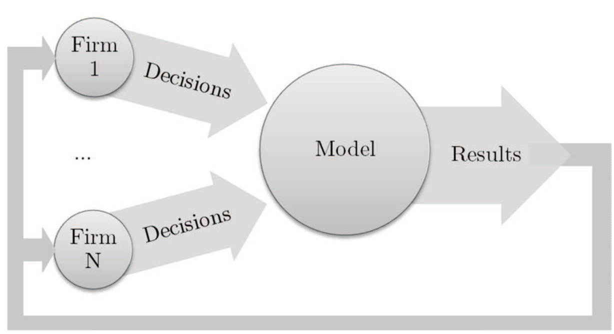


Figure 1.2: The principal elements of a business game: decisions, simulation model and results.

1.3.1 Decisions

Decisions play an important role in business games as they represent the only form of interactivity between the participants and the simulated environment. Moreover, success in these games is solely dependent upon the quality of the decisions made.

Decisions in business games can be classified as tactical or strategic[2] (Keys 1997). The classification of decisions as tactical or strategic depends on the period of real time simulated. Games requiring quarterly decisions are more positioned in the tactical field whereas games based on yearly decision inputs are more strategic and require long-term planning.

In computerized business games decisions are submitted through an interface in the form of spreadsheets or more polished graphical screens (see Figure 1.3). Usually, decisions are made by determining the value of quantitative variable, such as the price of a product.

Generally, decisions are grouped into functional areas[3], such as manufacturing, marketing or accounting. Commonly, the decisions are grouped into three areas: marketing, production and finance (Gold and Pray 2001, Keys 1997). Business games can be classified according to the scope of the decisions made. Games placing more emphasis on a particular functional area are referred to as *functional games* whereas games where equal attention is placed on all areas, are designated as *top management games* or *total enterprise games* (Gentry 1990, chap. 5).

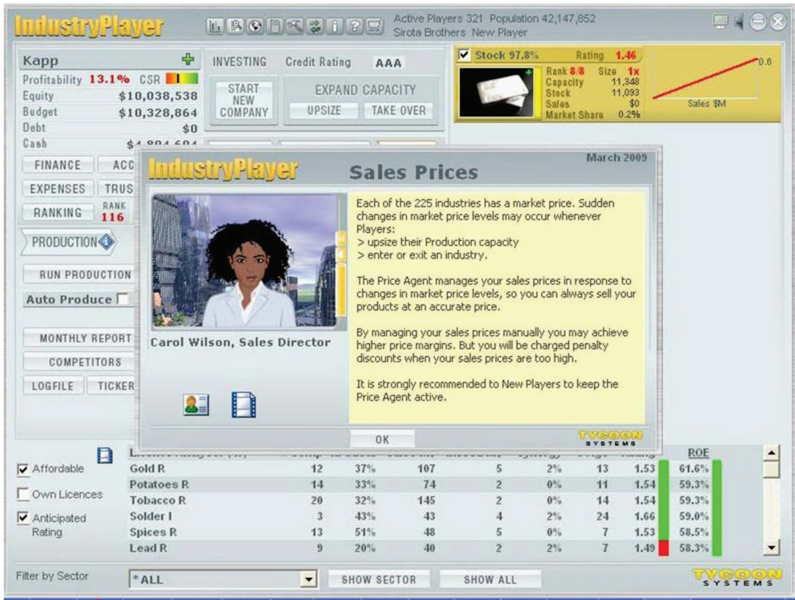
Although some decisions are common to a number of games, there appears to be no agreement on which decisions at a minimum should be included in a business game. Goosen et al. (2001) reviewed several business games and found that only three decisions appeared consistently in all games: price, research and development, and production scheduling. A list of the most common decision variables present in business games is presented in Table 1.1, as compiled by Keys (1997). An extensive description of decisions and strategies used in games can be found in Gentry (1990, chap. 5) or in Wolfe and Roge (1997).

1.3.2 Model

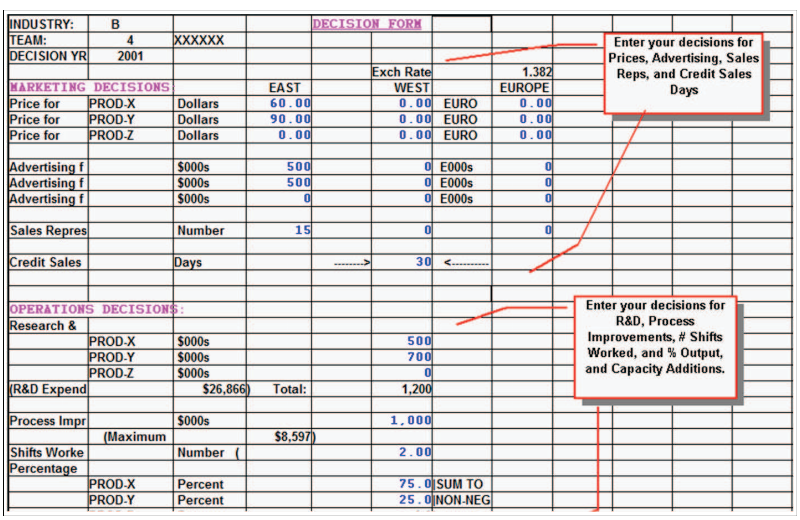
Kheir (1995, pag. 3) defined simulation as "the art and science of experi-

[2]Tactics are the actual means to achieve a goal and strategy is the overall plan (Jones and George 2003, pg. 9).

[3]Functional areas are logical divisions of organizations in which people have the same skills or use the same resources (Jones and George 2003, pg. 253).



(a) Refined input screen (Industry Player).



(b) Spreadsheet (Cornell Management game).

Figure 1.3: Examples of input screens in business games.

menting with models". The model is the core element of a simulation as it establishes the connection between the simulated environment and reality – the *model* is the simplified representation of reality (Kheir 1995).

Although models represent core elements in all games, in business games

Table 1.1: Common decision in business games (adapted from Keys 1997).

Marketing	Production	Finance
Product choice	Plant construction	Long-term loans
Market choice	Process R&D	Bonds
R&D	Closing of plant	Short-term loans
Distribution center, sales office, warehousing	Worker productivity	Special loans
	Production scheduling	Common stock
Number of salesperson	Purchase of raw materials	Dividends
Sales salaries	Hiring, training employees	Taxes
Advertising and promotion	Employee wages	Miscellaneous expenses
	Inventory	
Price	Overtime production	
Market research	Lost sales disposal	

the model assumes critical importance − the whole game is constructed around the notion of the model. As Elgood (1996) stated, the presence of the model in business games is "ubiquitous". All the other structural elements of a business game depend directly on the design of the model: decisions are submitted directly to the model and results are also directly extracted from the model (Elgood 1996, chap. 6). Consequently, the realism and the overall quality of the game experience is primarily dependent upon the design of the model.

The model of business games is a representation of the dynamic environment of an industry where several business firms compete (between five to eight firms). The specificity of the simulated industry is one of the dimensions which characterizes these games (see Table 1.2 for a compilation of the dimensions considered in this study).

The industry can range from being very specific to completely generic (Gentry 1990, chap. 7). Some games, the *industry specific games*, provide scenarios

Table 1.2: Classification of business games.

Classification dimension[4]	Game classification	Description
Organizational focus	Functional game	More focused on certain functional areas of an organization.
	Top management game	Encloses all the functional areas at the same level
Industry specificity	Industry specific	Simulates a specific industry
	Industry generic	Replicates only general business relationships
Period of time simulated	Tactical	Requires decisions inputs on a quarterly basis
	Strategic	Requires decisions inputs on a yearly basis

of particular industries however, in general, business games portray generic industries. These second games are referred to as *widget* or *general* games.

In terms of learning potential, both specific and general business games present advantages and disadvantages. As Keys (1997) noted, the richer the company and industry case background, the greater opportunity to put into practice specific strategic initiatives, but on the other hand, the greater risk of reducing the applicability of the concepts learned.

According to Gentry (1990, chap. 7) models in business games have been extensively based on economics theory. One of the purposes of the games has been to conform to the proposed economic models of industrial economic structure (Gentry 1990, chap.7).

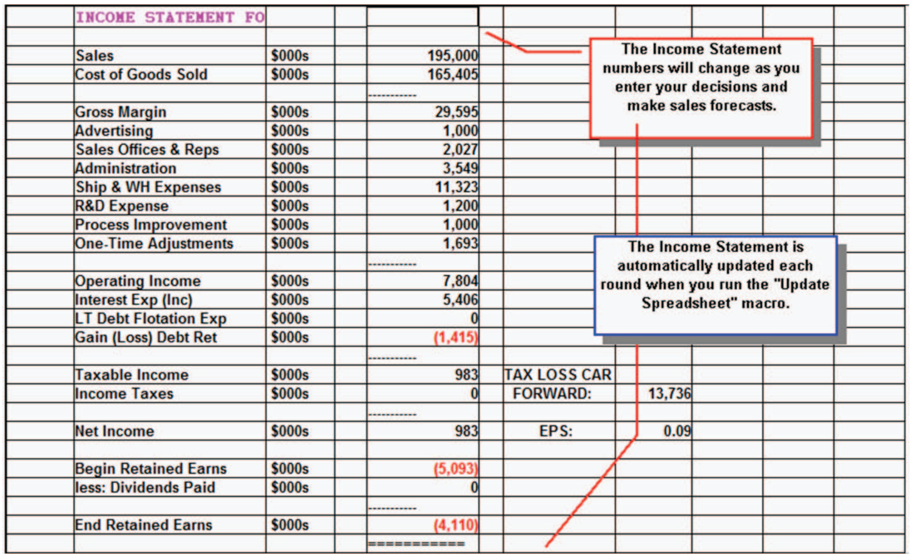
The operational computer program that implements the model (Kheir 1995, pg. 5) is designated as the *computerized model*. In business games, the computerized model is composed by a number of *algorithms*, operating procedures for computing the results according to the decision values submitted (Goosen et al. 2001). Algorithms are usually classified according to the functional area to which the decisions, received as input, relate to.

Designers of business games usually do not disclose the model behind the game and the specificities of the algorithms involved. The characteristics of the model are made known to the participants only in a vague qualitative manner (Gentry 1990). A number of algorithms has been presented by researchers (see Gold and Pray 2001), however, the extent to which these developments in the research community have influenced the design of commercial games, is not known.

1.3.3 Results

The outputs of business games are generated in terms of reports, usually financial statements. In computerized business games these reports are presented in the form of spreadsheets (see Figure 1.4). The *balance sheet* and *income statement* are the two most common reports (Gentry 1990, chap. 3).

There is not a common procedure for measuring the success of participants in business games (Gentry 1990, chap. 7). Although profits or stock value represent the primary measure of ranking the performance of participants (Goosen et al. 2001) its appropriateness has been fairly questioned by several researchers (see Gold and Pray 2001).



INCOME STATEMENT FO				
Sales	$000s	195,000		
Cost of Goods Sold	$000s	165,405		

Gross Margin	$000s	29,595		
Advertising	$000s	1,000		
Sales Offices & Reps	$000s	2,027		
Administration	$000s	3,549		
Ship & WH Expenses	$000s	11,323		
R&D Expense	$000s	1,200		
Process Improvement	$000s	1,000		
One-Time Adjustments	$000s	1,693		

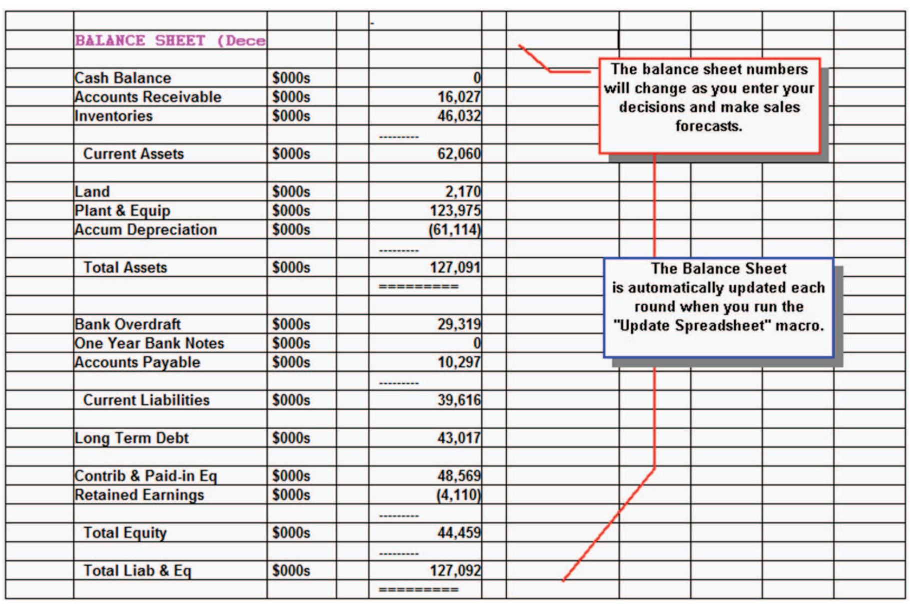
Operating Income	$000s	7,804		
Interest Exp (Inc)	$000s	5,406		
LT Debt Flotation Exp	$000s	0		
Gain (Loss) Debt Ret	$000s	(1,415)		

Taxable Income	$000s	983	TAX LOSS CAR	
Income Taxes	$000s	0	FORWARD:	13,736

Net Income	$000s	983	EPS:	0.09
Begin Retained Earns	$000s	(5,093)		
less: Dividends Paid	$000s	0		

End Retained Earns	$000s	(4,110)		
		==========		

(a) Example of an income statement (Cornell Management game). The tncome statement is a financial statement that indicates how revenue is transformed into net income (the result after all revenues and expenses have been accounted for).



BALANCE SHEET (Dece		
Cash Balance	$000s	0
Accounts Receivable	$000s	16,027
Inventories	$000s	46,032

Current Assets	$000s	62,060
Land	$000s	2,170
Plant & Equip	$000s	123,975
Accum Depreciation	$000s	(61,114)

Total Assets	$000s	127,091
		=========
Bank Overdraft	$000s	29,319
One Year Bank Notes	$000s	0
Accounts Payable	$000s	10,297

Current Liabilities	$000s	39,616
Long Term Debt	$000s	43,017
Contrib & Paid-in Eq	$000s	48,569
Retained Earnings	$000s	(4,110)

Total Equity	$000s	44,459

Total Liab & Eq	$000s	127,092
		=========

(b) Example of a balance sheet (Cornell Management game). The balance sheet is a summary of the value of all assets, liabilities and equity.

Figure 1.4: Samples of financial reports in business games.

1.4 Problem

The lack of model transparency in business games earned them a designation of "black boxes" (Machuca 2000). The transparency of the model was subject to much polemic and discussion among researchers in the field. Kheir (1995) argued that the concealment of the model had to be considered beneficial since it prevented participants from trying to manipulate the model instead of making reasoned decisions.

Other authors such as Goosen et al. (2001), Machuca (2000) defended that the secrecy surrounding the internal algorithms was a major obstacle to the expansion and realism of the games. The concealment of the model was pointed by Machuca (2000) as the primary cause of the inability of participants to perceive cause-and-effect relationships. This difficulty has originated, what Goosen et al. (2001) defined as the "dilemma of simplicity versus real-world complexity". Although simple models present the desirable advantage of allowing participants to perceive the consequences of their actions, detailed models are more realistic, as they can incorporate complex inter-relationships.

Notwithstanding the designers efforts, empirical results in academia have shown that neither realism nor game understanding were perceived as accomplished goals in business games as detailed in the following subsections.

1.4.1 Lack of realism in business games

A survey in the USA (Faria and Wellington 2004) found that only 13,6% of the students considered business games as realistic exercises. A survey in Sweden (Bruhn and Mozgira 2007) presented similar results, with more than 88% of the inquired students declaring that games did not provide a realistic view of the business environment.

Students perceived realism differently according functional area − the areas of finance and production were perceived to be more realistically modeled than the areas of marketing and human resources (McKenna 1991).

1.4.2 Lack of understandability of business games

In the same USA survey (Faria and Wellington 2004), 78% of the students stated that they could not understand the consequences of their decisions. Surprisingly, even with a tutor feedback, only 44% of the students inquired in the Swedish survey (Bruhn and Mozgira 2007) considered it was possible to establish a parallel between their actions and the results of the game.

1.4.3 Aim

The aim of this essay is the creation of a transparent and informative model for a business game, with the potential to achieve a high degree of realism. The hypothesis posed is that the *agent-based approach can help solving the research problems of lack of realism and understandability of business games*. The application of the agent-based technique to all functional areas would require a very extensive research. Therefore, it was decided that this study would focus on the most problematic area: the area of marketing.

1.5 Outline

This chapter attempted to introduce the research problem of this study and present a brief overlook of the domain problem.

Chapter 2 reviews the major demand models applied in business games and examines how the exposure of such models could potentially provide more information and create a more realistic game (section 2.2). The agent-based modeling technique (section 2.3) and the economic foundations for the current models (section 2.1) are also reviewed. In parallel with the neoclassical theory, models proposed in the field of agent-based economics are also presented.

Based on the research work of various fields, a collection of conceptual agent-based models was developed. Chapter 3 details the creation of such models and described the methodology used. Chapter 4 describes the concrete implementation of the conceptual models in a business game and details the methodology followed to create a more informative game.

Chapter 5 reviews theoretically and empirically the two problematic dimensions: the degree of realism of the model is reviewed through its compliance with economic theory and the ability to provide efficient information regarding the model is evaluated through empirical results with real participants.

The concluding chapter resumes the main ideas and conclusions of this study and discusses possible directions for future work.

Chapter 2

Related Work

The problem of modeling the marketplace is a central and unavoidable issue in business games. The marketplace is usually simulated through the implementation of a demand algorithm. The demand algorithm is responsible for determining the industry's overall demand and for allocating that same industry demand to each individual firm.

The demand algorithm has been considered one of the most complex and important algorithms of a business game (Goosen et al. 2001). The importance of such algorithm follows from the fact that the ability of one firm to capture demand share from other firms is the essence of the game. The complexity of the algorithm derives from the fact that a considerable number of variables, such as price, advertising and sales staff expenditures, as well as its intricate interactions, have to be taken into account, when modeling demand.

The development of demand models for business games has been, to a large extent, based on classical economic demand theory (Gold and Pray 2001). Therefore, it was necessary to understand the sustaining economic theory prior to the study of the models applied in games. This chapter begins with an introduction to economic demand theory (section 2.1), presenting the classical model of supply and demand and the theory of rational consumer behavior.

The research work concerning demand models for use in business games is described in section 2.2. The section analyzes the strengths and weaknesses of the demand models proposed for use and how these approaches addressed the problems of lack of realism and shortage of information. The chapter continues by situating the reader in the context of the agent-based modeling technique (section 2.3). The advantages of agent-based modeling over the alternatives and the research work already developed in the area is reviewed. The consumer models proposed in the field of agent-based economics are also analyzed.

Section 2.4 concludes the chapter with a critical review of the current research scene and introduces in general lines the approach followed to address the research problem.

2.1 Microeconomics theory

To study reality, economists have developed models of social phenomena (Varian 1990, pg. 4). Business managers often develop those same economic models and rely on economic concepts to analyze and identify appropriate solutions for the problems they face in the real world (Zernik 1988).

Although the authority of economic models to simulate reality has been severely discussed (see Frank 2006, pg. 6-7) designers of business games continue to rely extensively on economic principles to construct their models (Gentry 1990, Gold and Pray 2001). Some authors such as Zernik (1988) go as far as to consider that the principal role of a business game should be to give life to the abstract economic concepts to prepare participants to the more difficult task of applying such concepts to real world problems. Consequently, the realism of models used in business games has been commonly measured through an evaluation of its compliance with economics (Gold and Pray 2001).

Two models proposed in microeconomics[1], in the area of modeling demand, are further detailed in this section − the model of supply and demand and the model of rational consumer behavior. These models represent the foundations of the models proposed for business games (detailed in section 2.2). For the following sections, Frank (2006), Samuelson (2005) and Mata (2006) were followed.

2.1.1 The model of supply and demand

A fundamental research topic in microeconomics is the study of markets. A *market* consists, by definition, of a number of buyers and sellers of a good or service. To determine the prices and quantities sold in a general market, microeconomics has developed the *model of supply and demand*.

To analyze the behavior of buyers, the supply and demand model employs an important analytical tool: the demand schedule. Formally, *demand* refers

[1] Microeconomics is the study of individual choices under conditions of scarcity and the study of group behavior in individual markets (Frank 2006, pg. 22).

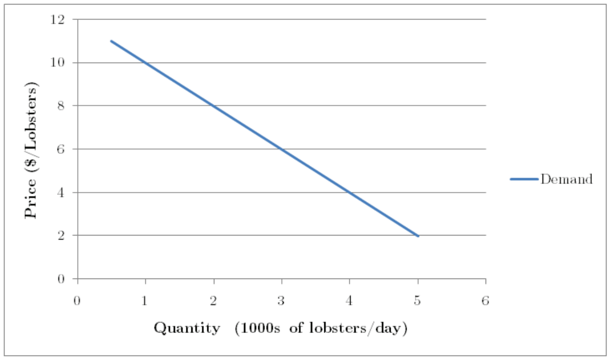


Figure 2.1: The demand curve tells the quantities demanded at various prices. Its key property is its downward slopping: as price falls quantity increases (adapted from Frank 2006).

to how much quantity of a product or service is desired by buyers. The *demand schedule* describes the relation between the quantity demanded and the price of the product. Graphically, this relation takes the form of a line or curve (see example of a demand curve in Figure 2.1). The key property assumed from the *demand curve*, often called the *law of demand*, is that it's downward slopping, or in other words, the quantity demanded rises as the price of the product falls.

Although the most important determinant of demand, particularly in the short-term, is price, demand is also determined by other factors such as incomes, tastes of the consumers, market dimension, prices of substitutes and complements[2], and other particular influences. The shape and position of the demand curve of a market is determined by these factors.

The function that relates the quantity demanded with its determinants is the *demand function* and is mathematically formulated as:

$$Q = f(P, I, T, D, P_c, P_s, O) \tag{2.1}$$

where Q is the quantity demanded, P is the price of the good/service, I and T the income and tastes of the consumers, D is the market dimension, P_s and P_c are the prices of substitute and complement goods and O stands for other factors.

Another analytical tool of central importance, closely connected to the supply and demand model, is price elasticity of demand. *Price elasticity of demand*

[2] A substitute good can replace the consumption/use of another good. A complement good can be consumed/used with the other good.

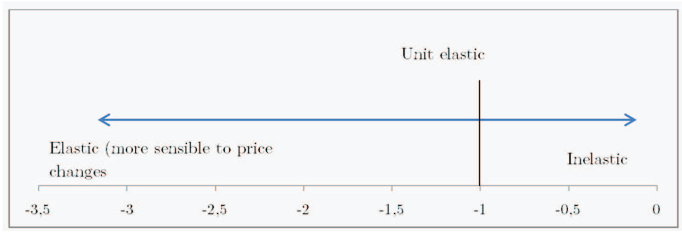


Figure 2.2: Categories of price elasticity of demand (adapted from Frank 2006, pg. 124).

is a quantitative measurement of the responsiveness of quantity purchased to variations in price. Price elasticity of demand can be expressed by the following formula:

$$\epsilon = -\frac{\Delta Q/Q_{av}}{\Delta P/P_{av}} \tag{2.2}$$

where ϵ is price elasticity of demand, ΔP is the variation of price for a given interval, ΔQ is the variation of quantity, P_{av} is the average price of a good and Q_{av} is the average quantity demanded at that price for the same interval.

With respect for price, demand for a good is called *elastic* if its price elasticity is less than -1, *inelastic* if its price exceeds -1 and *unit elastic* if its price is equal to -1 (see Figure 2.2). Price elasticity is always negative, although for the sake of convenience, it is usually referred by absolute value. The more elastic a good is, the more sensible are consumers to price changes, or in other words, increases in price will lead to higher percentage decreases in quantity.

When the demand curve is linear, two important properties of the price elasticity of demand become apparent: (1) price elasticity decreases along the demand curve (see Figure 2.3) and (2) the steeper a demand curve is, the less elastic (less sensible to price changes) is demand at any point along it.

The value of price elasticity of demand depends largely on how many substitutes it has. If a good has many close substitutes the demand curve is typically more responsive to price changes (more elastic), since consumers have a direct alternative.

Economy distinguishes between the *market demand curve* and *demand curve facing the firm*. Market demand curve measures the relationship between the market price and the total quantity bought, whereas the demand curve facing the firm measures the relationship between the price stipulated by a firm and

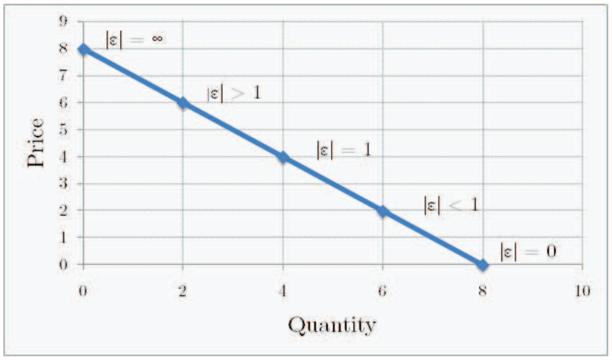


Figure 2.3: Price elasticity of demand varies along a linear demand curve (adapted Frank 2006, pg. 125).

the quantity it can sell.

There are several possible market structures that originate different types of demand curves facing the firm (see Table 2.1 for a description of the most important market structures). There are two main types of markets: the perfectly competitive and the imperfectly competitive markets. Markets studied in microeconomics are usually *perfectly competitive markets* that abide to a set of requirements, namely:

- Standardized product: the product sold by one company is a perfect substitute for the products sold by other firms.
- Firms are price takers: No single seller has effect on price and treats the market price as given[3].
- Perfect factor mobility: Firms have unlimited production power and their resources are perfectly mobile. There are low entry and exit barriers.
- Perfect information: Firms and consumers have access to all the information needed to make their choices.

In perfectly competitive markets the demand curve facing the firm is described as an horizontal line with infinite elasticity (see Figure 2.4a). If a firm raises its price, even slightly, above the market price it will sell nothing, as buyers will prefer to buy products from its competitors. This type of market converges to an equilibrium where the market price is equal to the cost of the

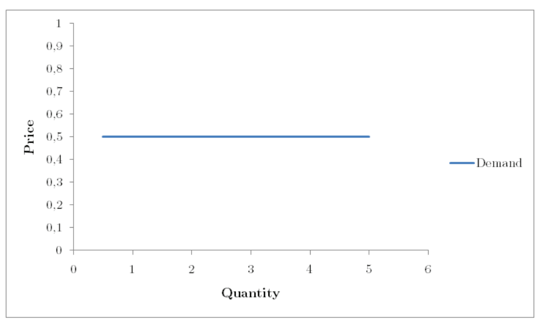
[3]This condition is usually satisfied when the market is served by a large number of suppliers, each one producing a small fraction of the total production.

Market structure	Number of suppliers	Product differentiation	Market power
Perfect competition	Many suppliers	Identical products	None
Oligopoly	Few suppliers	Different or similar products	Some
Monopoly	A single supplier	Product with no substitutes	Considerable

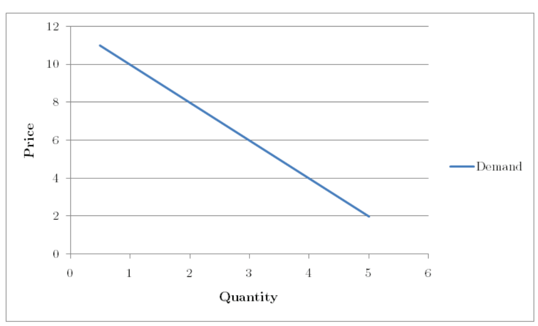
Table 2.1: Market structures (transcript from Samuelson 2005, chap. 9).

last unit produced, meaning that if a firm sets the price of their products below the market price, it will have a negative profit. As firms are supposed to maximize profit they behave as price-takers, that is, firms accept the market price as given.

In the real world, hardly markets satisfy the conditions of perfectly competitive markets. In *imperfect competition* environments the demand curve facing the firm is downward slopping (see Figure 2.4b), meaning that firms have some



(a) Perfect competition



(b) Imperfect competition

Figure 2.4: Examples of different demand curves facing the firm in different market structures.

margin to change their prices, either because they are one of the few players in the market or because they can differentiate their products. In imperfectly competitive markets, the higher the price elasticity of the demand curve facing the firm, the lesser the control the firm has to set prices above the marginal cost, or in other words, the lesser the *market power* of the firm.

An extreme case of imperfect competition is the *monopoly*, a market structure in which a single seller of a product with no close substitutes serves the entire market. *Oligopoly* is a type of market structure that lies between the two extremes. There are several competitors in the market but not as many as to regard each of them as having a negligible effect on price. This type of market is usually simulated in business games (Goosen et al. 2001).

2.1.2 Theory of rational consumer behavior

To derive the law of demand, microeconomics had to study the consumption choice behavior of each individual. The most basic model presented by microeconomics is known as the theory of *rational consumer choice* or *neoclassical economic theory*. This model underlies all individual purchase decisions, which aggregated, derive the demand curves explained in the preceding section.

The underlying idea behind rational choice theory is simple: it is assumed that consumers choose to purchase the most preferred bundle of goods they can afford. Two steps are considered to accomplish optimal allocation:

1. Budget constraint: Determination of the various consumptions bundles (combination of goods) the consumer is able to buy.

2. Preferences: Selection of the preferred bundle from among the alternatives (previously calculated).

Considering the step of determining the budget constraint, the consumer can choose among several consumption bundles. A consumption bundle can be represented as $X = (x_1, x_2, ...x_n)$, in which (x_i) is the quantity of product $(i = 1, ...n)$ the consumers wish to purchase. The universe of possible consumption bundles is restricted to the budget of each consumer. Therefore, the consumer is subject to a budget constraint which can be written as:

$$p_1x_1 + ... + p_nx_n <= m \tag{2.3}$$

where p_i and x_i is the price and quantity purchased of good i and m represents the amount of money the consumer has to spend.

Rational choice model assumes consumers enter the marketplace with well-defined preferences. To analyze the behavior and preferences of each consumer, microeconomics developed the concept of *utility*. The concept of utility is used to describe the *preferences* of each consumer. An *utility function* assigns values to consumption bundles, such that more-preferred bundles get assigned larger numbers than less-preferred bundles. The utility function is written as:

$$u = U(q_1, q_2, \ldots, q_n) \tag{2.4}$$

where u is the total utility gained by consuming $q1, ..., q_n$ *quantities of* $g_1, ..., g_n$ *goods according to the utility function* U*.*

Although the budget constraint results in a collection of affordable bundles the utility function ranks these bundles in order of preference. Consumers always attempt to maximize their utility and consequently always choose the bundle with the highest utility relative to the other bundles.

The concept of marginal utility is also used to explain how consumers choose their optimal bundle. *Marginal utility* with respect to a certain good, measures the rate at which the total utility acquired changes with the increase of quantity consumed. The concept of marginal utility is useful in explaining how a consumer decides on a given bundle of goods. According to the *equimarginal principle*, the consumer reaches the equilibrium when the ratio of marginal utility (UM) to price (p) is the same for all the goods. In the equilibrium state the consumer maximizes its total satisfaction in such a manner that the last monetary unit bought of each good yields an equal amount of marginal utility.

$$\frac{UM_{good_1}}{p_1} = \frac{UM_{good_2}}{p_2} = ... = \frac{UM_{good_N}}{p_N} = UM \text{ per monetary unit} \tag{2.5}$$

2.2 Demand models in business games

Gold and Pray (2001) reviewed a number of articles presenting algorithms for business games in the following categories: (1) Equation-based models: two mathematical functions were used to model both the industry demand and firm demand (2) Interpolation based approach: an interpolation method was used to derive the graphics of the two demand functions and (3) Statistical-based approach: the proportion of consumers which consume a given product was measured using purchase probability distributions.

These three approaches are reviewed briefly in the following subsections. A special focus is placed in analyzing the information the model could provide and in the model realism. Realism was evaluated by reviewing the compliance of models with economic theory.

2.2.1 Equation-based models

Gold and Pray (1983) reviewed a number of business games and found that a sensible number of games used a similar construction to model demand, constituted by two modules:

1. A mathematical function which calculated market demand from the mean calculations of the demand determinants. The industry simulated was usually an oligopoly with product differentiation and as a result, the demand function had to take into account variables such as marketing and product quality variables.

$$Q = f(P, M, R) \tag{2.6}$$

where Q represents the quantity demanded, P the average price, M the average value of marketing expenditures and R the average value of R&D expenditures.

2. A mathematical function of firm (Equation 2.8) demand which calculated the weight of each firm when allocating market share (Equation 2.7).

$$q_i = w_i Q \tag{2.7}$$

$$w_i = f(p_i, m_i, r_i) \tag{2.8}$$

where w_i represents the weight of firm i when allocating its share (q_i) of market demand (Q), p_i the price set by firm i, m_i the value of the marketing expenditures for firm i and r_i the value of expenditures in R&D for firm i.

Usually the same type of function (f) was used to model market (equation 2.6) and firm (equation 2.8) demand. Equation-based models presented some limitations in terms of realism, namely:

- Calculation of industry demand: the fact that market demand (equation 2.6) was calculated from average values was problematic since firms could have an unrealistic control upon market demand.

Suppose there were three firms in the industry and two of them choose to set extremely high prices while the third firm decided on a reasonable price. Market demand would be calculated from the average value of the three decisions and as a result, demand would be reduced to such a degree that the third firm would sell an undersized quantity compared to a real market situation.

- Determinants of demand: another limitation of the model was that it did not take into account all the determinants of demand, such as the average income, population dimension and consumer preferences.

The degree of information which could be provided by the equation-based model was also limited. The model relied mostly on the values of the input decisions, and as a result, no explicit information existed relative to consumers.

According to the functional form used, models were classified as *linear*, *non-linear* or *log-linear* (Gentry 1990, chap. 8). The specificities of each category are detailed in the following topics.

Linear model

$$Q = -aP + bM + cR,\ with\ a, b, c \in \Re^{+} \tag{2.9}$$

A representative linear is expressed as equation 2.9. In terms of compliance with economic theory, the linear model presented two important properties:

- The model respected the law of demand.

$$\frac{dQ}{dP} = -a < 0,\ with\ a\ \in \Re^{+} \tag{2.10}$$

- Price elasticity decreased along the demand curve so that successive percentage increases of price resulted in smaller percentage increases in quantity demanded (see Figure 2.5b).

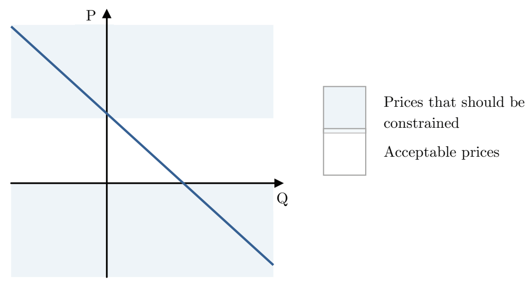
The model also presented limitations:

- The impact of a marginal change in any determinant of demand was independent of the other determinants, thus there was no interactivity between determinants of demand.

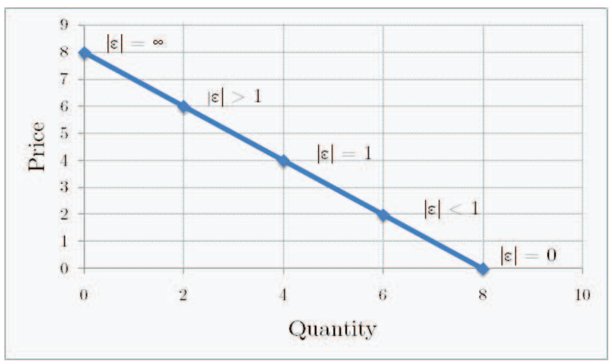
  Realistically, the same amount of marketing expenditures should lead to different quantities demanded at different prices. However, the variation of quantity according to marketing did not depend on price:

$$\frac{dQ}{dM} = b, \text{ with } b \in \Re^{+} \tag{2.11}$$

- Price elasticity could vary rapidly with changes in price and was very sensitive to the value selected for a.



(a) Input restrictions



(b) Price elasticity of demand

Figure 2.5: The linear model

- Input constraints had to be applied to prevent unrealistic results such as negative demanded quantities (Q).

  Negative prices and prices that resulted in positive values of price elasticity yielded unrealistic results (see Figure 2.5a).

Nonlinear model

$$Q = (a + bP + cM + dR)/P^e,\ \textit{with}\ a, b, c, d, e \in \Re \tag{2.12}$$

Nonlinear demand models presented a wide range of functional forms. The most widely used form was the one described in equation 2.12. Using this form, the law of demand could not prevail, since marginal impact of price (dQ/dP) could be either negative or positive. This model was considered to be very unrealistic and unpredictable (Gentry 1990, chap. 8).

Log-linear model

$$Q = a + bP^{-c}M^dR^e,\ \textit{with}\ a \in \Re_0^+ \text{ and } b, c, d, e \in \Re^+ \tag{2.13}$$

An alternative model was the log-linear, or multiplicative model, where functions presented the form of equation 2.13. The model had the following strengths in terms of realism:

- The law of demand was respected.

$$\frac{dQ}{dP} = -cbP^{-c-1}M^{d}R^{e} < 0,\ with\ bc, d, e \in \Re^{+} \tag{2.14}$$

- The model supported interactivity between variables − the impact of a marginal change in an independent variable was related to the level of the other independent variables.

  The variation of demand according to marketing depended on the other determinants:

$$\frac{dQ}{dM} = dbP^{-c}R^{e}dM^{d-1}, \text{ with } b, c, d, e \ \in \Re^{+} \tag{2.15}$$

The model presented the following limitations in terms of realism:

- The multiplicative function maintained a constant price elasticity over the range of possible decision values.

- Input restrictions had to be certified, namely to guarantee that there are no negative or zero values in the decisions inputted (see Figure 2.6).

To overcome the disadvantages of the multiplicative model, Gold and Pray (1983) proposed another multiplicative demand function with a decreasing price elasticity of demand which, according to the authors, did not require input restrictions (except for negative values). Since its proposal this form became the most popular form and was extensively altered (Goosen 2007). However, some of the supposedly realistic features of the model were contested (see Murff et al. 2007).

Figure 2.6: Input constraints had to be applied to the multiplicative demand model to ensure realistic results.

2.2.2 Interpolation approach

Goosen and Kusel (1993) approached the problem of modeling demand in business games from a different perspective than the previous studies. The authors recognized that the task of finding a single general flexible demand equation for modeling market and firm demand was a complex problem. Therefore, the authors proposed a method of implementing self-designed functions which they advocated to be able to generate sophisticated demand equations.

The method proposed consisted on a graphical approach where the simulation designer had to sketch the function desired between two variables, such as price and quantity, choose a number of important points (inflection, minimum and maximum points), program an interpolation function and finally, using that function, generate the remaining points (see Figure 2.7).

The interpolation method did not prescribed the nature of the functional relationships. Consequently, the approach did not solve the underlying problem of finding a flexible demand function. Furthermore, the designer had the burden of identifying all the relevant points in the functional relationship.

Modeling interactivity effects was also not straightforward, as Gold (1993) illustrated. For example, to incorporate the effect of advertising, the designer had to determine the increase in quantity that resulted from changing advertising for all the relevant points in the functional relationship between price and quantity (see Figure 2.7).

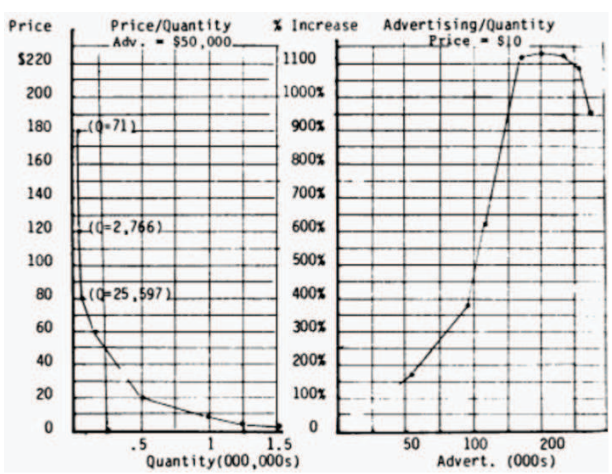


Figure 2.7: Example of graphs resulting from applying the interpolation method (transcript from Goosen and Kusel 1993).

The degree of information which could be provided was even lesser than in the linear or multiplicative models. In fact, there was no real mathematical model from which the outputs could be derived, just an exhaustive representation of the outcomes according to the inputs.

2.2.3 Statistical-based approach

Carvalho (1995) proposed another approach to model market demand. The author disagreed with all of the previous models, which were mostly based on the inputted decisions, not modeling explicitly the crucial element of a demand model: the consumer itself. Carvalho proposed a model for market demand based on the equimarginal principle (see Section 2.1):

$$\frac{UM_1}{P_1} = \frac{UM_2}{P_2} = \ldots = \frac{UM_N}{P_N} = UM \text{ per monetary unit} = \pi \tag{2.16}$$

Since the marginal utility depended on the utility function which was different from consumer to consumer, each consumer had consequently a different marginal utility per monetary unit (π). Carvalho used a probability distribution, the gamma distribution function, to model the probability distribution of π over the market. The market was modeled according to the two parameters of the distribution, α and β[4] (see Figure 2.8a).

Each product had a particular marginal utility/price ratio (UM/π_p), where marginal utility (UM) was directly related to the quality of the product (Q) and the price (P). The quality (Q) and price (P) were average values calculated from the individual values set by each firm:

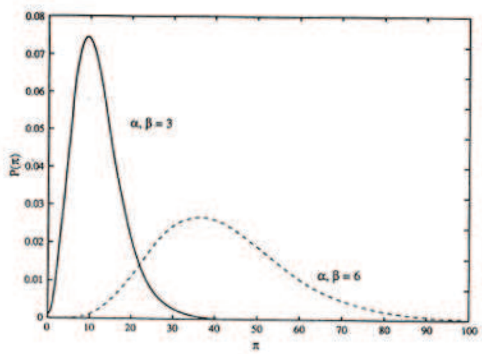
$$\pi_p = k_1 + \frac{k_2 - P}{k_2 * k_3} + \frac{R - k_4}{k_4 * k_5} + \frac{M - k_6}{k_6 * k_7}, \text{with } k_{i=1\ldots7} \in \Re \tag{2.17}$$

A purchase was made when $\pi \leq \pi_p$. The following equation determined the proportion of consumers in the market that bought the products offered (see Figure 2.8b) :

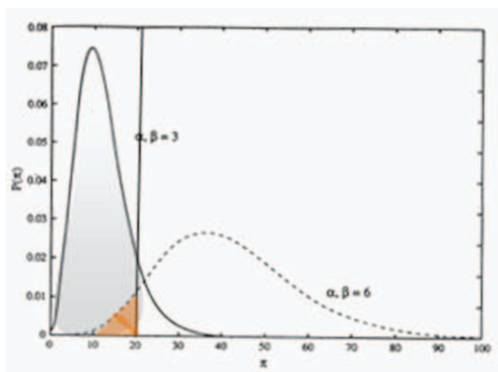
$$F(p) = \int_0^{\pi_p} p(\pi)\, d\pi \tag{2.18}$$

Carvalho's efforts in modeling the consumer were praised by Gold and Pray (1995), who stated that more attention should be placed in the explicit modeling of the consumer in demand models. In terms of realism, this model

[4] The gamma distribution is determined by choosing the parameter α, the shape parameter, and *beta*, the scale parameter of the probabilistic distribution.



(a) Purchase probability distribution of two markets.



(b) Proportion of the two markets with $\pi_p = 20$.

Figure 2.8: Purchase probability distributions of two markets (transcript from Carvalho 1995).

presented an innovative characteristic: the terms α and β could be changed to reflect changes in the incomes, tastes and number of consumers in the market.

Notwithstanding the model's flexibility, the model presented limitations. The model used average values to calculate demand and, as Gold and Pray (1995) criticized, the distribution parameter values (α and β) were difficult to control. It was not clear how these parameters could be related to income, market dimension and other useful information. Furthermore, Carvalho did not provide an explanation on how firm demand could be modeled − his proposal only modeled market demand.

	Linear model[5]	Multiplicative model	Gold and Pray's model	Graph-based model	Statistical-based model
Demand law	✓	✓	✓	✓	✓
Variable elasticity of price	✓	✗	✓	✓	✓
Stable (minor input restrictions)	✗	✗	✓	✓	✓
Interactivity between variables	✗	✓	✓	Difficult to implement	✓
Demand determinants relative to the consumer	✗	✗	✗	✗	✓
Firm and industry demand modeled	✓	✓	✓	✓	✗

Table 2.2: Comparison between demand models used in business games.

2.2.4 Discussion of the state of the art models

This section reviewed the major demand algorithms, proposed in the research community. All models presented limitations in terms of realism and transparency. The strengths and weaknesses of the models reviewed are summarized in Table 2.2.

The equation-based models (linear, non-linear and log-linear) attempted to model the complex relations emergent from the interaction of consumers and firms in a single set of equations. The negative aspects of these models were the use of mean calculations for the determinants of demand, the difficulty in modeling realistic interactions between demand determinants, the requirement of input restrictions and the nonexistence of demand determinants relative to the consumer itself. The information provided was also minimal as models derived its results mainly from the decisions inputed.

In view of the shortcomings of equation-based models, Goosen and Kusel (1993) proposed an interpolation method to model demand in business games. Despite the flexibility of this approach, the author did not solve the problem of determining a demand function. Moreover, information regarding the market was minimal since the outcomes of the demand functions were solely dependent upon the designer.

Carvalho's model (1995) differentiated itself from the other models by attempting to model indirectly the behavior of the consumers. Notwithstanding its value, this approach was, nevertheless, not exceptionally flexible. The information provided was also vague.

In the real world, the dynamics of a marketplace derive from the behavior of each single consumer in the market, that is, the complex emergent properties of the market derive from the behavior of each consumer and his local interactions. Although the approach of Carvalho followed this direction, the explicit modeling of each consumer could prove to be a more flexible alternative to derive all the emergent relationships that define a marketplace.

An alternative to the statistical modeling technique used by Carvalho (1995) is the agent-based approach. This modeling technique allows the explicit modeling of each consumer in the market and of his interactions with other consumers. The application of this technique could increase the complexity of the model and consequently, its realism. Moreover, agent-based model could contribute to a more transparent and informative model.

The following section will provide further insights into what is the agent-based modeling technique and how this modeling technique has been applied to model consumer behavior.

2.3 Agent-based modeling

Agent-Based Modeling (ABM), a relatively new simulation paradigm (Deguchi 2004, chap. 4), consists in the modeling of phenomena as a *Complex Adaptive System* (CAS), that is, a system composed of a number of interacting autonomous units, the agents, from whose interactions the properties of the system emerge (Macal and North 2005).

Borshchev and Filippov (2006) considered the agent-based approach as the most flexible technique used in simulation. The key characteristic of the approach, which sets it apart from other modeling techniques, is that it always involves a bottom-up approach to understand the behavior of a system. The focus of the agent-based approach is turned into the properties of the individual agents that compose the system and their interactions (see Table 2.3).

Summers (2004) reasoned that research work in the area of agent-based models for business games was still in a formative stage. The author explained that the lack of consolidated work in the area was due to two reasons: the late introduction of the agent-based approach (late 90s) to the field of business games and the difficulty in designing this type of model.

Dobson et al. (2004) developed a simplistic agent-based model for business games and recognized the difficulties inherent with developing this type of model. The authors concluded that adequate models of rational decision making were a critical factor of success and also that the assurance of model transparency and information visualization were key properties for the significant improvement of business gaming applications.

Although research in the field of agent-based models for business games is not fully developed, relevant work has been developed in the parallel field of Agent-based Computational Economics (ACE). This section proceeds by describing the field of ACE and the models proposed in the area.

2.3.1 Agent-based Computational Economics (ACE)

Rennard (2007, chap. 14) posed the interesting question "Terming a specific approach to economics as agent-based may appear paradoxical. Isn't human behavior the foundation of economics - and shouldn't all economic theory be based on agents behavior in some sense?". This was the main question which led to the creation of the research field of Agent-based Computational Economics (ACE).

In ACE, economy is conceived as a Complex Adaptive System (CAS). The agent-based approach presents advantages and disadvantages relative to more standard economic modeling techniques. A positive aspect is the fact that the agent-based approach allows the modeling of cognitive agents with more pragmatic social and learning competences (Tesfatsion 2003). Other key departure from standard approaches, is the fact that emergent patterns result solely from agent interactions once initial conditions have been specified.

The modeling of agent-based economic models also presents shortcomings. It is a concrete challenge to ACE to create models which provide comprehensible outcomes of large-scale economic systems with many thousands of agents. Another critical problem is the difficulty of validating model outcomes against

Characteristic	Agent-based modeling
Perspective	Bottom-up
Main building block	Individual agent
Unit of analysis	Agents' rules
Level of modeling	Individual
Handling of time	Discrete or continuous

Table 2.3: Agent-based modeling major characteristics (adapted from Schieritz and GroBler 2003).

empirical data (Tesfatsion 2003).

A number of frameworks were proposed in the field of ACE with the intent of modeling consumer behavior (see Said et al. 2002, Patel and Schlijper 2003, McGeary and Decker 2003, Riechmann 2002, Jager 2007). Most of these frameworks, attempted to explain a particular economic phenomena such as the decoy effect[6] (such as the model proposed by Patel and Schlijper 2003) or the lock-in effect[7] (for instance, the models of Patel and Schlijper 2003, McGeary and Decker 2003). A number of frameworks diverged from neoclassical economics and found support in theories from similar disciplines, namely marketing, such as the CUbes framework (Said et al. 2002).

Twomey and Cadman (2002) reviewed the research scene in the area of agent-based modeling of the consumer and considered that the only consistent attempt to model consumer was the framework of Janssen and Jager (1999). The following subsections describe in detail the (1) Jager and Janssen's model and the (2) CUbes model.

2.3.2 Jager and Janseen's model

Since their original paper, Janssen and Jager (1999) released a number of papers regarding the modeling of consumer behavior using an agent-based approach. Their proposed model considered the existence a population of N consumers, connected to k consumers, their *friends*, and a collection of M products, differing in one dimension d. At each period, each consumer would choose one of the M products available.

The model differentiated between the *expected* ($E[U_{ij}]$) and the *experienced utility* of a product (U_{ij}). A consumer had a given expectation for the utility of a product and experienced its concrete utility after consumption:

$$\textit{Experienced utility: } U_{ij} = \alpha E[U_{ij}], \quad 0 \leq \alpha \leq 1 \tag{2.19}$$

$$\textit{Expected utility: } E[U_{ij}] = \beta_i(1 - |d_j - p_{ji}|) + (1 - \beta_i)x_{ij}, \quad 0 \leq \beta_i \leq 1 \tag{2.20}$$

Where the utility of consuming a product $E[U_{ij}]$ consisted of an individual part $\beta_i(1 - |d_j - p_{ij}|)$ *and a* social *part* $(1 - \beta_i)x_{ij}$. β_i *determined how sensitive a consumer i was of not having the same choice as his friends,* p_{ij} *represented his personal preferences*

[6] The decoy effect is phenomenon whereby consumers will tend to have a specific change in preference between two options when also presented with a third option which is asymmetrically dominated.

[7] The phenomenon of lock-in happens when the consumer becomes dependent on a supplier for products and services, unable to switch to another supplier without substantial switching costs.

for each product j, d_j was the product dimension and x_{ij} the number of friends who consumed the same product. The value α, the visibility of a product, reflected the degree to which a type of product could ultimately satisfy a consumer U_{ij}.

The model considered that each customer had imperfect information relative to the products utility. The *expected uncertainty* ($E[Unc_{ij}]$) (see Equation 2.21) reflected how uncertain a consumer (i) was about having made the best choice when choosing product (j). The more friends consumed other products, the more uncertain the consumer would be. The more important the social need (the lower the value of β_i), the more uncertain he would become when his friends consumed different products. The *uncertainty* (Unc_{ij}) the consumer experienced when deciding which product to consume was equal to the expected uncertainty ($E[Unc_{ij}]$) in the last consumption act.

$$E[Unc_{ij}] = (1 - \beta_i)(1 - x_{ij}) \tag{2.21}$$

Consumers could engage in different cognitive processes while deciding which products to choose, depending on their level of need satisfaction and degree of uncertainty. Each consumer had a given limit for the *minimum utility* that satisfied him (U_{min}) and a *maximum tolerable uncertainty* (Unc_T). The following four types of cognitive processes were formalized in the model:

- *Repetition (satisfied and certain: $U_i \geq U_{min}; Unc_i \leq Unc_T$)*: The customer was satisfied by the last product and was certain he made the right choice. The consumer would repeat his last consumption act.

- *Deliberation (dissatisfied and certain: $U_i < U_{min}; Unc_i \leq Unc_T$)*: The consumer was dissatisfied but was certain he could make the right choice by himself. The consumer would evaluate the expected U_{ij} of each product, and would use a logit function[8] to solve the discrete choice problem.

$$\Gamma_{ij} = \frac{e^{b_1 * E[U_{ij}]}}{\sum_j e^{b_1 * E[U_{ij}]}} \tag{2.22}$$

- *Imitation (satisfied and uncertain: $U_i \geq U_{min}; Unc_i > Unc_T$)*: If the consumer was satisfied but soon saw few other friends using the same product he would evaluate the products being consumed by his friends.

$$\Gamma_{ij} = \frac{e^{b_2 * x_{ij}}}{\sum_j e^{b_2 * x_{ij}}} \tag{2.23}$$

[8] A logit function is a common mathematical model to address discrete choice problems.

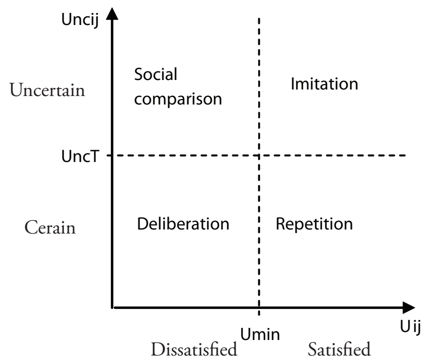


Figure 2.9: Cognitive processes in the Jager and Janssen's model.

- *Social comparison (dissatisfied and uncertain:* $U_i < U_{min}; Unc_i > Unc_T$*)*: The consumer made a choice between the expected satisfaction resulting from consuming products already consumed by his friends. Thus, the socially comparing consumer might consider a smaller set of products than the deliberating consumer.

The primary purpose of Janssen and Jager (2001) was to develop an agent-based model that could simulate different market dynamics. The model could evolve to different *market structures* by changing the two thresholds of *maximum tolerable uncertainty* and *minimum utility* of consumers.

Janssen and Jager (2003) stated that price could be included in the product dimension (d_j) but noted that this was not the major matter of concern of the model. However, the introduction of price and the verification of the law of demand was considered the most important feature business games should present to guarantee compliance with economic theory (Gentry 1990). Marketing and promotion were also not considered in the model.

2.3.3 The CUbes model

In 2002 Said et al. presented the CUstomer BEhavior Simulator (CUBES), a software for simulating consumer behavior in a competitive market. Although the paper was not descriptive enough to be implemented and the model presented several limitations, the research work introduced a new perspective on how interactivity and social processes could be modeled.

The consumer behavior model was based on what the authors defined as the *behavioral attitudes* (BA), modules which filtered the external stimulus

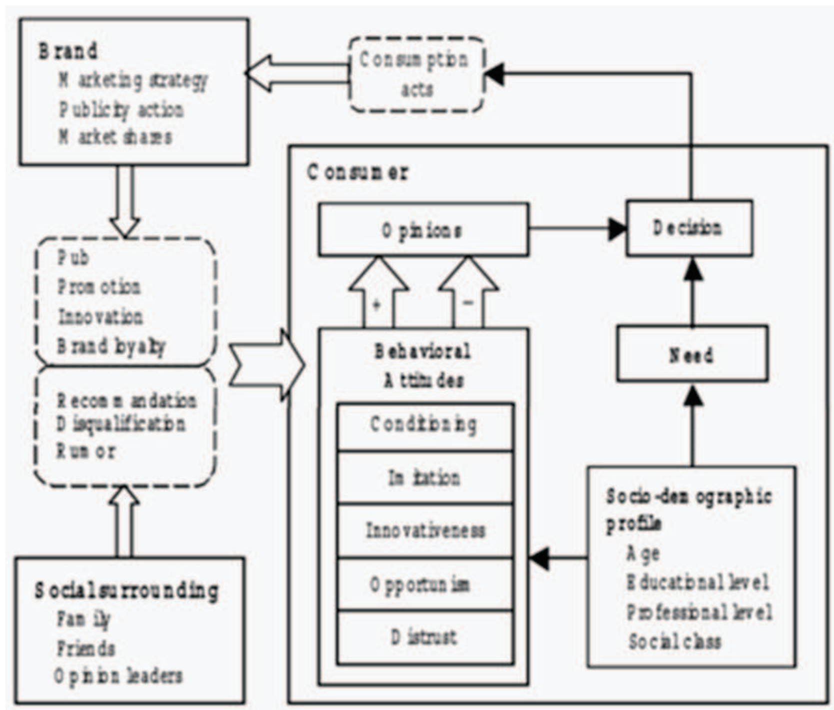


Figure 2.10: The internal modules of CUbes (transcript from Said et al. 2002).

concerning a brand (such as publicities, innovations and recommendations). The effect that stimulus had on the consumer, its *opinions*, was determined by the BAs' thresholds and inner mechanisms (see Figure 2.10). Each behavioral attitude (BA) had a complex mechanism that guarded memory of the last stimulus received and only after a certain threshold, the stimulus would start to have an impact on the consumer's *brand opinions*. There were two thresholds since a stimulus can have a negative or positive impact upon *opinions*.

Two behavioral attitudes (BA) were also responsible for issuing new stimulus, namely *recommendation* and *disqualification*. The model did not detail any further the inner *behavioral attitudes* (BA), neither in terms of which stimulus they react to, or how the social and individual process were accomplished.

This model relied heavily on exploiting interaction between the consumers, a key advantage of agent-based modeling. Therefore, the model presented relevant ideas on how interaction between consumers could be used to achieve a more realistic modeling of marketing strategies.

2.3.4 Discussion of the agent-based models

Quite often, economic models are criticized for making unrealistic assumptions about how people or organizations behave (Frank 2006, pg. 6-7). Progress in computational fields opened new possibilities to the study of these aspects. One such approach was the field of ACE, the computational study of economy modeled as dynamic systems of interacting agents.

A number of agent-based frameworks were proposed to model consumer behavior. The majority of the models attempted to simulate particular phenomena. In this field, the model by Janssen and Jager (1999) emerged as the most consistent framework which, aside from abiding to economic theory, incorporated a crucial element in agent-based modeling: the effects of interaction between consumers. Notwithstanding the relevance of this model, the model was not extremely flexible and did not consider directly the variable price.

The CUBEs model (2002) went even further in the exploration of the computational advantages provided by the agent-based approach. However, the apparent flexibility of the model could be considered misleading, since it was difficult to validate the model and to control the myriad of thresholds.

Jager (2007) noted that there was a major space for improvement in the area of modeling consumer behavior using the agent-based approach. The author concluded that although challenging, such approach presented the potential to develop even more complex and rich models of economic phenomena.

2.4 Conclusion

The majority of demand models for business games focus on modeling the emergent relations derived from the local interactions and micro-decision processes of consumers in the marketplace. The agent-based modeling approach appears in this context as an interesting and flexible alternative. The possibility to model each consumer and his interactions could create new possibilities in terms of additional realism and quality of information provided.

The need for a business game to possess realistic features has been discussed by several researchers (Elgood 1996, pg. 76). Nevertheless, the majority of researchers agreed that at least minimal realistic validity should exist in a business game (Gentry 1990, chap. 5). In this context, the use of the agent-based approach provides new possibilities to cope with complexity and to simulate realistic scenarios.

The pursuit of realism applying the agent-based approach also endeavors challenges since, as Elgood (1996, pg. 76) stated, a complex simulation is not necessarily a good or realistic simulation. To minimize the risk of an unsuccessful application of the agent-based technique to model demand in business games, the correspondence between the emergent properties of the market and the properties of models studied should be verified. The same emergent properties observed in the models should also be observed in an agent-based model.

The fact that both macro and micro levels of a marketplace could be modeled using the agent-based approach could provide more information. The exposure of the agent-based model and the presentation of further information regarding the micro-levels of the simulation could improve the participants perception of cause-effect relationships, even in complex models. This study proposes itself to determine how the information should be presented effectively to contribute to the understanding of cause-and-effect relations.

The primary development idea is to base the model of consumer behavior in the rational theory of consumer choice. This simplistic theory will act as the starting point for a more complex and realistic model which will incorporate ideas from more recent and complex economic models, from models in the ACE field (such as Janssen and Jager's model, the CUbes model) and ideas from other complementary knowledge areas (Chapter 3).

Furthermore, a novel business game will be prototyped to investigate how the exposure of the developed agent-based model could promote a better understanding of the game (Chapter 4).

Chapter 3

Conceptual model

"I can't work without a model. I won't say I turn my back on nature ruthlessly in order to turn a study into a picture, arranging the colors, enlarging and simplifying; but in the matter of form I am too afraid of departing from the possible and the true."
Vincent Van Gogh, 1888

The main question of this research was whether the agent-based modeling technique could enhance the realism and understandability of a business game. To further investigate this question an agent-based model was developed and evaluated. Given the complexity of the problem, the model scope was restricted to the central area of a business game − the marketplace. This chapter describes the development process of the model of consumer behavior and underlying architecture.

The development of the conceptual model of consumer behavior followed an iterative and incremental approach. The creation of incremental and iterative versions was intended to lead to a process of iterative enhancement where valuable lessons could be learned along the process.

Prior to the design of the consumer model an architecture for the consumer behavior had to be created. The architecture implemented the reasoning mechanisms whereas the consumer model represented the embodiment of the consumer preferences. The most important characteristic of the designed architecture was the flexibility to adapt to any kind of consumer model.

The developed architecture is abstractly defined in section 3.1 while section 3.2 describes briefly the process of designing the several consumer models.

3.1 Deliberative architecture of consumer behavior

In the beginning of the development of the conceptual model, the first important question which arose, was which agent architecture would be more suitable to model consumer behavior. From the possible alternatives (see Remondino 2005) the deliberative architecture was preferred.

Deliberative architectures allow the construction of an internal model of the world for each agent and agents possess planning capabilities to undertake a sequence of actions with the intent to satisfy a given goal (Shen et al. 2001). These two characteristics are important for designing the mind of a consumer since real consumers have limited access to information and often have to alter their purchase intentions due to the unavailability of products.

The developed architecture was inspired by the deliberative *Beliefs, Desires and Intentions* (BDI) architecture (Shen et al. 2001). Accordingly, the internal state of each consumer was described by means of a set of rationality elements namely *beliefs*, *desires* and *intentions*, by which the consumer planning system, based on these representations, selected the optimal bundle of products to purchase. The architecture contained representations of the following elements:

1. The beliefs of the consumer agent represented his expectations relative to the current state of the world. Two types of beliefs were defined:

    - Belief in the existence of a certain product at a certain price: the consumer could believe a store had a product at a particular price.
    - Belief in economic capacity: the consumer had the belief he could purchase at least one additional unit of a product given his budget.

2. The desires of the consumer represented his aspirations. For example, the consumer had the desire to consume a given product.

3. The intentions represented the deliberative states of the agent. The consumer could generate a number of desires, each for a bundle of products, possibly from different stores, some of which could be transformed into an effective plan.

4. Plans represented the sequences of actions the consumer performed to achieve his intentions. For example, an agent could generate a plan witch comprised the action of purchasing X number of apples from store M and Y apples from store N.

The decision-making system of the architecture was based on the economic theory of consumer behavior (see Section 2.1.2). An additional reasoning step was introduced to the process, with the intent to unify classical theory and the rationality elements of the architecture. The reasoning steps of the deliberative consumer were the following:

1. If the consumer had the desire to consume, he would develop a list of all combinations of goods he was able to buy, according to his beliefs in the existence of products. For each combination of goods an intention would be generated[1].

2. The consumer would select from among the feasible intentions the particular one he preferred according to his consumer model which attempted to maximize an utility function. From this intention a plan to purchase products from stores would be generated.

3. The consumer would attempt to accomplish his plan as a factual sequence of actions. Following each action, the consumer beliefs would be updated accordingly. The agent might not succeed in accomplishing every single action. In that case, another plan would be generated.

For a better understanding of the architecture suppose the following scenario: a consumer with a budget of 300 could purchase products from a market of two firms, *firm1* and *firm2*, each producing two products, X and Y. Suppose firm1 had the following prices $p_X = 100, p_Y = 200$ and firm2 $p_X = 120, p_Y = 180$ (the consumer had access to the selling prices of both firms).

In the first step of his reasoning process, the consumer would produce a list of purchase intentions for all the possible combinations of products. The generation of such combinations could be restricted in accordance with the consumer model.

In the second reasoning step the consumer would attempt to maximize the value of his utility function $U(x, y)$ where x was the quantity of product X from firm1 and y the quantity of product Y from firm2. The maximization of the utility function varied according to the model of consumer behavior. As a result of the utility maximization, a plan to purchase a given quantity of product X from firm1 and quantity of product Y from firm2 would be generated.

[1] Each consumer can only buy a discrete quantity ($q \in \mathbb{Z}$) of each product.

Suppose the consumer attempted to purchase product X from firm1 and did not succeed, since firm1 no longer had the requested product. The consumer would restart the reasoning process, now with the updated belief that firm1 did not have the product X in stock.

The cycle would finish in case the consumer believed no affordable products existed, when the consumer exhausted his budget, or if the generation of a plan yielded an empty set of actions.

It was from the complex (indirect) interaction of consumers that emergent demand was raised. Each consumer did not possess, at the beginning of the execution, information regarding the intentions of other consumers nor information relative to the available quantities of products at the firms.

The existence of an internal state of the world, specific to each consumer, represented an important characteristic of this architecture since this feature created a world of imperfect information. Moreover, this characteristic could be explored to introduce marketing effects in the sense that marketing could be used to control the beliefs of the consumer.

The architecture allowed a clear separation between the intentions of consumers and their successful actions which consequently improved the quality of the information provided. For example, suppose a scenario of two firms, firm1 and firm2, each one producing 50 units of a product. Suppose firm1 set a market price of 100 and firm2 a price of 200. In this scenario it was more informative to visualize 100 consumers moving towards the first firm and later on, 50 of them, unsatisfied, moving towards the second firm, than to see 50 consumers approaching firm1 and 50 of them approaching firm2 at the beginning of the round.

Although the planning process of each consumer was independent from other consumers, the reformulation of intentions was influenced by the decisions of other firms and consumers. A consumer decided independently which product to purchase, however, the accomplishment of his decision depended upon the purchases of stores and peers. This resulted in an effective interaction between consumers and consequently in a more closely interdependence between the decisions of each firm.

In conclusion, the main benefits of the developed architecture were: (a) the introduction of a scenario of imperfect information, (b) the separation between purchase intention and concrete successful actions and (c) the inter-dependence and influence consumers exerted upon each other.

3.2 Models of consumer behavior

Even though the agent-based models studied in section 2.3, namely the model of Janssen and Jager (1999) and the CUbes model (2002), presented interesting characteristics they comprised a particularity which made them not suitable to be directly implemented as models for business games − price was not explicitly considered. Furthermore, the models were, to a certain extent, very complex and given their ground-breaking traits, conveyed the inherent risk of not being effortlessly understood. Therefore, a decision was made to develop a simpler model, where the variable price would play a central role and whose foundations would be based on rational consumer choice. Afterwards, a more complex model would evolve from this version through the introduction of ideas present in agent-based and economic models (discussed in chapter 2).

The most important characteristics which the developed models should convey, were flexibility and abstraction. Although the development of a model which was tailored for a specific type of market was simpler, the purpose of this study was the creation of a model which could simulate any type of market. The model should be able to simulate a market with more or less competitors, selling substitute, ordinary or complement goods whose consumers could be more or less eager to purchase products.

It was also essential that the parameterization of the models was straightforward and did not involve a large number of control variables, such as the opposing example of the CUbes model (see Section 2.3.3). This section describes the several consumer models developed.

3.2.1 Linear model

$$f(x_1, x_2, ..., x_N) = x_1 + x_2 + ... + x_N \tag{3.1}$$

where $x_1, x_2, ..., x_N$ represent the quantities of the product from firm $X_1, X_2, ..., X_N$ which could be purchased at prices $p_1, p_2, ..., p_N$ for a consumer with a given budget.

The first model was a simplistic implementation of the rational consumer choice theory. The model considered the existence of the several firms producing the same product with equal marginal cost. Each consumer would attempt to maximize the utility function described in Equation 3.1 (considering products were perfect substitutes). In case of identical utility values the consumer would prefer bundles which contained products sold by the same firm. As last

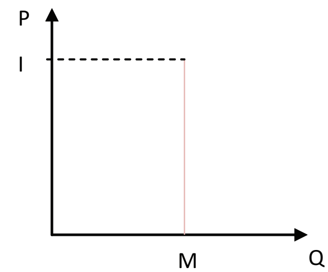


Figure 3.1: The first version of the neoclassical model considered that each consumer would only buy one product.

resort, a random factor was used to decide. Three versions of this model were developed:

1. A first version where the consumer would buy one unit (restriction: $x_1 + x_2 + ... + x_N = 1$) and all consumers had the same budget I.

2. A second version where each consumer would exhaust his total budget and all consumers had the same budget I (see Fig. 3.2).

3. A third version similar to the second version but considering a probabilistic distribution of budget.

In the first version, the consumer would attempt to purchase one unit of the cheapest product in market, as long as the cheapest price wouldn't exceed his budget. Given the fact that all consumers had the same budget (I), the market demand curve which emerged was perfectly inelastic (see Figure 3.1). Although this first version respected the law of demand the model was constrained in terms of its emergent range of price elasticity.

The second version was an improvement over the first version in terms of range of emergent price elasticity. The consumer could purchase as many units of a good as he could afford (restriction: $p_1x_1 + p_2x_2 + ... + p_Nx_N = I$). Price elasticity was equal to 1 in all points along the curve (see Figure 3.2). This result followed from the fact that each consumer would spend his entire budget on a product disregarding the quantity purchased or price. Although this was in line with neoclassical economic theory, both the emergent equation and the behavior of the consumer were not extremely flexible.

The third version introduced a probabilistic distribution of budget. This alteration led to the existence of a demand curve with variable price elasticity.

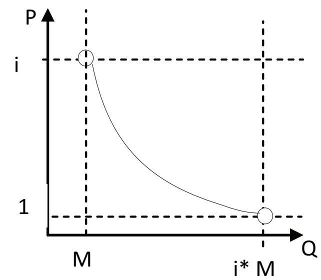


Figure 3.2: The second version of the neoclassical model considered that each consumer would exhaust his budget.

Considering a Normal (see example in Figure 3.3a) or Fisk distribution[2], price elasticity of demand would diminish along the curve, as more and more consumers could afford to spend their entire budget on a product, and would reach the unitary value when the price of the product reached the minimum budget value (all consumers were spending their budget) maintaining this value throughout the rest of the curve (see example in Figure 3.3b).

Although the third model was in accordance with economic theory, the model was not extremely flexible and the result was not entirely intuitive. The fact that a consumer could be willing to purchase an enormous quantity of product when the product had an extremely low price was not very realistic in an everyday situation.

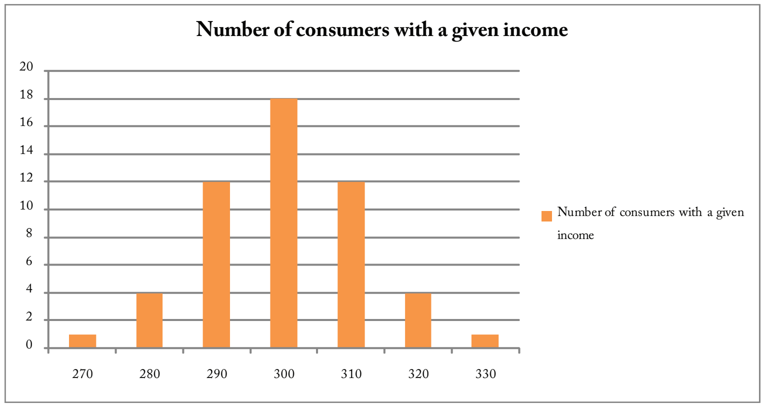
The dilemma could be solved by restricting the amount of quantity purchased by each consumer. However, in the real world, consumers are more willing to purchase more units of a good if its a bargain. Moreover, economic theory states that consumers are never satisfied ("more is better"). The following model attempted to solve this problem from a different perspective.

3.2.2 Cobb-Douglas model

To solve the problem of consumer satiation, substitute effects had to be introduced to the model. In a real-world situation, a consumer would not spend his entire budget in a single product since he could purchase other products.

To accomplish this solution, another product − the "money product", representing all the other possible products that the consumer could purchase

[2]The log-logistic distribution or Fisk distribution is a continuous probability distribution for a non-negative random variable. It is used in economics to model the distribution of wealth or income.



(a) Budget distribution

(b) Emergent demand curve (Quantity vs Price)

Figure 3.3: The third version of the neoclassical model considered a population with variable budget.

was introduced to the utility equation. The price of this composite product (p_m) was fixed and represented the "value for money" of each consumer. To reflect the inter-dependence between the quantities purchased of each product a Cobb-Douglas function was used as the utility function (see Equation 3.2).

$$f(x_1, x_2, ..., x_N) = x_1^{a_1} x_2^{a_2} ... x_N^{a_N} m^{a_m} \ \ a_i \in \mathbb{Z}^+ \tag{3.2}$$

$$x_1 p_1 + x_2 p_2 + ... + x_N p_N + m p_m = I \tag{3.3}$$

$$m = (I - x_1 p_1 + x_2 p_2 + ... + x_N p_N)/p_m, \ \ p_m \in \mathbb{Z}^+ \tag{3.4}$$

where $x_1, x_2, ..., x_N$ represent the quantities of products from firms $X_1, X_2, ..., X_N$ which could be purchased at prices $p_1, p_2, ..., p_N$ for a consumer with a given budget

(I) and m represent the quantity of the "money product" and p_m the price of money.

The formula used to calculate the preferred affordable bundle with Cobb-Douglas preferences is a well known equation (see Equation 3.5), which simplified the calculations of the most preferred quantities for each product[3].

$$(x_1^*, ..., x_N^*) = (\frac{a_1 I}{(a_1 + ... + a_N + a_m)p_1}, ..., \frac{a_m I}{(a_1 + ... + a_N + a_m)p_m}) \qquad (3.5)$$

where $x_1^*, x_2^*, ..., x_N^*, x_m^*$ represent the most preferred quantities of products from firms $X_1, X_2, ..., X_N$ affordable at prices $p_1, p_2, ..., p_N$ for a consumer with a budget (I).

This model had the advantage of presenting inter-dependence between the quantities demanded. In case of a price reduction of both products or budget increase, quantities demanded would be reduced/increased accordingly. However, the increase or reduction was always proportional − the consumer would always allocate a certain percentage of his budget to each product. The following model introduced this alteration to solve the dilemma. Realistically, the consumer at some moment in time, should be satisfied and should decide to save the rest of his budget. The following model attempted to solve this dilemma.

3.2.3 Discount-rate model

The third model developed was based on the idea of associating a discount rate to the affordable quantities. A tax rate, with a value smaller that one, associated with each quantity of a product would result in the product exhibiting a diminishing marginal utility. This idea originated the utility function of Equation 3.6.

$$f(x_1, x_2, ..., x_N) = (\sum_{j=1}^{x_1} b_1^j)^{a_1} + ... + (\sum_{j=1}^{x_m} b_m^j)^{a_m} \;\; a_i \in \mathbb{Z}^+, 0 < b_i \leq 1 \qquad (3.6)$$

$$x_1 p_1 + x_2 p_2 + ... + x_N p_N + m p_m = I \qquad (3.7)$$

$$m = (I - x_1 p_1 + x_2 p_2 + ... + x_N p_N)/p_m, \;\; p_m \in \mathbb{Z}^+ \qquad (3.8)$$

where $x_1, x_2, ..., x_N$ represent the quantities of products from firms $X_1, X_2, ..., X_N$ which could be purchased at prices $p_1, p_2, ..., p_N$ with preferences a_i for a consumer with a given budget (I), m represent the quantity of the "money product" and p_m the value for money and $0 < b_i \leq 1$ represent the decay rate.

[3] Refer to Varian (1990) for a complete demonstration of the derivation of the formula.

This new utility function solved the dilemma of "consumer satiation". The addition of additional units of product would result in a total utility increase while, at the same time, in a decreasing marginal utility due to the $b_1^{x_1}$ factor.

The smallest the decay rate $(b_1, ..., b_m)$ associated with a product, the more rapidly marginal utility would decrease. The lesser the value of money (p_m) the greater the value the consumer attributes for money would be.

Although the utility function yielded the desired results, the utility function (Equation 3.6) was non-linear, which meant that in order to calculate the most preferred quantities, algorithms such as the Simplex, commonly used to solve linear problems, could not be employed. A specific algorithm had to be developed to solve the optimization problem.

The developed optimization algorithm used a Greedy approach to solve the problem of finding the optimal bundle. The algorithm started with an empty bundle of products and would choose successively the product which should be added to the bundle, according to the highest utility resulting from testing the addition of all currently affordable products.

The major advantages of this model were the following:

- More than one type of product could be sold by each firm in the same market. This addition increased comprehensively the game complexity.
- A preference for each product was introduced to the model through the use of the factor $a_i \in \mathbb{R}$.
- Consumers would be satisfied after a certain quantity of a good, depending on the price set, valuing their money instead.

The model allowed the simulation of ordinary, substitute and complementary products. One kind of good is said to be a substitute for another kind, as long as the two kinds of goods can be consumed in place of one another (such as margarine and butter). To simulate perfect substitute goods the two goods should have equal decay rates (b_i) and preferences (a_i) and the decay rate should be raised to a power reflecting the quantities already purchased of the other substitute product: $(\sum_{j=x_2}^{x_1+x_2} b_1^j)^{a_1}$. For instance, if a bundle of goods had one unit of margarine and zero units of butter (with an utility of 0.8^1 for $b_1 = 0.8$) the addition of one unit of butter should increase the overall utility by 0.8^2.

Perfect complementary goods, goods which have to be consumed in combination (such as the purchase of a left and right foot shoe), could also be simulated. This could be achieved by adding another product to the equation: the "complementary product". For example, suppose a scenario of two perfect complementary products where the utility function was depicted by Equation 3.9. The quantity of the complementary product was given by the formula $floor[(x_1 + x_2)/2]$ meaning that a unit of complementary good was added when one unit of product 1 and one unit of product 2 was in the bundle.

$$f(x_1, x_2) = \sum_{j=1}^{x_1} b_1^j + \sum_{j=1}^{x_2} b_1^j + \sum_{j=1}^{x_{12}} b_1^j + \sum_{j=1}^{x_m} b_m^j \tag{3.9}$$

where x_1, x_2 represent the quantities of the two substitute products X_1, X_2, x_{12} represent the quantity of the complement product which is originated from two units of product X_1 and X_2, m represent the quantity of the "money product" and $0 < b_i \leq 1$ represent the decay rate.

The formula could be explored to simulate more intricate relationships between goods. Suppose the case of a meal of steak and potatoes. An additional unit of complementary product would only be added to the equation when the quantity of potatoes reached a certain number of potatoes (for example four) and the quantity of steak in the bundle was at least one. Supposing the potatoes were cheaper than steak, the consumer would continue to add potatoes to the bundle until the addition of the steak increased the overall utility to a higher utility (bundle with 4 potatoes, 1 steak and 1 complementary product).

This formula allowed to explain why in certain situations, in which the consumer does not afford the complementary good, the consumer still attributes utility to the individual purchase of goods.

3.2.4 Drive model

Although the discount-rate model presented an increased degree of complexity and flexibility compared to the previous models a question remained unsolved − how to determine the price of the "money product". This model attempted to solve this question by extending the discount-rate model previously described.

The development of this model introduced an alteration to the deliberative architecture of the consumer − the introduction of *drives*. The drives of the consumer simulated the forces compelling the desires of the agent.

The use of drives was inspired by the theory of motivated behavior of Hull

(1943). According to this theory, internal human behavior is directed to actions which reduce the level of the internal drives/necessities of the individual[4].

Hull's theory defined the term "reaction potential" (sEr) of an organism as the probability with which a given behavior occurred. The theory was expressed mathematically in the form of Equation 3.10, where the probability of a given reaction was a multiplicative law combining habits and the drive level (reward and inhibition factors were included later).

$$sEr = DKH - I \tag{3.10}$$

where sEr represents the probability of the occurrence of a given behavior, D represents drive level, K represents reward, H is the habit strength of that action and I represents inhibition.

Hull's theory inspired the inclusion of a *drive of hunger* to the discount-rate model as a mean to simulate the evolving necessities of the consumer. Each drive had a value expressing the consumer drive to act ranging from 0 to 1. The drive value evolved according to external stimulus applied to the consumer.

Each round the drive of hunger was increased by a certain amount. In case the drive level was already at its maximum the level remained unaltered. At the end of the round, each consumer would choose several products from his stock to decrease his hunger. Each product would contribute with a certain satisfaction value to the drive reduction. The goal of the consumer was to reduce his drive to a minimum of zero.

The drive of hunger was responsible for determining the "money value". The higher the current drive level, the higher the money value would be, or in other words, the hungrier the consumer the less important money was.

A variable had to be considered, the tolerance level (t_l). The tolerance level ($1 <= (t_l) <= 0$) represented the level of the drive at which the consumer would spend his entire budget (I) on products. As the drive value (D) tended to increase the price of money (p_m) would also increase leading to a lower value attributed to money. Using this model, the game designer would only have to parametrize the tolerance level (t_l). The general formula used to calculate dynamically the value of money is depicted in Equation 3.11.

[4]Hull's theory has been implemented by Schmansky (2004) in an agent-based model.

$$p_m = \frac{D}{t_l} I,\ 0 \leq D \leq 1,\ 0 < t_l \leq 1 \tag{3.11}$$

where p_m is the price of money at the tolerance level (t_l), D is the current drive level and I is the consumer budget.

3.3 Conclusion

This chapter provided an overview of the methodology used to develop the deliberative architecture and the model of consumer behavior. The chapter attempted to answer the question of how to create a complex and realistic simulation model for business games using the agent-based approach.

The first section of the chapter described in general the developed architecture of consumer behavior. The architecture represented a common structure for the reasoning process of a consumer, regardless of the consumer model used. The architecture was inspired by the BDI architecture.

The main advantages of the architecture was that it allowed the consumer to form an internal view of the external world through his beliefs. Other important features of the developed architecture were the emergent influence each consumer had upon the actions and decisions of others and also the process of self-adaptation each consumer engaged if their purchase plans did not succeed.

The flexibility of the architecture developed allowed the implementation of different utility functions. Consequently four different consumer models were developed: Linear, Cobb-Douglas, Discount-rate and Drive model. Each of these models was inspired by the classical economic theory of consumer behavior, even though, the inter-disciplinary concepts also influenced the design.

Classical economic theory was a flexible framework for developing consumer behavior. Notwithstanding the potential associated with this framework the major challenge lied in understanding the fundamental principles of such framework and trying to customize the framework to simulate specific behaviors.

A major dilemma, was the inclusion of a sense of satisfaction by each consumer. At extremely low prices it wouldn't seem realistic if a consumer spent his total budget on a product. The major solution for this problem was the inclusion of a "money product" and the creation of a diminishing marginal utility associated with each product in the discount-rate model. The drive model was an extension to the discount-rate model which included drives which allowing the simulation of necessities and its influence upon the reasoning process.

Even though the final model did not simulate a realistic consumer (marketing effects, loyalty, direct interaction between consumers), it was a step closer to that objective. The advantages of using microeconomics as the theoretical foundation for the models were the abstraction and flexibility provided by the neoclassical framework. Ideas from other fields such as artificial intelligence and psychology also contributed to a more validated and complete model.

Chapter 4

Implementation

"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."
Herbert Simon, 1971

This study hypothesized that the exposure of the underlying model and the disclosure of information could enhance the comprehensibility of a business game. To implement the conceptual models designed and to evaluate that hypothesis, a whole game was developed.

The first section of the chapter presents the general concept of the game. Section 4.2 details the process of selecting and implementing the most appropriate techniques to present the information enclosed in the conceptual model.

4.1 Game concept

The developed game was a functional business game restricted to the functional area of marketing. The game modeled a competitive market in which each participant managed a retail store and sold a number of products to the final consumer. The performance of each firm was evaluated according to their current wealth. The participant had to decide on two fundamentals: (a) quantity of each product the store should purchase from the available suppliers (b) selling price of products at the store (see the game interface in Figure 4.1).

The game was based on a turn-based architecture, as the game would flow throughout several rounds in a continuous cycle of input decisions, model exe-

Figure 4.1: The game interface was formed by the decisions panel, simulation panel and information relative to firms/consumers and suppliers.

cution and presentation of results to the participants. Even though the game purpose was not to mimic a specific industry, a great effort was put on creating a customizable game. A game editor was developed to customize the scenario, the consumers and the industry environment (see Figure 4.2).

In terms of period of time simulated, the game was more tactical than

Figure 4.2: A game editor enabled the customization of the model.

Table 4.1: Classification of the game developed (according to table 1.2).

Classification dimension	Game classification	Description
Organizational focus	Functional game	The game was focused on the functional areas of marketing.
Industry specificity	Industry specific	The game was highly customizable
Period of time simulated	Tactical	The game required decisions inputs on a quarterly basis

strategic, since the nature of the decisions and the minor volume of purchases during each round implicitly led the game to acquire a tactical direction. The classification of game developed, according to the major dimensions identified in Table 1.2, is summarized in Table 4.1. Technical details of the game are described in Appendix A.

4.2 Visualization of information

If creating an informative model was a major objective of this study, the successful presentation of the information comprised in the model was a goal no less important.

Several authors argued that for a business game to be realistic it should conceal information regarding the model, information which may not be accessible in real-world situations (see Section 1.4). This topic was not the major concern of this study, as this study was uniquely committed to guarantee that business games could become more understandable. The choice of which part of the model should be disclosed or concealed is a subject matter left at the game designer discretion (according to the game audience and specific purpose).

The development of the game architecture was decisive, as a means to investigate the most appropriate information system which should support the business game. The solution proposed was intended to be abstract and not specific to the game developed. This section is focused on describing in an abstract manner the information system created using some examples of the game developed to illustrate the text.

4.2.1 The simulation of performance indicators

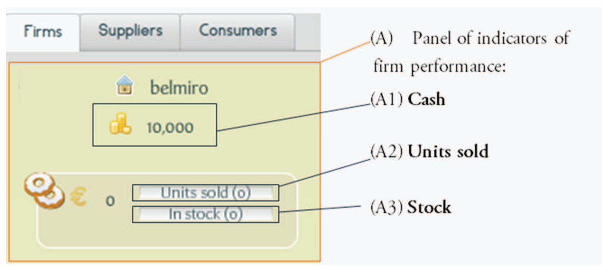
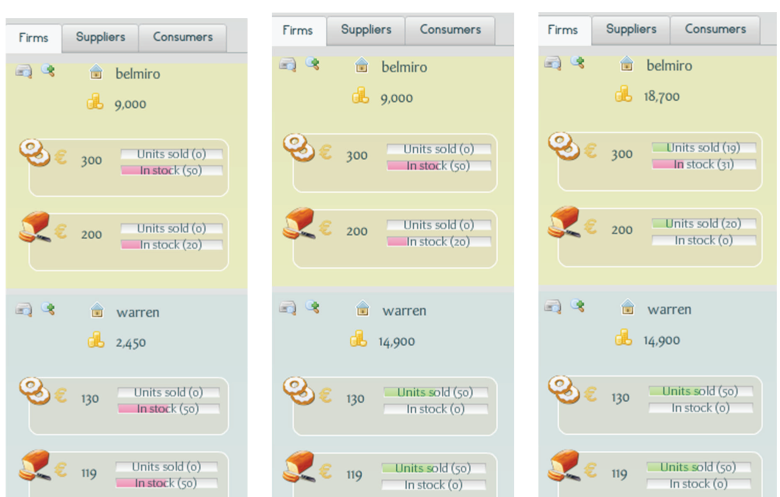
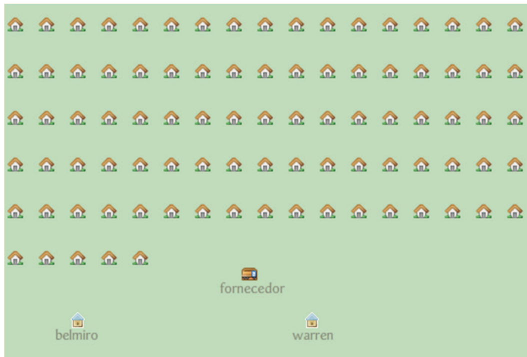


Figure 4.3: Indicators of firm performance.



(a) Round start (b) Middle of round (c) End of round

Figure 4.4: With agent-based models participants could analyze performance indicators changing in virtual time.



(a) Scenario Map: each house had a consumer associated

Figure 4.5: The representation of consumers was preferred to be graphically suggestive and adjustable for larger or smaller populations of consumers.

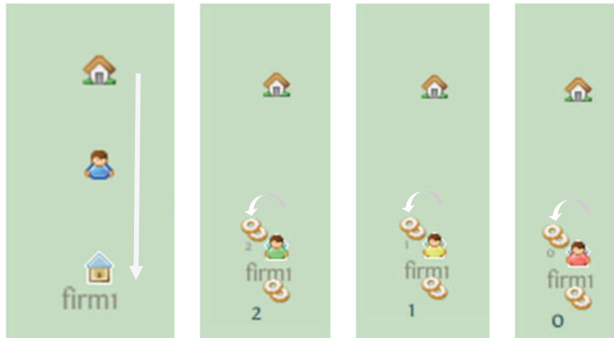
One of the aspects which could be improved in business games was the presentation of results. In majority of the business games results are presented in a static manner through the use of spreadsheets. One advantage of the agent-based models is that the final results of a round, are not the outcome of a single equation, they emerge from the complex and time-based interaction of several agents. Consequently, the internal execution of each round could be displayed in virtual time.

The game allowed participants to analyze in virtual time the alteration of several indicators of performance of a particular firm, namely the sales, stock and current cash (see Figure 4.3). It was possible to visualize the sequence of purchases, such as: firm1 sold the totality of his stock of cookies at 100 and afterwards, firm2 sold 50% of his stock of cookies at 150. Consequently, participants could retrieve additional conclusions, other than the ones available from the analysis of final results (see Figure 4.4).

4.2.2 The simulation of consumers

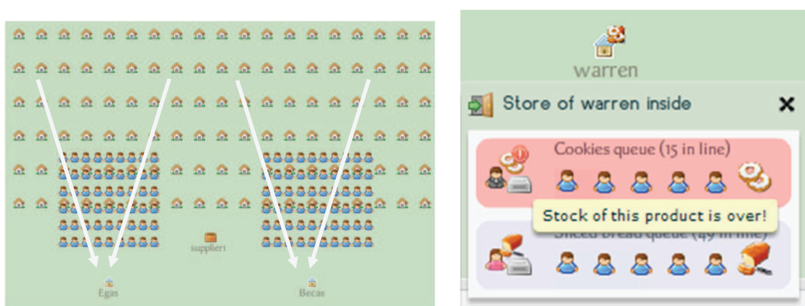
The agent-based model of the marketplace comprised more information than common equation-based models, particularly information regarding the behavior of consumers. The presentation of such information enclosed a number of problems. The first problem was how to represent the population. To represent the population a map was created with a number of houses and in each house lived one or more consumers (see Figure 4.5a).

An important issue, which led to a higher number of experiments and alter-



(a) Movement (b) Intention accomplished (c) Intention not fully accomplished (d) Intention not accomplished

Figure 4.6: The movement of the consumer and his change of state, displayed using colors and/or colors, represented the intentions of each consumer.



(a) Start of round (b) Queues inside a store

Figure 4.7: The coordination of consumers reflected the internal model execution.

ations, was the representation of the purchases of consumers. The notion of sequence and interdependency between consumers was not captured completely using graphical state changes solely. Therefore, the intention to purchase a particular product from a firm was represented by the movement of one consumer from his house to the firm while the accomplishment of the intention was expressed through a graphical change of state (see Figure 4.6).

In the game at the beginning of a simulation turn, a flow of consumers would move simultaneously to their desired firms to accomplish their purchase intentions (see Figure 4.7a). The sequential dynamic of the purchases was captured using a queue mechanism in each store (see Figure 4.7b).

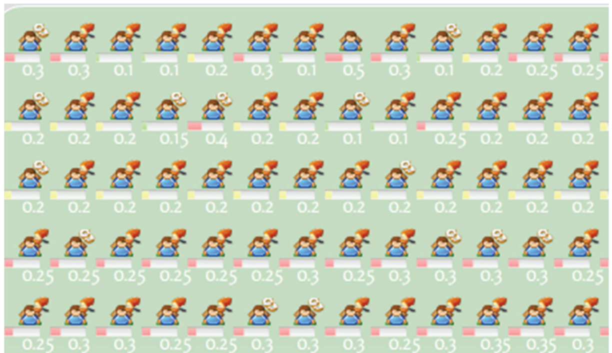


Figure 4.8: Participants could visualize the hunger of each consumer (green being not hungry and red being very hungry) through a scenario filter.

4.2.3 Individual and aggregated information

Even though the simulation execution provided a substantial degree of information, additional information had to be provided. The understanding of the simulation was difficult as the observer had to process a large amount of data simultaneously. To simplify the assimilation process, the interface provided a number of tools which aggregated information. The game employed two techniques to aggregate information: the use of charts and scenario filters. Scenario filters presented information on the map (see Figure 4.8).

Information regarding the decisions of each agent was also provided. The participant could access the sequence of intentions and thoughts of a consumer with a single click on the consumer icon (see Fig. 4.9).

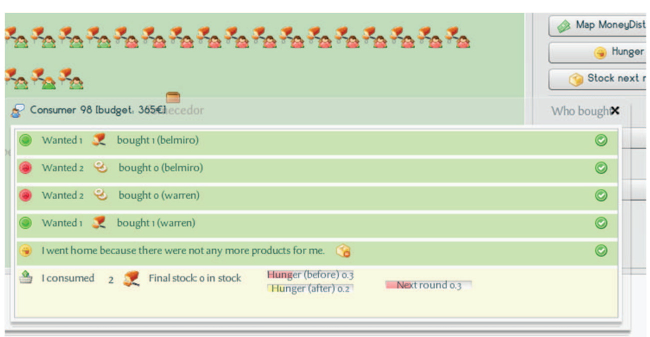


Figure 4.9: Information regarding an individual consumer.

4.3 Conclusion

An entire game was developed to implement the drive model described in chapter 3 and used to test several approaches for presenting information. The developed business game was a functional game based on the metaphor of a retail market.

The model underlying the game presented only two exogenous variables to the participants, the price set at the stores and the quantity of products purchased from supplier, the simulation of the underlying business environment was quite complex. Such complexity led to the existence of a large amount of information, not usually present in standard models of business games, which needed to be efficiently presented to the participants. This fact represented the major challenge of the game implementation.

The design of the information system of the game aimed at two complementary goals: (a) the creation of a game where the participant could visualize the simulation of the behaviors of the consumer agents in virtual time and (b) the creation of a game where the information regarding the simulation could be presented in a static manner using techniques such as statistic charts and map filters. The following chapter evaluates the effectiveness and importance of the informative elements implemented in the game developed.

Chapter 5

Results

"The proof of the pudding is [in] the eating."
Miguel Cervantes, 1616

The evaluation of the solution proposed had to take place both at a theoretical and experimental level. To evaluate the hypothesis which stated agent-based models could enhance the realism of a business game, the conceptual models described in chapter 3 were reviewed in section 5.1 according to their economic emergent characteristics, previously identified in the state-of-the-art models (Table 2.2).

The second hypothesis, the one which stated agent-based models could improve the comprehensibility of business games was tested experimentally. Such evaluation is described in section 5.2.

5.1 Theoretical results

A major goal of this study was the design of a realistic model of consumer behavior for business games. However, the experimental evaluation of realism with participants, would difficultly achieve satisfactory results, since the agent-based models developed were still in an incipient stage. Moreover, it was not clear if participants could evaluate realism correctly. Therefore, the evaluation of the realism of the models passed through the verification of compliance of the emergent behavior of the models with classical economic theory.

The several agent-based models developed unraveled the problem of using average values of the firms decisions to calculate demand. In the models, market demand was independent from the decisions of each firm and consequently,

	Linear model	Cobb-Douglas model	Discount-rate model	Drive model
Demand law	✓	✓	✓	✓
Variable elasticity of price	✓[1]	✓	✓	✓
Stable (minor input restrictions)	✓	✓	✓	✓
Interactivity between variables	✗	✓[2]	✓	✓
Demand determinants relative to the consumer	✓	✓	✓	✓
Firm and industry demand modeled	✓	✓	✓	✓

Table 5.1: Comparison between the developed agent-based models (models described in chapter 3).

demand directed towards a firm was not constrained artificially by the other firms decisions.

The agent-based models also proved to be more flexible in terms of emergent behavior. A mere alteration in the utility function of each consumer could result in a different demand curve and market structure.

With regard to compliance with economic theory, the models presented positive results in the totality of the features identified in chapter 1 (see Table 5.1), which were used to compare the models used in business games. Emergent behavior was in line with the expected behavior of standard models.

All the agent-based models introduced supplementary information, regarding the consumers, than standard models for business games. As a consequence, it was more straightforward to modify the determinants of demand relative to the consumer.

Considering the interactivity between the determinants of demand considered by the consumer, only the drive model achieved the desired effects, resulting in a consumer who pondered his purchases according to the quantity already consumed and his evolving necessities.

In conclusion, the agent-based models produced the same emergent behavior expected from standard models, provided additional flexibility and solved some of the dilemmas which standard models presented, such as the use of mean values determinants of demand and the non-existence of determinants of demand related to consumer. Moreover, the drive model model introduced the presence of a population of boundedly rational consumers with evolving necessities.

[1] The first version of the linear model presented unitary demand elasticity of price.

[2] The interactivity which existed in the Cobb-Douglas model was not the desired interactivity. The consumer would always spend his entire budget proportionally on products.

5.2 Experimental results

A major question of this study was whether an agent-based model could enhance the comprehension of the participants of the business game. This question had to be tested experimentally with real participants. This section presents the empirical evaluation of the game which implemented the drive model and enclosed the informative elements described in Chapter 4.

According to Cannon and Burns (1999) an "impressive" number of studies have attempted to evaluate the comprehension of students in business games. The same author considered that it was difficult to support objectively even the most fundamental claims of participants comprehension. This study assesses the comprehension of participants evaluating their perception of their own comprehension.

The following section describes the empirical evaluation of the game in two experiments. The first experiment assesses the improvement of the comprehension of the game by manipulating the presence/absence of informative elements in the game. The second experiment investigates the contribution of each informative element to the overall comprehension of the game.

5.2.1 Methodology

This study comprised two experiments. The first experiment measured four dependent variables: (1) the interface *usability*, (2) *usefulness* of the information for the game comprehension, (3) the *amount of information* presented and (4) the perception of the participant of his *comprehension* of the game. One single independent variable was manipulated, the presence or absence of informative elements in the game. To measure these variables a 5-point likert-scale was used, with 1 representing disagreement and 5 agreement. In the case of the dependent variable amount of information a 5-point likert-scale was used with 1 representing insufficient, 3 adequate and 5 excessive.

The second experiment comprised a single independent variable, the *information element* to be classified by the participant. The experiment evaluated twelve information elements of the game interface. Two dependent variables were measured: the *usefulness* for the game comprehension and the *ability to be easily understood*. To measure these variables a 5-point likert-scale was used, with 1 representing disagreement and 5 agreement.

A total of 15 male volunteers, between the ages of 22 and 26, from a computer science background, took part in the two experiments. The participants varied in terms of their prior experience with business games.

The participants were subject to two different exercises: one exercise (exercise 1) where participants played the complete game developed and another exercise (exercise 2) with the same game excluding the informative elements (see Appendix B and C for an extensive description of the scenarios). The order by which the participants performed the two exercises varied.

Each participant was provided with a debriefing and a survey document before starting the test (copies of the debriefing and survey documents can be found in Appendix B,C and D).

The survey (see Appendix D) was divided in four parts: a part for each exercise composed of seven questions (part I and II), a third part composed of twenty two questions (part III) and part IV which consisted of two open questions regarding the participants suggestions to improve the game comprehension and the visualization of the information.

After receiving the debriefing and survey documents, two participants played against each other in one of the two available exercises. After each exercise the participants completed part I or II of the survey, respectively. At the end the participants completed the two final parts (III and IV).

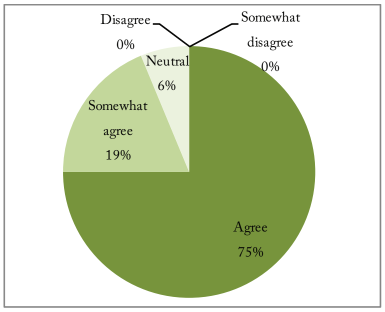
5.2.2 Quantitative data for the first experiment

The first experiment aimed to study the contribution of the presence of informative elements to the overall comprehension of the underlying model of a business game. The results of the two exercises of the experiment are depicted in Figure 5.1, with exercise A being the exercise with the complete game and exercise B the exercise with minimal informative elements.

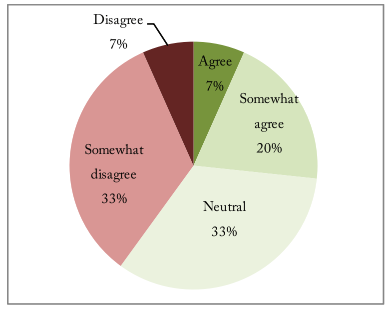
The experiment revealed high levels of agreement (95%) when the participants where asked if they understood the results of the game in the exercise which provided a complete set of informative elements (see Chart 5.1a). However, in the absence of those elements (exercise B), the responses of participants varied, revealing a low level of agreement, with 40% of the respondents stating they were not able to understand the results of the game. In terms of comprehension of the results, all participants rated exercise A with a higher (87.5%) or equal (12.5%) grade than exercise B.

The results suggested that the interface of exercise B was slightly more usable than the interface of exercise A (see Figure 5.1c and 5.1d).

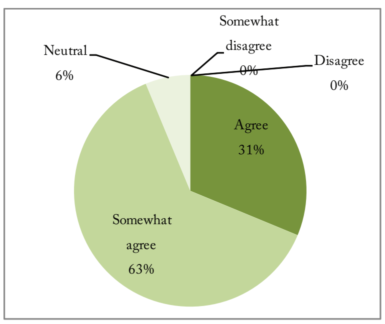
Although a high percentage of participants described the information pro-



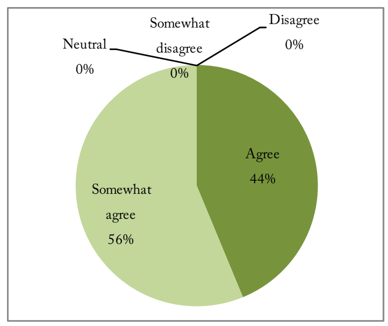
(a) I understood the results (ex. A).



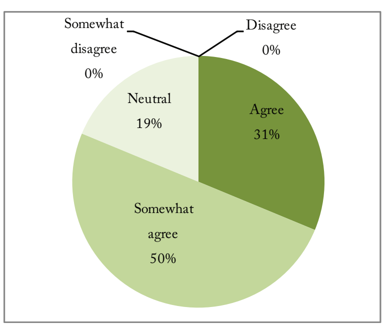
(b) I understood the results (ex. B).



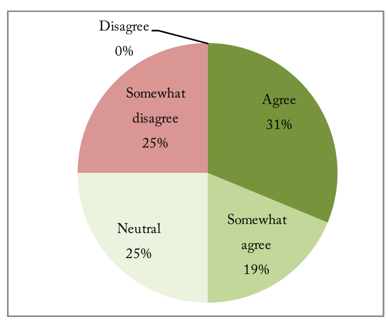
(c) The interface was usable (ex. A).



(d) The interface was usable (ex. B).



(e) The information was useful (ex. A).

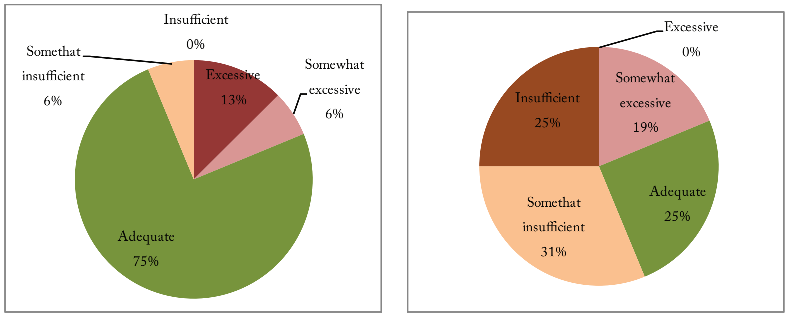


(f) The information was useful (ex. B).

Figure 5.1: Quantitative data relative to the exercises of the first experiment.

vided in exercise A as adequate (73%), a considerable percentage (27%) considered it to be excessive, somewhat excessive or somewhat insufficient (see Figure 5.2). In the majority of cases ($\simeq$81%), the participants rated the quantity of information provided in scenario A with higher/equal grades than exercise B.

To further investigate the relationship between the game comprehension and the other dependent variables, a correlation analysis was conducted. Ta-



(a) Information classification (ex. A). (b) Information classification (ex. B).

Figure 5.2: Quantitative data relative to the exercises of the first experiment.

Table 5.2: Correlation of the comprehension of participants and other variables.

		Experience with business games	Usefulness of information (same exercise)	Comprehension (other exercise)
Comprehension (exercise A)	Rho	-0.036	**0,706**	0.543
	Sig.	0.895	**0,002**	0.030
Comprehension (exercise B)	Rho	**-0.673**	0,282	0.543
	Sig.	**0.004**	0,289	0.030

ble 5.2 presents the Spearman's correlation coefficients (ρ) and significance (p) values. The correlation analysis provided evidence that, in the absence of informative elements, the comprehension of the results was related to prior experience with business games[3] ($\rho = 0,673, p = 0.004$) $-$ participants with more experience found more difficulties in understanding the results of exercise B[4]. However, in the presence of informative elements, results showed no evidence that comprehension was related to experience with business games ($\rho = -0,036, p = 0.895$).

The correlation analysis showed a strong correlation ($\rho = 0,706, p = 0.002$) between the perceived usefulness of information and the comprehension of the game in exercise A. In exercise B, no correlation between the usefulness of information and comprehension of participants was registered (see Table 5.2).

Spearman's correlation (see Table 5.3) suggested a strong linear relationship between the usability of the interface and the usefulness of information in the presence of informative elements ($\rho = 0,6113, p = 0.012$). The classification

[3]Experience with business games refers to experience with games popular in academia.

[4]The majority of the participants with more experience in playing business games performed exercise 1 prior to exercise 2, which could have influenced the results.

Table 5.3: Correlation of the usefulness of information and other variables.

		Sequence of exercises	Usability (exercise A)	Usability (exercise B)	Usefulness of information (other exercise)
Usefulness information (exercise A)	Rho	**0.529**	**0,6113**	0.209	0.647
	Sig.	**0.035**	**0,012**	0.438	0.007
Usefulness information (exercise B)	Rho	0.469	0,652	0.226	0.647
	Sig.	0.067	0,006	0.400	0.007

of the usefulness of information in exercise A was also related to the sequence of exercises ($\rho = 0,529, p = 0.035$) $-$ participants who first participated in exercise B valued more the usefulness of information provided in exercise A.

5.2.3 Quantitative data for the second experiment

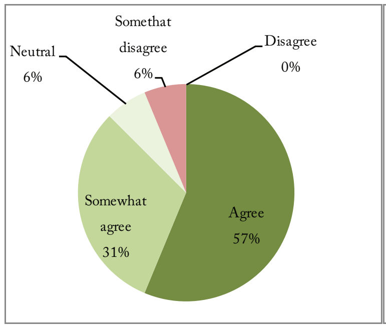
Although the quantitative data collected for the first experiment provided evidence that the informative elements of the agent-based model enhanced the understandability of the business game, it was also important to study the impact of each element in the overall comprehension of the game.

There were three indicators of firm performance: (A1) cash of the firm, (A2) units sold of a product in the current round and (A3) units in stock.

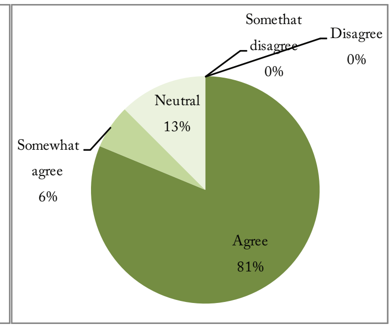
The results pointed to a consensual agreement in terms of the usefulness and understandability of the indicators (see Figure 5.8). The most consensual indicator was the units sold reaching a 94% agreement regarding the usefulness and understandability of the indicator, followed by the cash indicator (88% and 87%) and finally the stock indicator (75% and 87%).

The second experiment evaluated the informative elements which provided aggregated information, such as:

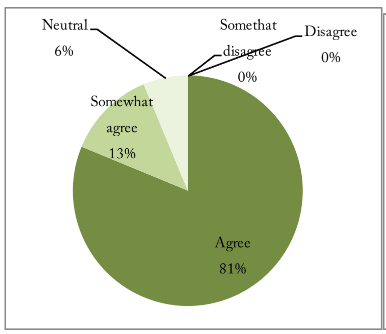
- (B1) Timeline charts, which showed the evolution of price/profit/sales and other indicators through several rounds.
- (B2) Market share charts.
- (B3) Top Panel, which appeared at the end of the round and presented the winning top along with information regarding the sales/profit/costs of each firm.
- (B4, B5) Filters, which allowed the participant to view information regarding each consumer directly on the scenario map.



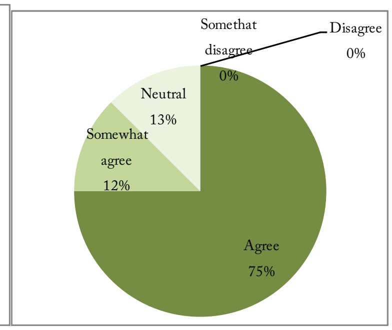
(a) Usefulness of Cash (A1)



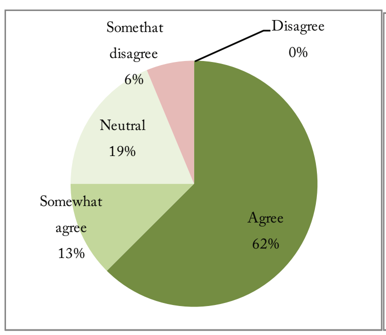
(b) Understandability of Cash (A1)



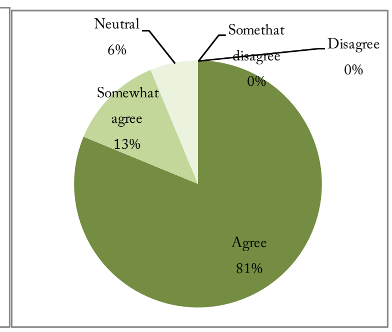
(c) Usefulness of Units sold (A2)



(d) Understandability of Unit sold (A2)



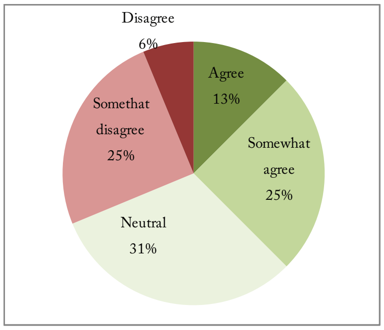
(e) Usefulness of Units in stock (A3)



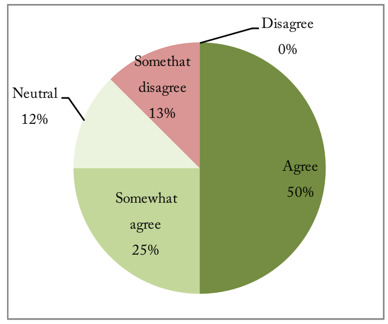
(f) Understandability of Units stock (A3)

Figure 5.3: Quantitative data regarding the indicators of firm performance.

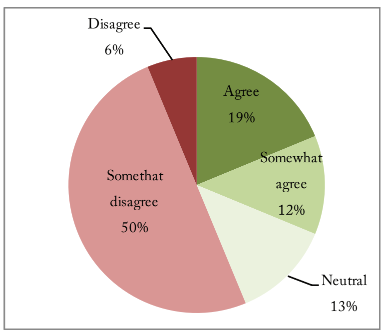
The responses regarding the usefulness of charts varied (see Figure 5.4). Market share charts registered the lowest level of agreement with 56% of the participants stating they disagreed the charts were useful and with 21% of the participants agreeing that the charts were useful to understand the results of the game. The sentence relative to the usefulness of timeline charts reg-



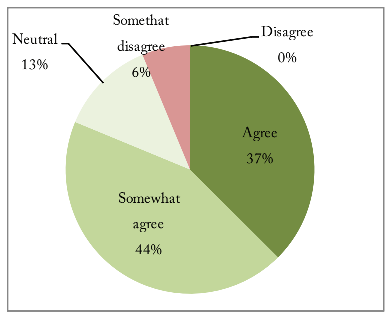
(a) Usefulness of timeline charts (B1)



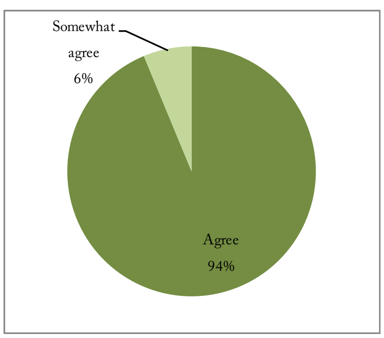
(b) Understandability of timeline charts (B1)



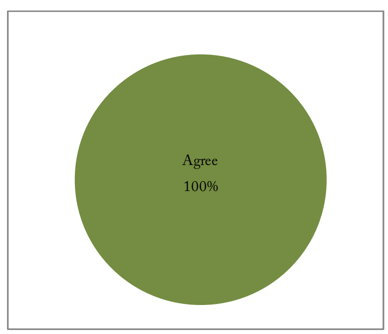
(c) Usefulness of Market share charts (B2)



(d) Understandability of Market share charts (B2)



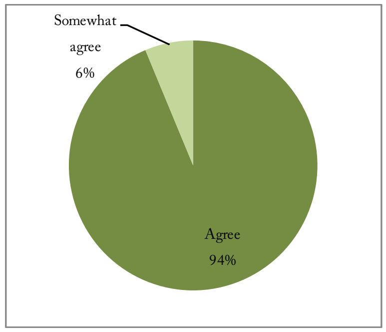
(e) Usefulness of Top (B3)



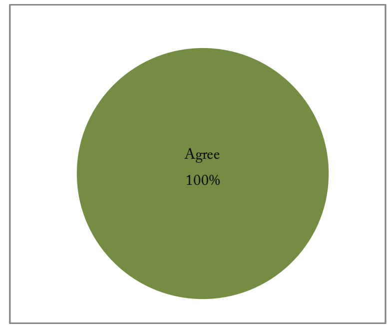
(f) Understandability of Top (B3)

Figure 5.4: Quantitative data regarding the benefits of charts in the game.

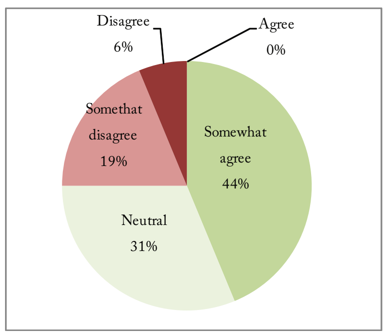
istered a percentage of 38% of agreement and 31% of disagreement. Despite the considerable level of disagreement regarding the usefulness of charts, both the timeline and market share charts were considered easy to understand (75% and 81% of agreement).



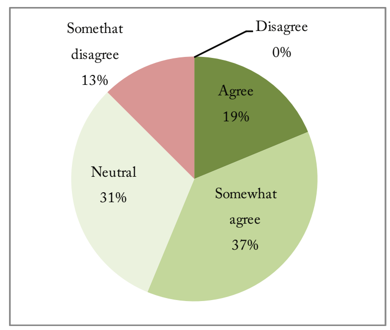
(a) Usefulness of Top (B3)



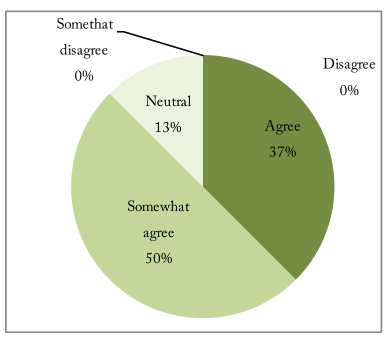
(b) Understandability of Top (B3)



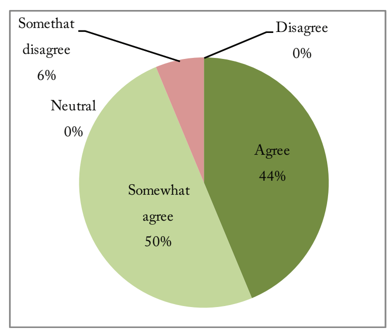
(c) Usefulness of filters (B4)



(d) Understandability of filters (B4)



(e) Usefulness of budget filters/charts (B5)



(f) Understandability of budget filters/charts (B5)

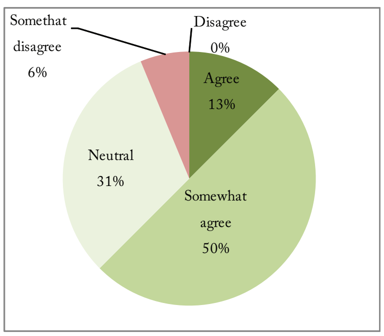
Figure 5.5: Quantitative data regarding the benefits of filters and other aggregate measures in the game.

The usefulness of charts was perceived differently according to the prior experience of participants with business games – evidence in Table 5.4 suggested participants with more experience found charts more useful. A linear relation was also found between the understandability of market share charts and the

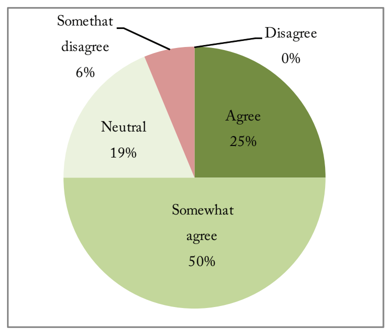
Table 5.4: Correlation of experience with business games and use of charts.

		Experience with business games
Usefulness of Timeline charts	Rho	0.559
	Sig.	0.024
Usefulness of Market share charts	Rho	0.830
	Sig.	0.000

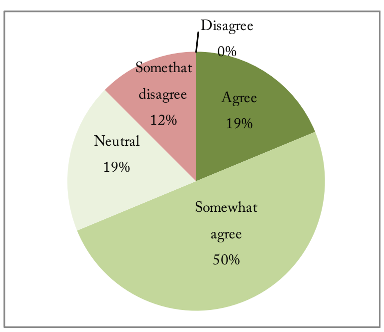
understandability of the behavior of consumers. The results suggested that participants who considered charts to be easy to understand found more difficulties in understanding the behavior of consumers ($\rho = -0.528, p = 0.036$).



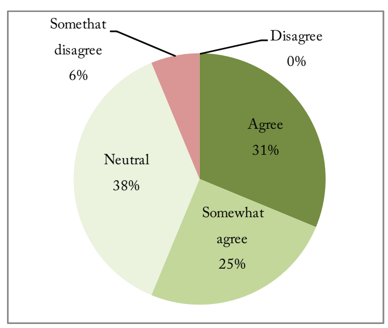
(a) Usefulness of State of consumer (C1)



(b) Understandability of State of consumer (C1)



(c) Usefulness of the Mind of consumer (C2)



(d) Understandability of the Mind of consumer (C2)

Figure 5.6: Quantitative data regarding the individual information of each consumer.

From the analysis of results concerning the top panel, it was clear that this informative element was considered useful and easy to understand. However, in the case of filters, 25% of the inquired reported that these elements were not useful. Regarding both the usefulness and understandability, filters registered

Table 5.5: Correlation of the usefulness of the information and other variables.

		Usefulness indicators	Usefulness mind	Understandability interior stores	Understandability simulation
Usefulness simulation	Rho	0.761	0,75	0.592	0.543
	Sig.	0.001	0,001	0.016	0.03
Understandability simulation	Rho			0.538	1
	Sig.			0.031	0.000

a considerable amount of neutral responses which could suggest participants were confused in this subject matter. The information regarding the budget was presented in the form of filters and charts and registered a high level of agreement regarding its usefulness and understandability (87% and 94%).

Informative elements regarding the behavior of consumers

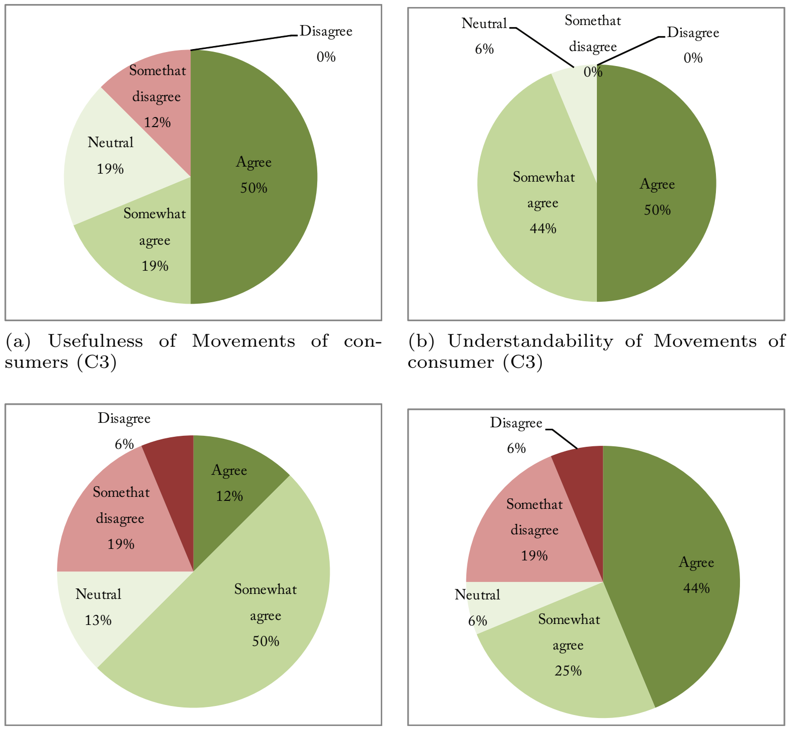
The data collected suggest that the majority of the participants considered the several elements of the simulation concerning the consumer easy to understand and useful to understand the results (see Figure 5.8d and 5.8c).

The element which presented the less satisfying results was (C4) the movements of consumers inside stores (see Figure 5.8e and 5.8e). A considerable percentage of participants classified this element as not useful (25%) and difficult to understand (25%). These lower ratings could be explained by the difficulties faced by participants while attempting to understand this element. A Spearman's correlation analysis showed these two variables, usefulness and understandability of this element, to be strongly related ($\rho = 0.624, p = 0.010$).

Two informative elements appeared to be strongly connected: the state and the mind of consumers (see Figure 5.7). The understandability of state and the mind of the consumer were linearly related ($\rho = 0.762, p = 0.001$). The usefulness of the state was also related to the comprehension of the mind ($\rho = 0.510, p = 0.044$).

Informative elements regarding the simulation

The simulation comprised the simulation of performance indicators (see Figure 4.3) and the simulation of consumer behavior. A significant percentage of the inquired (75%) considered the simulation useful while the remaining respondents (25%) provided a neutral response (see Figure 5.8a). Respondents were unanimous in considering the simulation easy to understand (94% in Figure 5.8b).



(a) Usefulness of Movements of consumers (C3)

(b) Understandability of Movements of consumer (C3)

(c) Usefulness of Store interior (C4)

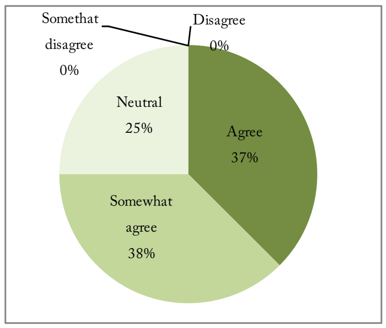
(d) Understandability of Store interior (C4)

Figure 5.7: Quantitative data regarding the behavior of consumers.

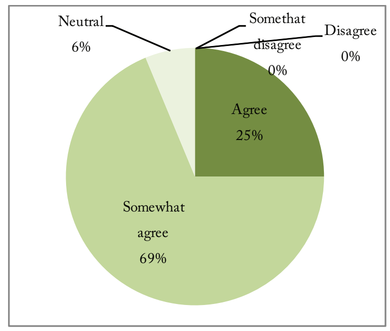
The simulation of performance indicators was considered useful and easy to understand (69% agreement levels in Figures 5.8e and 5.8f). Although participants considered the simulation of consumers slightly more useful (81%) than the evolution of indicators, participants considered more difficult to understand the behavior of consumers (75% of agreement and 19% of disagreement levels in Figures 5.8c and 5.8d).

Spearman's correlation analysis showed a strong correlation between the usefulness of the simulation and the usefulness of the simulation of indicators and the usefulness of analyzing the mind of each consumer (see Table 5.5). The results also suggest that the perception of the usefulness of the simulation was influenced by the understandability of the interior of stores ($\rho = 0.592, p = 0.0016$). In fact, the understandability of the simulation was linearly related to the understandability of the movements inside stores ($\rho = 0.538, p = 0.031$).

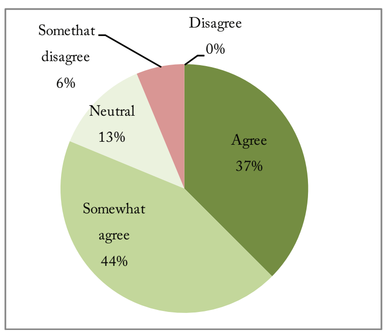
Both the understandability of consumers and indicators was related to the sequence by which the participants executed the exercises. The participants which first experienced the game with all the informative elements, rated more negatively the understandability of consumer behavior ($\rho = 0.693, p = 0.003$)



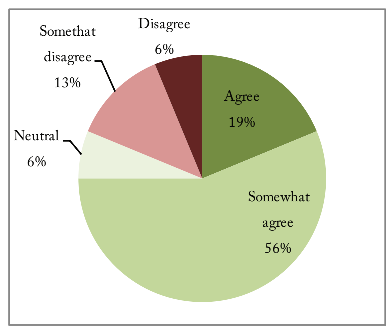
(a) Usefulness of the simulation



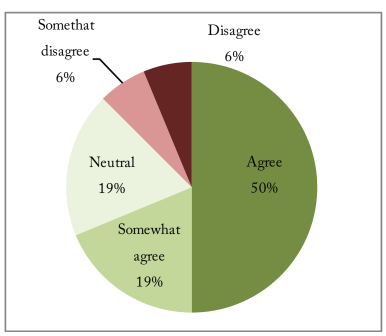
(b) Understandability of the simulation



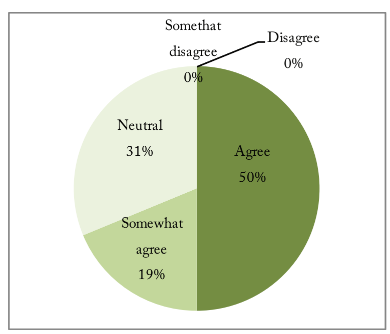
(c) Usefulness of the visualization of the consumers



(d) Understandability of consumers



(e) Usefulness of the visualization of the alteration indicators of performance



(f) Understandability of the alteration of the performance indicators

Figure 5.8: Quantitative data regarding the benefits of the simulation visualization.

and indicators ($\rho = 0.539, p = 0.031$). Finally, results provide evidence that the understandability of the behavior of consumers was correlated with the understandability of (B5) budget information ($\rho = 0.688, p = 0.003$) and (C1) state ($\rho = 0.551, p = 0.027$).

5.2.4 Discussion

The results of both experiments provided some evidence to sustain the hypothesis that agent-based models provide additional information which enhance the comprehension of participants of business games.

The results were very encouraging showing a considerable improvement of the perception each participant had of his comprehension of the results, in the presence of informative elements. The collected data presented no correlation between the comprehension of the results and prior experience with business games. Even though the strategy of each participant may depend upon his prior experience and expertise in management, the analytical results suggest that with agent-based business games the results of the game can become more understandable to all participants. One could anticipate optimistically, that the barriers which restricted participants non-acquainted with management and economics, from enjoying this type of game, may be potentially broken, with the advent of applying the agent-based approach to business games.

Participants were unanimous in considering the simulation useful to understand the game. However, the results suggest that the behavior of consumers were somewhat difficult to understand. Therefore, the movements of consumers inside and outside stores should be subject to a careful examination and re-planning. Attention should also be placed in the improvement of how the information regarding the mind and state of each consumer is provided to participants.

The fact that the participants who were first submitted to a game exercise with access to a full set of informative elements, were more critical relative to the understandability and usefulness of information was an unexpected result. This fact could mean that the automatic presentation of information was against a primary objective of a business game: to motivate the exploration and of the business environment. Therefore, the presentation of the information should be progressive, and possibly, costs should be associated with the access to each type of information.

More incentives should encourage participants to use statistical information. The combination of filters and statistical charts proved to be a successful presentation of information regarding the budget of consumers. This example should be followed in similar cases.

The need to further investigate many of the questions which emerged from the results is foreseeable. It would be interesting to survey participants with a strong background in management and economics. Moreover, it was important to understand if these participants found more difficulties in understanding the simulation and if their perception of the game was similar to a participant with no prior background in economics and management. It would be also interesting to investigate the evolution of the perception and understanding of a participant along several rounds.

Chapter 6

Conclusion

> *"I think it was very informative, but a lot still needs to be done."*
> Pablo Neruda, 1973

This chapter summarizes the main findings of this study and draws the implications of applying the agent-based approach to model the marketplace in business games. The final section of this chapter discusses the future work regarding the different aspects of the research presented in this essay.

...

Gold and Pray (1983) were the first researchers in the field to criticize the obscurity surrounding the underlying model of business games. Until then participants were not provided with any knowledge of the internal workings of a business game and designers refused to disclose the inner mechanisms of their models.

Such was the impact of the secrecy surrounding the internal algorithms of the business games that researchers as Machuca (2000) considered it a major obstacle to the realism of the games and the primary cause of the inability of participants to perceive cause-and-effect relationships.

Supporting the claim of lack of realism and understandability of business games were a number of surveys (Faria and Wellington 2004, Bruhn and Mozgira 2007, McKenna 1991) which reported that academic students considered business games not realistic and were not able to completely understand the game results.

This study proposed itself to address these two interrelated problems, the lack of realism and the difficulty to understand cause-effect relationships through the creation of a transparent game. The scope of this study was however, limited to the area which, according to McKenna (1991), was classified by participants as one of the most problematic areas of business games: the simulation of the marketplace.

The difficulties inherent to the creation of a transparent business game were closely connected to the limitations of the models used. The majority of the models proposed in the field of business games were equation-based models which modeled the complex relationships resultant from the interaction of consumers and firms through mathematical equations.

The flexibility of the equation-based models was limited which hindered the realism of the models and the information provided by these models was also minimal since demand results were derived solely from the decisions inputed. The details of the mathematical model used were not disclosed to the participants since researchers Cohen and Rhenman (1961) claimed that the exposure of the such models enclosed the risk of converting the business game into more of a prediction challenge than a true decision making propeller.

This study attempted to solve the lack of realism and the understandability of business games by applying an alternative to the equation-based approach: agent-based modeling. This modeling technique appeared as an interesting and flexible alternative to equation-based models. Agent-based modeling conveyed the possibility to model each consumer and its interactions which could open new possibilities in terms of additional realism and degree of information provided.

The challenges of applying the agent-based technique, still a novel technique to the field of business games Summers (2004), were various. First, agent-based modeling is a novel technique in the field of business games and few researchers referred or presented consistent work in the area. Secondly, the existing agent-based models of consumer behavior (Said et al. 2002, Janssen and Jager 1999) were focused in simulating specific economic phenomena and did not represent flexible models for business games. Third, it was not clear if the large quantity of information comprised in agent-based models could be effectively presented to the participant as a means to enhance his understanding of the game.

As a means to overcome the numerous challenges a first very simplistic agent-based model of consumer behavior was developed. The purpose of this model was the simulation of a realistic marketplace where the participants could interact. The foundations of the model were drawn from microeconomic theory following the example of the existing models for business games.

From the first simplistic version other few four conceptual models of consumer behavior were iteratively developed: linear, cobb-Douglas, tax-rate and drive model. The models were also inspired by the classical economic theory of consumer behavior. Classical economic theory proved to be flexible framework for developing consumer or general human behavior. Microeconomic concepts such as the utility function, the marginal utility and price elasticity of demand guided the development process validating it and creating a powerful abstraction. Notwithstanding the potential associated the major challenge lied in understanding and customizing the framework to simulate specific behaviors.

A major dilemma was the inclusion of a sense of satisfaction by each consumer. At extremely low prices it wouldn't seem realistic that a consumer spent entirely his budget on a product. The solution for this problem was the introduction of a "money product" to the utility function and the creation of a diminishing marginal utility associated with each product.

Notwithstanding the advantages of using microeconomics as the theoretical foundation for the models, ideas from other fields such as artificial intelligence and psychology (Hull's theory) contributed to a more complete model. The final model was inspired by the ideas of Hull (1943) and simulated the evolving necessities of the consumer, which influenced his reasoning process and consequently his purchases.

The evaluation of the realism of the models was based on the correspondence between the emergent properties of the agent-based models and the properties of models studied in the literature review. Agent-based models produced the same emergent behavior expected from standard models and provided additional flexibility. Even though the final model did not simulate many features of a real consumer, such as marketing effects, loyalty and direct interaction between consumers, it was a step closer to that objective.

The conceptual model of consumer behavior was not the exclusive outcome of this study. A novel business game, implementing the drive model was developed. The differentiating factor of the game was the fact that it comprised a number of additional informative elements, not present in state of the art business games, such as:

- Simulation in virtual time portraying the evolution of the behavior of consumers and the performance of firms during the execution of the model.

- Statistical information detailed in timeline and market share charts.
- Information regarding the behavior of each individual such as his decisions, his satisfaction state or his purchases.

The results of the experiments provided significant evidence to sustain the hypothesis that agent-based models can provide additional information which enhance the understanding of participants. The results were very encouraging showing a considerable improvement of the perception each participant had of his understanding of the game in the presence of informative elements.

This study aspired to represent a small step in the direction of the new generation of business games, the agent-based business games. The agent-based approach brings a new perspective to the design of business games. Hopefully someday business games will have rich agent-based models for the different entities present in business - consumers, firms, suppliers. Hopefully in the future, the business game will represent truly a virtual environment where novice and expert participants can understand and learn through a "try and error" process the business reality.

The evolution of this business games will probably be closely connected to a number of inter-disciplinary fields such as artificial intelligence, agent-based economics, marketing and psychology. The research work still to unfold appears, in this context, as a fascinating challenge.

6.1 Future work

Rather than a complete solution, this study pretends to be a proof of concept. Further research is needed to create a truly realistic and understandable business game.

Future research should unfold in three different directions: improvement of the interface and of the informative character of the game, expansion of the model to the modeling of other areas such as production and human resources and finally the evaluation of more research experiments with participants with an academic background from the areas of management and economics.

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Appendices

Appendix A

Technological architecture

A.1 Model-View-Controller pattern

The pattern used for defining the game architecture was the Model-View-Controller (MVC) which is a common pattern used in software engineering particularly in software games (see Chandima 2007, chap. 12). Therefore the game architecture consisted of three elements (see Figure A.1):

- Model: Contained the game logic including the consumer deliberative architecture and reasoning model. The model resided in the server and its execution was also performed at the server.

- View: The user interface and state of the game was presented in the client Flex application. The view could be accessed by each participant through a browser.

- Controller: The controller received the decisions of participants from the view, transform it in a standard XML format message and send it to the server where the message was transformed to a model input.

Each element in the architecture communicated with the other elements through a sequence of events triggered by the participant who interacted with the game through the browser. The sequence of events is presented in Figure A.1 and could be summarized as:

1. The user interacted with the browser (view) and inputted decisions. The view sent the decisions submitted to the controller. The controller at the client side sent a XML message with the decisions to the server.

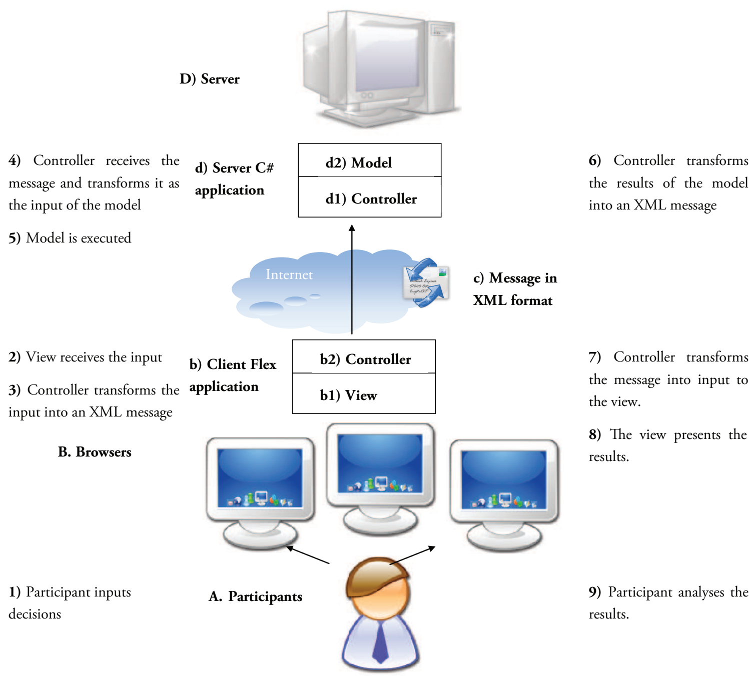


Figure A.1: The game implemented the MVC architecture pattern.

2. The controller at the server executed the model according to the decisions received. The controller created a new XML message with the results and sent it to the view. The view presented the results to the participant.

A.2 Applications architecture

Three applications were developed in simultaneous for the game:

1. Server application: Implemented the game model (.NET server).

2. Client application: Implemented the view and was accessed by the participants through a browser (Flex application).

3. Game editor application: Allowed the game customization and could be accessed using the browser (Flex application).

The game editor application was not the major focus of this study since its purpose was to be used by game administrators and not by the participants.

Therefore the inner details of the application and usability issues will not be further debated.

A.2.1 Client application

The client application had a layered architecture (see Figure A.2):

- View Layer: The View layer was composed by a number of View classes which defined the layout structure. This layer acted as the interaction layer between the game and the participants by receiving their stimulus and by presenting information.

- Logic Layer: The Logic layer was composed by: (a) Logic classes implemented the logic behavior of classes in the View Layer. These classes processed the stimulus received by the View classes and triggered alterations in the information presented by these classes and (b) Class Controller received data from the Logic classes and transformed that data into XML messages sent to the Communication layer. The class also received XML messages from the Communication layer and transformed them into input for the Logic classes.

- The Communication layer implemented the communication layer using sockets. It was responsible for receiving messages from the network and sending them to the logic layer and for receiving messages from the logic layer (through the Controller class) and sending them to the network.

The layered architecture created a clear separation and independence of elements. The technology used to implemented this application (Flex) aided this clear separation of the application interface and logic by allowing the definition of the interface in MXML (MXML is a XML-based declarative language) and the definition of the logic using an Object-Oriented language (the standard language of FLEX is Actionscript 3.0).

A.2.2 Server application

The server application also presented a layered architecture for the same reasons previously stated. The architecture was composed of three layers:

- Model Layer: The Model layer was composed by a number of classes representing different entities of the real world (such as the Market, Product, Firm, Population). A major and fundamental module of the model was

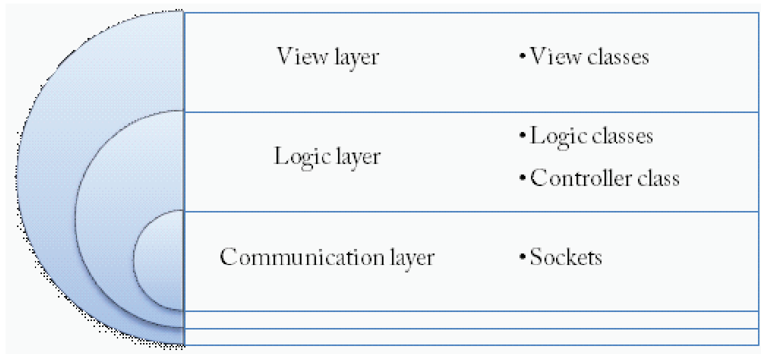


Figure A.2: The client application presented a layered architecture.

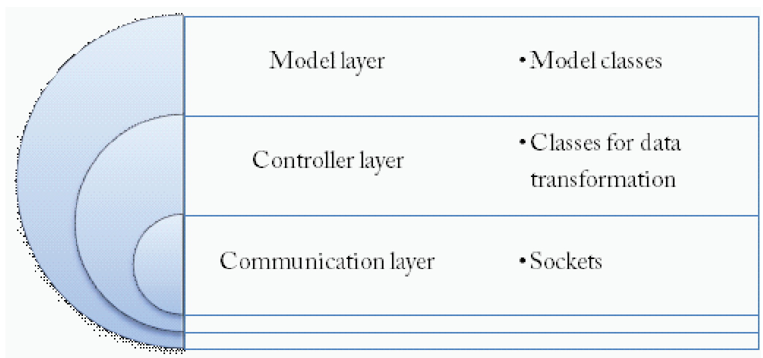


Figure A.3: The server application presented a layered architecture.

the population module which modeled the population and the deliberative architecture and reasoning model of each consumer.

- Controller Layer: The Controller layer was responsible for transforming and creating XML messages to guarantee the communication between the Communication and the Model layers.

- The Communication layer implemented the communication layer using sockets. It was responsible for receiving messages from the network and sending them to the Controller layer and for receiving messages from the Controller layer and sending them to the network.

Figure A.4 depicts a simple UML class diagram of the conceptual model at the server application. It represents all the classes enclosed in the Model Layer of the server application. The model execution encompassed the following steps: (a) Execution of the suppliers market (b) Execution of the retailers

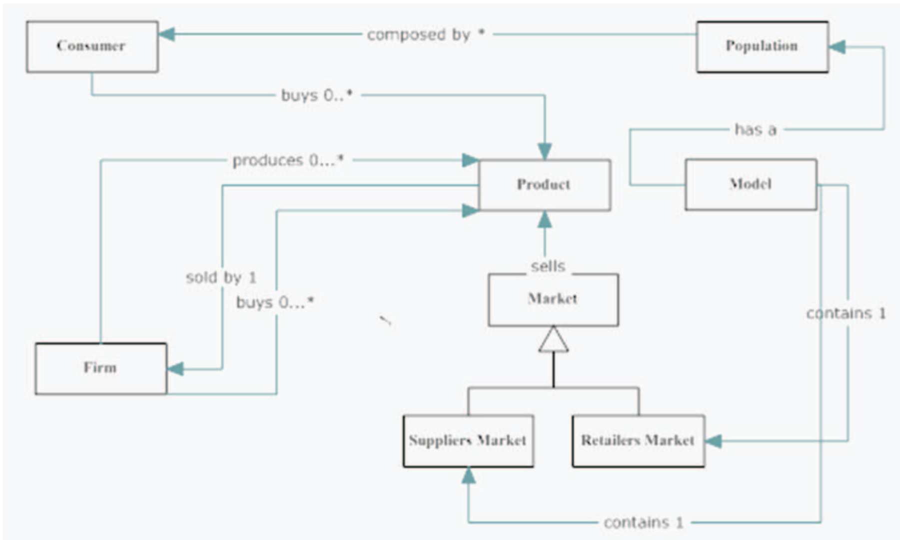


Figure A.4: The class diagram of the model (minimalist version).

market (c) The population engages on their purchases. Step (a) included the firms producing and selling their products at the supplier market, step (b) included firms purchasing products at the suppliers markets and selling products at the retailers market (according to the firms decisions) and the final step simulated the consumers final purchases.

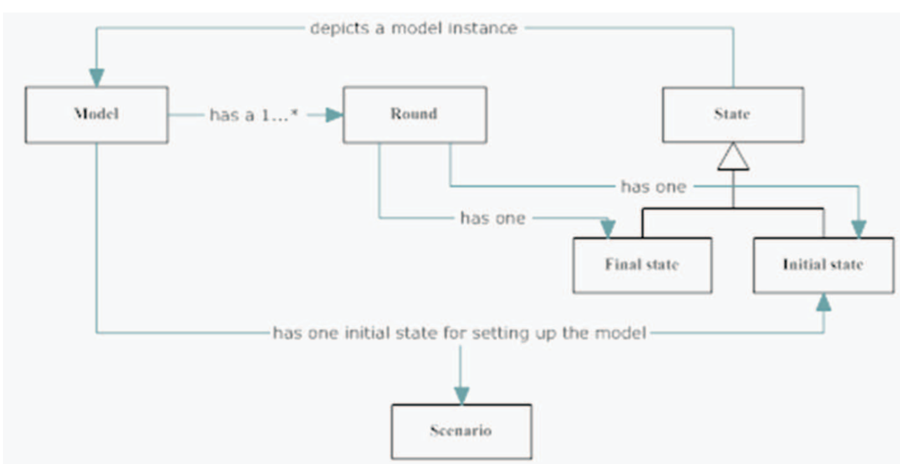


Figure A.5: The class diagram of the game persistence.

The Controller layer also included a set of classes which implemented the game persistence (see Figure A.5). It was important to store information relative to several rounds both for displaying historic charts of the game and also to allow the client application to access information from previous rounds. The participants had to be able to access the state of the game through browser at all times.

A.2.3 Communication layer

The communication layer was present both at the server and client application. There were two possible alternatives to implement the communication layer: sockets or web services. The preferred solution was the implementation of a socket channel between server and client. The major advantage of using sockets was the establishment of a bidirectional communication channel − the server application was able to contact the client at any time avoiding the situation of having the clients polling the server constantly with requests. This fact was very important since the game was turn-based and the temporal interval between turns was dependent upon the time each participant required to submit decisions. If the communication layer was based on the web-services technology the client application of the faster participants would have to be polling the server constantly for the results of the turn.

A.3 Future work

The following versions of the game should incorporate a number of additional functionalities such as:

- Chat functionality
- Development of the game model to enclose other functional areas such as production and research and development.
- Tutorial and help system

Appendix B

Instructions for exercise A

INSTRUÇÕES DO V3MANAGER[1] EXPERIÊNCIA A

OBJECTIVO

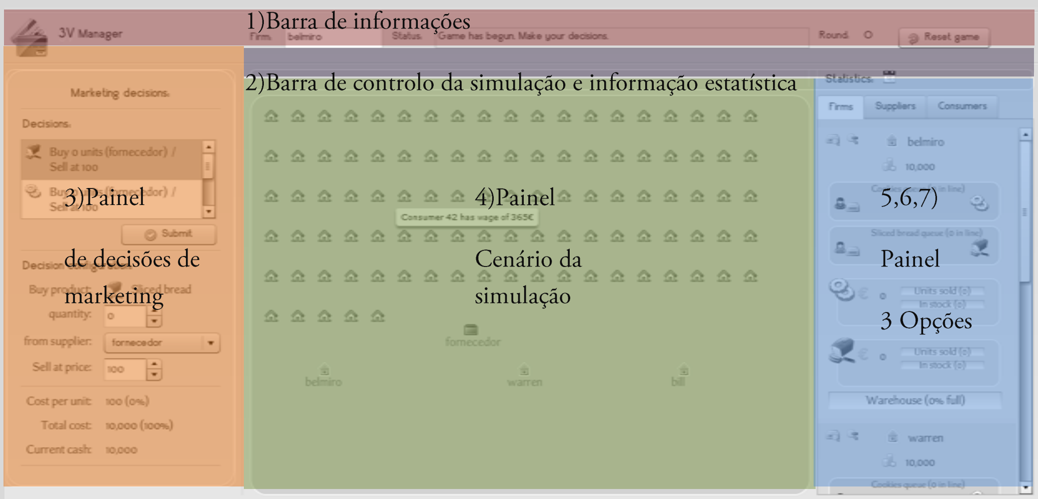
Neste jogo terá que gerir uma loja de revenda[2] e competir com outras lojas no mesmo mercado durante **4 rondas**. Ganhará a equipa que tiver **mais dinheiro amealhado** na sexta ronda. Antes do jogo terá um período prévio de treino que durará 2 rondas.

Durante o jogo poderá comprar e vender dois tipos de produtos na sua loja: Cookies e Sliced Bread. Os consumidores tem tendência para preferir Cookies em vez de Sliced Bread. Terá à sua disposição duas decisões de marketing em cada ronda:

- A **quantidade de cada produto** a comprar ao fornecedor
- O **preço de cada produto** na sua loja

Existe um único fornecedor para cada produto cujo preço de venda é sempre igual e cuja capacidade de fornecimento é ilimitada. A quantidade comprada é limitada pela capacidade de armazenamento da loja (100 unidades).

INTERFACE



Legenda:

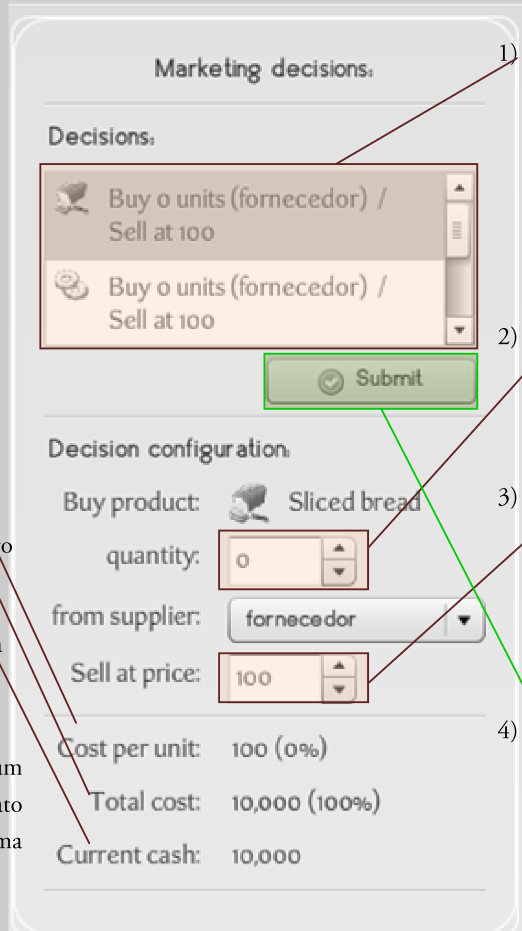
- 1)Barra de informações (Estado do jogo e ronda actual)
- 2)Barra de controlo de simulação (Play,Stop, Faster,etc) e acesso a informação estatística
- 3)Painel de decisões de marketing (quantidade e preço do produto)
- 4)Painel com cenário de simulação
- Painel 3 opções:
  - 5)Painel de indicadores de performance (Dinheiro/Unidades vendidas/Stock)
  - 6)Painel informativo sobre fornecedores e produtos (preço dos fornecedores)
  - 7)Painel informativo sobre consumidores (Filtros, Distribuição dos salários)

[1] Nota: É importante que leia atentamente as instruções antes de iniciar a experiência de jogo. Se esta é a sua segunda experiência de jogo não necessita ler a secção Objectivo e Como Submeter Decisões.

[2] Uma loja de revenda compra grandes quantidades de produtos aos fornecedores e vende em pequenas quantidades ao consumidor final.

COMO SUBMETER DECISÕES[3]

O painel esquerdo (2) é o painel onde deve <u>submeter as suas decisões</u> em cada ronda. As **instruções de 1 a 4** indicam os passos que deve seguir:



1) Seleccione a decisão que pretende alterar.

2) Seleccione a **quantidade a comprar** do produto

3) Seleccione o **preço a que deseja vender**o produto

4) Quando tiver tomado todas as decisões submeta e espere pelos resultados.

Custo por produto comprado (margem de lucro conforme o preço estipulado)

Custo de comprar a quantidade escolhida (percentagem do dinheiro total)

Dinheiro actual da firma

Nota: Se não perceber um indicador passe com o rato por cima até aparecer uma *tooltip* (pista).

[3] Não existe tempo limite para tomar decisões. O jogo inicia uma nova ronda após todos os jogadores terem submetido as suas decisões.

<u>Em caso de erro:</u>

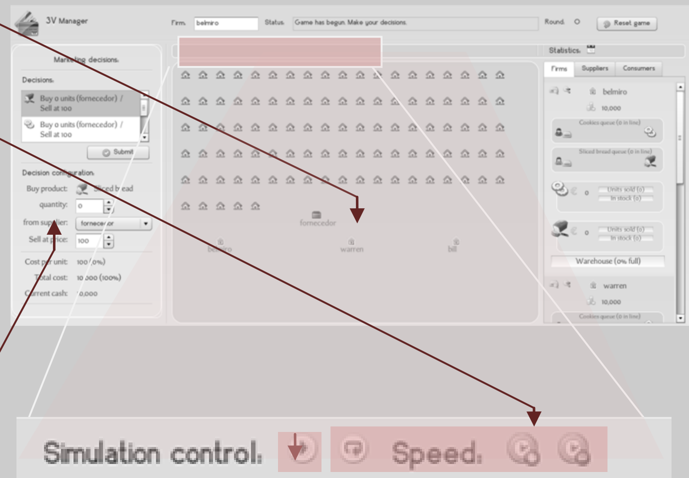
- Uma vez adicionada uma decisão de um produto pode sempre voltar a adicioná-la com valores diferentes (quantidade e preço) antes da submissão. Será válida unicamente a última adição.
- Em caso de erro na submissão das decisões pode voltar a submeter as decisões antes que as decisões de todos os jogadores tenham sido submetidas. Será válida unicamente a última submissão.

APÓS SUBMETER AS DECISÕES

Após todos os jogadores terem submetido as suas decisões **receberá os resultados** da ronda.

1) A simulação **executa-se automaticamente ( ).**
2) Pode controlar a simulação parando-a, voltando ao ínicio e mudando a sua velocidade.
3) No final da simulação aparece painel Top (painel dos vencedores).

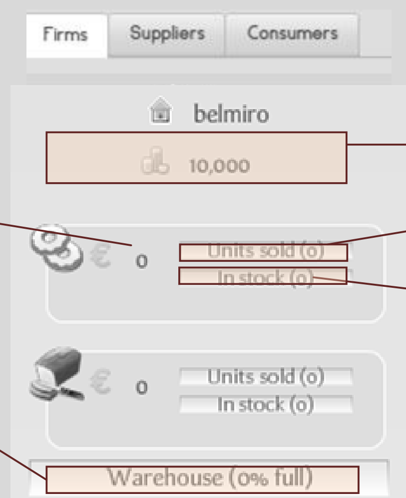
4) Após a simulação o painel de decisões ( ) é desbloqueado. Pode **tomar novas decisões**.



Correr/Pausa Rebobinar Mais rápido Mais lento

COMO ANALISAR A SIMULAÇÃO

Painel de indicadores de performance (3): Durante a simulação os indicadores de performance de cada loja (dinheiro, unidades vendidas, stock de produto) evoluem.



Preço de venda do produto na loja

Stock geral da loja

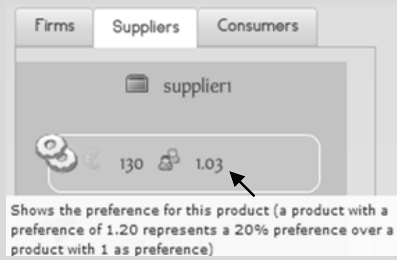
Indicadores de performance:

a) **Dinheiro** da firma

b) **Unidades vendidas**

c) **Stock de produto**

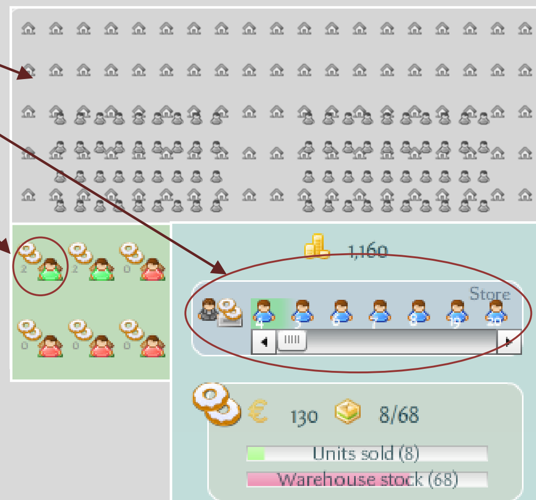
Painel de produto e fornecedores (7): Permite saber quais os **preços do fornecedor** e a preferência dos consumidores por um produto.



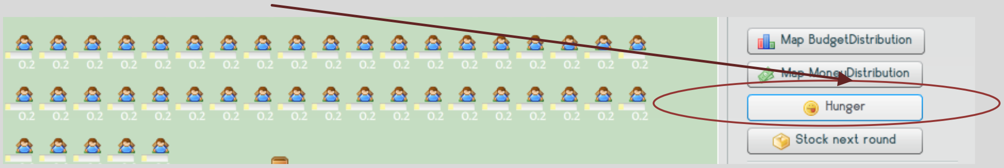
Comportamento dos consumidores (4 - Cenário da simulação e no 6 - Painel dos indicadores de performance): Vários elementos fornecem informação acerca dos consumidores e das suas escolhas:

5) **Movimentação** dos consumidores
6) Comportamento dos consumidores no **interior das lojas**
7) Alteração de **estado do consumidor**

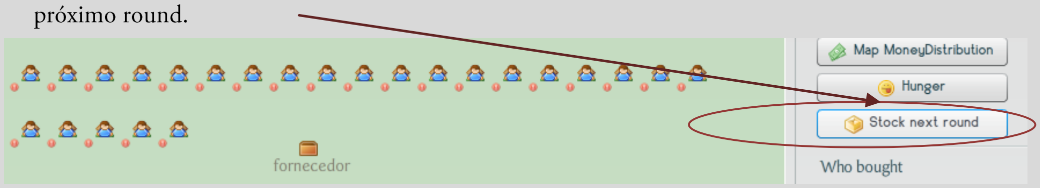
8) Intenções de compra do consumidor:
Deve clicar no consumidor para obter esta informação.



9) Fome de cada consumidor



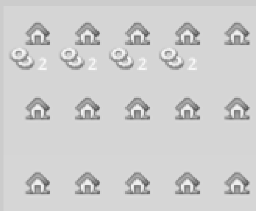
10) Stock que cada consumidor possui no próximo round.

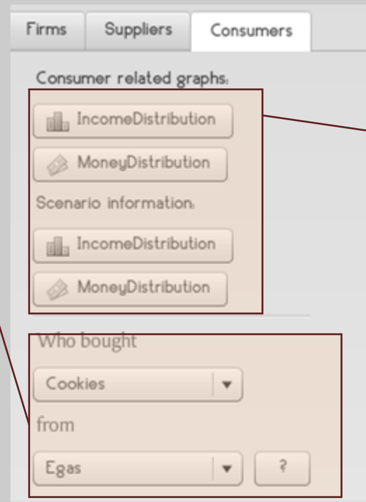


COMO ANALISAR OS RESULTADOS

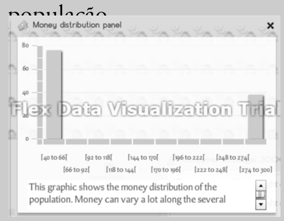
Painel de consumidores (8): Após ou durante a simulação pode ter acesso a informação relativa aos consumidores.

Filtros de compra: Permitem saber que consumidores e em quantidade compraram um dado produto a uma dada loja.

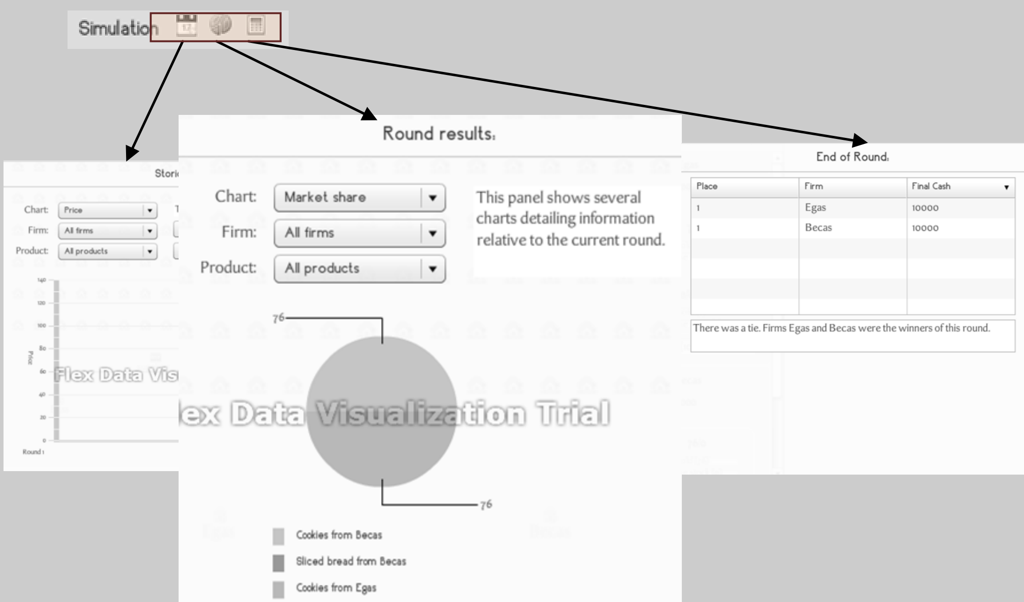




Gráficos e filtros de distribuição de salários e dinheiro: Gráficos com distribuição estatistica do dinheiro e salários da população.



Informação estatística: A barra de controlo da simulação e informação estatística (2) permite aceder a gráficos de market share, gráficos de histórico de várias rondas e ao painel Top com indicação dos vencedores da ronda.



(a) Gráfico com resultados **históricos** (b)Gráficos de **market share** (c)Painel de **Top Revenue**

O QUE DEVE SABER SOBRE OS CONSUMIDORES

Os consumidores deste cenário são consumidores informados. Antes de sairem de casa sabem quais os preços a que todas as lojas vendem os produtos.

Os consumidores preferem o produto Cookies a Sliced Bread mas não são indiferentes ao preço dos produtos.

Os consumidores preferem comprar um cabaz de produtos variados (exemplo: preferem um cabaz com Cookies e Sliced bread em vez de um cabaz só com Cookies).

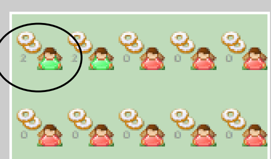
Na decisão da compra de um produto vendido em lojas diferentes (Cookies ou Sliced Bread) o consumidor **prefere o produto mais barato** e em caso de **empate escolhe a loja mais perto** de casa.

Os consumidores têm um salário para gastar nas suas compras mas também valorizam a poupança. Os consumidores não guardam as suas poupanças de uma ronda para a seguinte.

Os consumidores tem **fome** que aumenta em cada round. Quanto maior a fome mais disposto o consumidor está em gastar o seu dinheiro.

No final de cada ronda o consumidor consome alguns dos produtos que comprou e guarda outros em stock conforme a sua fome.

Os consumidores podem não conseguir comprar os produtos que desejavam numa loja por falta de stock. Neste caso ficam **vermelhos**. Se conseguirem comprar alguns dos produtos que queriam comprar naquela loja ficam **amarelos**. Se forem bem sucedidos ficam com a cor **verde**.



O estado do consumidor indica o resultado da sua última ida a uma loja. Assim se o consumidor comprou 2 Cookies na loja A e 2 Cookies na loja B o estado apresentará a informação acerca das 2 Cookies compradas na loja B.

FINAL DO CENÁRIO: No final do cenário deve responder a um questionário da experiência de jogo.

Appendix C

Instructions for exercise B

INSTRUÇÕES DO V3MANAGER[1] EXPERIÊNCIA B

OBJECTIVO

Neste jogo terá que gerir uma loja de revenda[2] e competir com outras lojas no mesmo mercado durante **6 rondas**. Ganhará a equipa que tiver **mais dinheiro amealhado** na sexta ronda. Antes do jogo terá um período prévio de treino que durará 2 rondas.

Durante o jogo poderá comprar e vender dois tipos de produtos na sua loja: Cookies e Sliced Bread. Os consumidores tem tendência para preferir Cookies em vez de Sliced Bread. Terá à sua disposição duas decisões de marketing em cada ronda:

- A **quantidade de cada produto** a comprar ao fornecedor
- O **preço de cada produto** na sua loja

Existe um único fornecedor para cada produto cujo preço de venda é sempre igual e cuja capacidade de fornecimento é ilimitada. A quantidade comprada é limitada pela capacidade de armazenamento da loja (100 unidades).

INTERFACE

Legenda:

- 1)Barra de informações (Estado do jogo e ronda actual)
- 2)Painel de decisões de marketing (quantidade e preço do produto)
- 3)Painel de indicadores de performance (Dinheiro/Unidades vendidas/Stock)

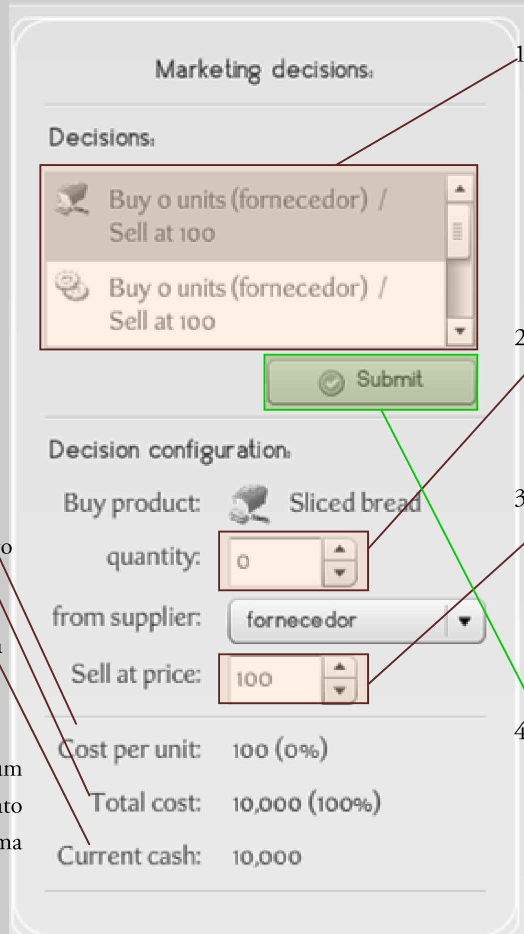
---

[1] Nota: É importante que leia atentamente as instruções antes de iniciar a experiência de jogo. Se esta é a sua segunda experiência de jogo não necessita ler a secção Objectivo e Como Submeter Decisões.

[2] Uma loja de revenda compra grandes quantidades de produtos aos fornecedores e vende em pequenas quantidades ao consumidor final.

COMO SUBMETER DECISÕES[3]

O painel esquerdo (2) é o painel onde deve <u>submeter as suas decisões</u> em cada ronda. As **instruções de 1 a 4** indicam os passos que deve seguir:



Custo por produto comprado (margem de lucro conforme o preço estipulado)

Custo de comprar a quantidade escolhida (percentagem do dinheiro total)

Dinheiro actual da firma

Nota: Se não perceber um indicador passe com o rato por cima até aparecer uma *tooltip* (pista).

1) Seleccione a decisão que pretende alterar.

2) Seleccione a **quantidade a comprar** do produto

3) Seleccione o **preço a que deseja vender**o produto

4) Quando tiver tomado todas as decisões submeta e espere pelos resultados.

---

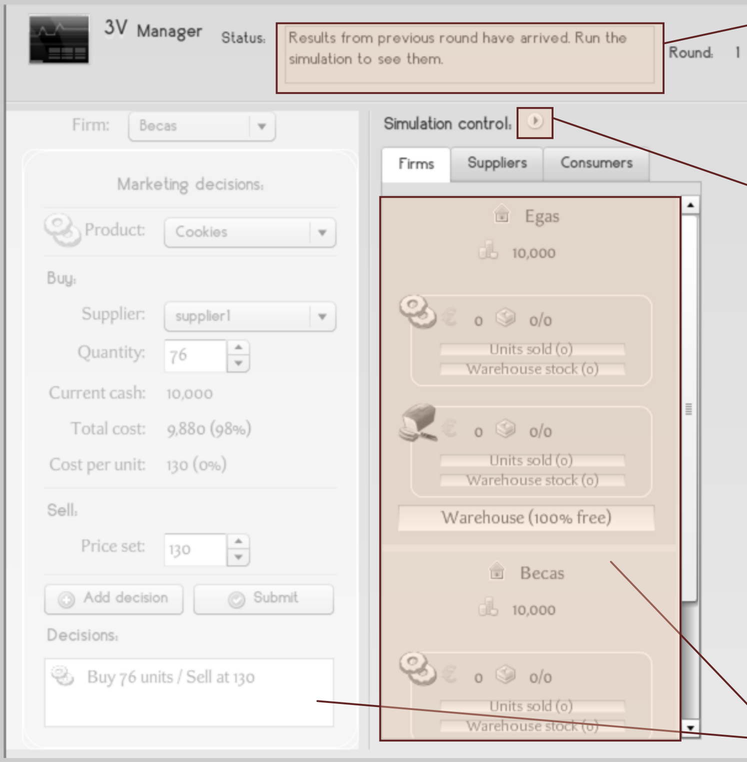
[3] Não existe tempo limite para tomar decisões. O jogo inicia uma nova ronda após todos os jogadores terem submetido as suas decisões.

<u>Em caso de erro:</u>

- Uma vez adicionada uma decisão de um produto pode sempre voltar a adicioná-la com valores diferentes (quantidade e preço) antes da submissão. Será válida unicamente a última adição.
- Em caso de erro na submissão das decisões pode voltar a submeter as decisões antes que as decisões de todos os jogadores tenham sido submetidas. Será válida unicamente a última submissão.

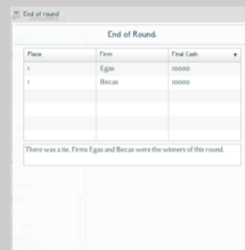
APÓS SUBMETER AS DECISÕES

Após todos os jogadores terem submetido as suas decisões receberá os **resultados** da ronda.



1) Estado do jogo indica que existem novos resultados e o painel de decisões está bloqueado.

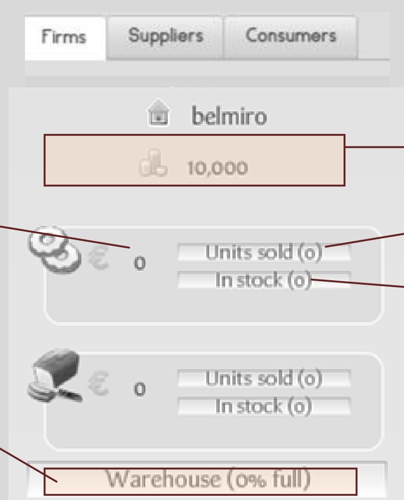
2) **A simulação irá correr.** Espere pelo painel Top (painel dos vencedores).



3) Após a simulação os indicadores de performance mostram os resultados e o painel de decisões é desbloqueado. Pode **tomar novas decisões.**

ANÁLISE DOS RESULTADOS

<u>Painel de indicadores de performance</u> (3): Durante a simulação os indicadores de performance de cada loja (dinheiro, unidades vendidas, stock de produto) evoluem.



Preço de venda do produto na loja

Stock geral da loja

<u>Indicadores de performance:</u>

a) **Dinheiro** da firma

b) **Unidades vendidas**

c) **Stock de produto**

FINAL DO CENÁRIO: No final do cenário deve responder a um questionário acerca da sua experiência de jogo.

Appendix D

Survey

IDENTIFICAÇÃO

Nome: ____

Idade: ____ Sexo (F/M): ☐ Habilitações académicas: ___________________________________

Primeira vez que joga um jogo de negócio (S/N)? ☐ Primeira vez que joga este jogo (S/N)? ☐

COMO COMPLETAR O QUESTIONÁRIO

Assinale cada afirmação com um círculo na escala de 5 níveis (num dos números):

1 – Discordo

5 – Concordo

Exemplo:

Gosto de jogos de negócio.

Discordo Concordo

1 2 3 4 5

Nesta questão o inquirido concordou que gostava de jogos de negócio.

INFORMAÇÕES IMPORTANTES

O questionário é composto por quatro partes:

I e II – Grupos de questões para duas experiências diferentes de jogo.

Nota: O grupo I deve ser completado entre a primeira e a segunda experiências. O grupo II deve ser completado depois da segunda experiência.

III – Questões finais sobre as duas experiências.

IV – Sugestões

No preenchimento do questionário é importante ser honesto e objectivo já que a finalidade desta avaliação é obter um registo fiel da sua experiência de jogo.

INFORMAÇÃO SOBRE JOGADOR

1. *Tenho bons conhecimentos em gestão.*

   Discordo Concordo

   1 2 3 4 5

2. *Considero a área de gestão interessante.*

   Discordo Concordo

   1 2 3 4 5

I – PRIMEIRA EXPERIÊNCIA DE JOGO

INSTRUÇÕES

Deve preencher este grupo entre a primeira e a segunda experiência de jogo. As respostas devem reflectir a sua opinião no final da experiência de jogo.

Exemplo:

> *Consegui compreender os resultados do jogo.*
>
> Esta questão deve ser respondida afirmativamente se o jogador conseguiu compreender o jogo mesmo que tivesse sentido dificuldades no início do jogo.

1. *O jogo tinha uma interface usável*[1].

   Discordo — Concordo

   1 2 3 4 5

2. *A informação apresentada foi útil para a compreensão do jogo.*

   Discordo — Concordo

   1 2 3 4 5

3. *Como classifica a quantidade de informação apresentada?*

   Insuficiente — Adequada — Demasiada

   1 2 3 4 5

4. *Consegui compreender os resultados da ronda*[2].

   Discordo — Concordo

   1 2 3 4 5

5. *Gostei do jogo.*

   Discordo — Concordo

   1 2 3 4 5

6. *Aprendi sobre gestão com o jogo.*

   Discordo — Concordo

   1 2 3 4 5

[1] Interface usável significa que a forma como a informação foi apresentada foi adequada.
[2] Consegui compreender o impacto das minhas decisões e a sua ligação com as decisões dos outros jogadores.

II – SEGUNDA EXPERIÊNCIA DE JOGO

INSTRUÇÕES

Deve preencher este grupo <u>depois da segunda experiência</u> de jogo. Mais uma vez as respostas devem reflectir a sua opinião no final da experiência de jogo.

1. *O jogo tinha uma interface usável*[3].

   Discordo — Concordo

   1 2 3 4 5

2. *A informação apresentada foi útil para a compreensão do jogo.*

   Discordo — Concordo

   1 2 3 4 5

3. *Como classifica a quantidade de informação apresentada?*

   Insuficiente — Adequada — Demasiada

   1 2 3 4 5

4. *Consegui compreender os resultados da ronda*[4].

   Discordo — Concordo

   1 2 3 4 5

5. *Gostei do jogo.*

   Discordo — Concordo

   1 2 3 4 5

6. *Aprendi sobre gestão com o jogo.*

   Discordo — Concordo

   1 2 3 4 5

[3] Interface usável significa que a forma como a informação foi apresentada foi adequada.
[4] Consegui compreender o impacto das minhas decisões e a sua ligação com as decisões dos outros jogadores.

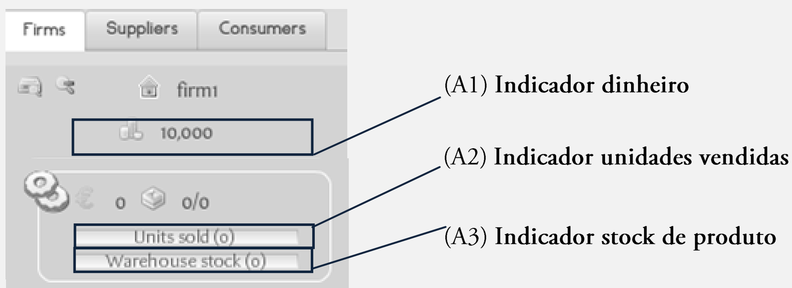
III – QUESTÕES GERAIS

1. INDICADORES E INFORMAÇÃO AGREGADA

Este grupo de questões é relativo a um grupo de elementos informativos. Para esclarecer quaisquer dúvidas as tabelas A e B descrevem os elementos referidos.

A - Indicadores de performance

Indicadores de performance (A1,A2,A3): Referem-se aos indicadores de cada loja como o dinheiro (A2), unidades vendidas (A2) e stock disponível (A3) visíveis no painel da direita do jogo.



1.1. O indicador dinheiro da loja (A1) foi:

a) *Útil para a compreensão do jogo*

Discordo — Concordo

1 2 3 4 5

b) *Fácil de compreender*

Discordo — Concordo

1 2 3 4 5

1.2. O indicador unidades vendidas (A2) foi:

a) *Útil para a compreensão do jogo*

Discordo — Concordo

1 2 3 4 5

b) *Fácil de compreender*

Discordo — Concordo

1 2 3 4 5

1.3. O indicador stock de produto (A3) foi:

a) *Útil para a compreensão do jogo*

Discordo — Concordo

1 2 3 4 5

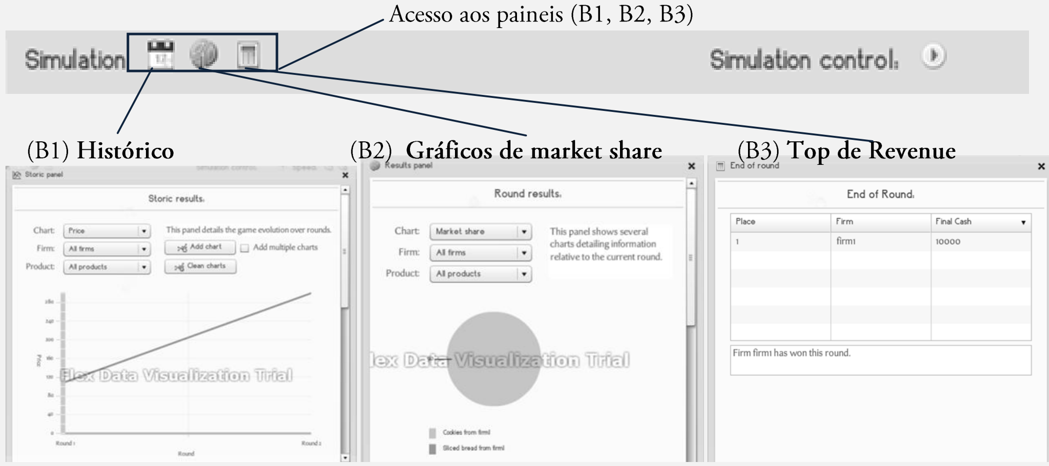
b) *Fácil de compreender*

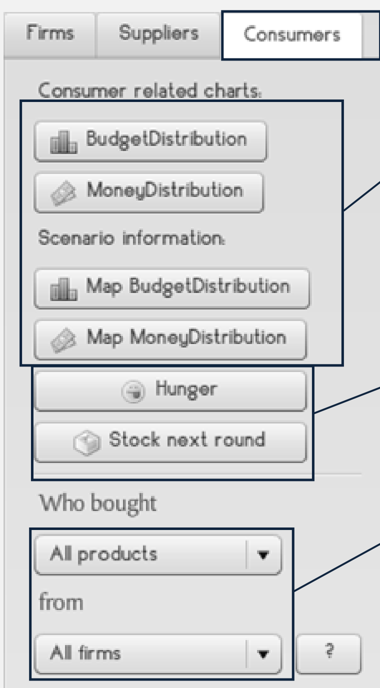
Discordo — Concordo

1 2 3 4 5

B – Informação agregada

Informação agregada (B1,B2,B3,B4,B5): A informação agregada inclui gráficos com histórico de várias rondas (B1), gráficos de market share (B2), painel Top de Revenue no final de cada ronda (B3), os filtros (B4), informação relativa aos orçamentos e dinheiro (B5). Os paineis B1, B2, B3 podiam ser acedidos através da barra superior do painel central. Os restantes paineis podiam ser acedidos através do painel direito na opção consumers.





Acesso aos paineis (B4, B5)

Os (B5) **gráficos de distribuição e filtros de distribuição de income/dinheiro** permitem visualizar a distribuição dos salários e dinheiro.

Os (B4) filtros são constituidos por **filtros da fome** do consumidor permitem visualizar a fome do consumidor, **filtros de stock** do consumidor permitem visualizar o stock de cada consumidor no próximo round e **filtros de compra** permitiam seleccionar produto e loja e visualizar que consumidores tinham comprado esse produto a essa loja e em quantidade.

1.4. O painel de resultados históricos (B1) foi:

a) Útil para a compreensão do jogo

Discordo 1 2 3 4 5 Concordo

b) Fácil de compreender

Discordo 1 2 3 4 5 Concordo

1.5. O painel de market share (B2) foi:

a) Útil para a compreensão do jogo

Discordo 1 2 3 4 5 Concordo

b) Fácil de compreender

Discordo 1 2 3 4 5 Concordo

1.6. O painel de Top de revenue (B3) foi:

a) Útil para a compreensão do jogo

Discordo 1 2 3 4 5 Concordo

b) Fácil de compreender

Discordo 1 2 3 4 5 Concordo

1.7. O uso de filtros (B4) foi:

a) Útil para a compreensão do jogo

Discordo 1 2 3 4 5 Concordo

b) Fácil de compreender

Discordo 1 2 3 4 5 Concordo

1.8. A informação acerca do dinheiro e salários dos consumidores (B5) foi:

a) Útil para a compreensão do jogo

Discordo 1 2 3 4 5 Concordo

b) Fácil de compreender

Discordo 1 2 3 4 5 Concordo

2. SIMULAÇÃO

Este grupo de questões é relativo ao grupo de mecanismos e elementos informativos dinâmicos que foram acrescentados entre experiências (comportamento dos consumidores e evolução dos indicadores de performance). A palavra simulação engloba todo esse grupo.

2.1. A simulação foi:

a) *Útil para a compreensão do jogo*

Discordo — Concordo

1 2 3 4 5

b) *Fácil de compreender*

Discordo — Concordo

1 2 3 4 5

2.2. Visualizar o comportamento dos consumidores foi:

a) *Útil para a compreensão do jogo*

Discordo — Concordo

1 2 3 4 5

b) *Fácil de compreender*

Discordo — Concordo

1 2 3 4 5

2.3. A evolução dos indicadores de performance[5] *ao longo da simulação foi:*

a) *Útil para a compreensão do jogo*

Discordo — Concordo

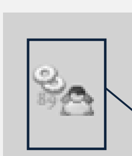
1 2 3 4 5

b) *Fácil de compreender*

Discordo — Concordo

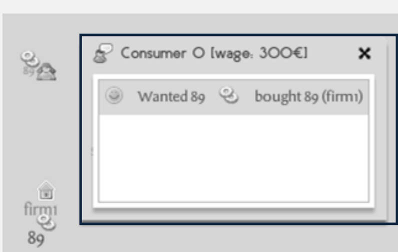
1 2 3 4 5

C –Consumidor

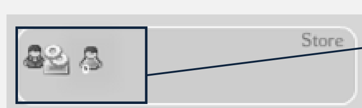


Informação do consumidor (C1, C2, C3, C4) A informação do consumidor inclui o estado do consumidor (C1), intenções de compra (C2), movimentação entre lojas (C3) e comportamento no interior da loja (C4).

Estado do consumidor (C1): Cada consumidor apresentava cores diferentes conforme a sua satisfação na última tentativa de compra. Cada consumidor apresentava também um símbolo do último produto e quantidade comprada.



Intenções de compra (C2): Ao clicar num consumidor era possível ter acesso às suas intenções de compra.



Interior da loja (C4): Era possível visualizar o comportamento de um consumidor no interior da loja (lugar na fila, tempo de espera, as suas compras).

[5] (A1 - dinheiro, A2 – unidades vendidas, A3 - stock)

2.4. A visualização do estado dos consumidores (C1) foi:

a) Útil para a compreensão do jogo

Discordo — Concordo

1 2 3 4 5

b) Fácil de compreender

Discordo — Concordo

1 2 3 4 5

2.5. A visualização das intenções de compra dos consumidores (C2) foi:

a) Útil para a compreensão do jogo

Discordo — Concordo

1 2 3 4 5

b) Fácil de compreender

Discordo — Concordo

1 2 3 4 5

2.6. A visualização das movimentações dos consumidores entre lojas (C3) foi:

a) Útil para a compreensão do jogo

Discordo — Concordo

1 2 3 4 5

b) Fácil de compreender

Discordo — Concordo

1 2 3 4 5

2.7. A visualização do comportamento dos consumidores no interior das lojas (C4) foi:

a) Útil para a compreensão do jogo

Discordo — Concordo

1 2 3 4 5

b) Fácil de compreender

Discordo — Concordo

1 2 3 4 5

IV – SUGESTÕES

1. Como poderia o jogo ser melhorado:
   a. Relativamente à informação apresentada?

   ____

   ____

   ____

   b. Relativamente à compreensão do jogo?

   ____

   ____

   ____

FIM

Obrigado pela sua cooperação ☺!