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der Christian-Albrechts-Universität zu Kiel

Agent-based modelling for investigating consumer behaviour in risky markets –
the case of food scares

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List of abbreviations

ACE	-	Agent-based computational economics
ACL	-	Agent communication language
A.D.	-	Anno Domini
AI	-	Artificial Intelligence
BSE	-	Bovine Spongiform Encephalopathy
CA	-	Cellular automata
CUP	-	Communication and updating processes
DAI	-	Distributed artificial intelligence
IS	-	Information strategy
IT	-	Information technology
KQML	-	Knowledge query manipulation language
LTM	-	Long-term memory
MAS	-	Multi-agent simulation
MIT	-	Massachusetts Institute of Technology
NWS	-	Network structure
OOA	-	Object oriented analysis
OOD	-	Object oriented design
SFI	-	Santa Fe Institute
SNA	-	Social network analysis
SPARTA	-	S(ubjective norm), P(erceived behavioural control), A(ttitude), R(isk perception), T(rust), A(lia)
SR	-	Stimulus-Response
STM	-	Short-term memory
TPB	-	Theory of Planned Behaviour
TV	-	Television
UML	-	Unified Modelling Language
USM	-	Ultra short-term memory
vCJD	-	(new) variant of Creutzfeldt-Jakob Disease
ZMP	-	Zentrale Markt- und Preisberichtsstelle GmbH, Bonn

1. Introduction

Human beings live in a world of uncertainty, facing various risks every day. In the long run, these risks influence trust. Information can reduce uncertainty and risks, and thus ensure trust. The media pass information to consumers, which face consumption decisions within the food market every day.

This thesis investigates consumer behaviour within risky markets, especially in the case of a food scare, using a multi-agent simulation.

These risks are manifold, from negligible risks up to perilous individual risks. People participate in various different markets. These markets are also characterised by uncertainties. Incomplete information about quantities, qualities and price developments make future-oriented planning difficult. Competition concerning resources leads to strategic behaviour which is abundant. The resulting dynamics bear risks in the sense of uncertainty for everyone.

Human beings as consumers have to decide about consumption every day. The single is responsible for his single household whereas the parents, mother or father, respectively the one who is doing the every day shopping is responsible for the children and for the entire household. Children trust their parents that they keep care of them. The consumers respectively the purchasers have to trust the suppliers and the producers to be reliable. Hence risk and trust are somehow interconnected and influence each other and both influence the behaviour of the individuals and the consumers.

Information is one important mean to reduce risk and uncertainty. In former times information was sparse and the media was not or only partly installed. Word-of-mouth and the social networks were the sources to get information. This environment was a good opportunity for rumours to diffuse over the population. Later newspapers and the radio were available as information sources. They had a large influence on the formation of opinions within a population and offered the ones who owned or controlled these media good opportunities to use these influencing capacities for own purposes. The variety of these media sources and hence the information released by them was limited. In this time the power of the media and especially the power of their controllers were very high. Later and due to technological development new types of media like TV and the Internet yield to the fact that more people could be reached in parallel and also the variety and the number of information increased rapidly. Today there is an immense amount of information present so that each individual can find its own personalised information package – theoretically. In former times information was scarce, now, due to the information overload, it is the consumer's, respectively the listener's attention that is scarce. Thus this effect leads to an increase of uncertainty. Hence the problem is that too little information can not decrease uncertainty on the one hand and on the other hand too many information leads to an increase of uncertainty.

Uncertainty can also be found in the food market. This kind of risky market is connected to every individual since food consumption has to be done by everybody. This is a very sensitive area of risky markets. The case of food scares is combined with a high degree of uncertainty of the consumers. This uncertainty is influenced by food safety information released by the media. Germany was for a long time officially declared as free of BSE¹. But in the winter 2000/2001 when the first cases of BSE infected cows was discovered in Germany, the country went into a national BSE-crisis. The market for beef broke down and whole herds of cattle were killed if only one BSE infected cow was discovered. The existence of a lot of farmers was endangered. The responsible politicians made fast and momentous decisions and initiated actions to cope with the crisis at the same time. The media have spread increasing numbers of scandal messages and they also supported the discussion regarding the safety of food. The uncertainty of the consumers has increased and as a reaction to this health risk which was not assessable for them, they changed their meat buying and consumption behaviour at least in the short-term. The appearance of BSE in Germany was followed by massive economic consequences which were noticeable in the economic markets as well as in politics (EGENOLF 2004).

Consumption decisions of consumers, risky markets and the media as the sources of information releases are strongly interconnected. They form a complex system. A recent interdisciplinary research approach which is highly engaged in the investigation of complex economic phenomena is called 'econophysics'. The idea of this research direction is to combine physical research methodologies – especially simulation techniques – with economic and social research fields. Some economic and social phenomena are viewed to have similar characteristics physical phenomena, which in turn are investigated in the field of complex systems research. Economic research is linked to people and their behaviour in economic decision situations. It is closely related to social sciences where human beings and their relations and networks are in the focus of the investigations of researchers. The network aspect and the collective social behaviour is a domain of social sciences whereas economic research is more engaged in topics like decision finding and making. In recent time, networks also became of more interest for economic research. This finds its reason in the fact that decision makers faced problems which became more and more complex – among others by the development of information technology within the last decade. Network effects became increasingly important. One example for econophysics is the application of simulation methods which were formerly used to model multi-particle physics for investigating economic phenomena. The decision makers can be modelled as artificial agents in a network. They are connected to several other agents which more or less influence the decision making process. The agents act on the individual level but they are influenced by reciprocal network relations. The entire system has a non-linear behaviour which seems to be a collective behaviour governed not by one single

¹ BSE – Bovine Spongiform Encephalopathy also known as 'mad cow disease'.

‘market maker’ but by the sum of individual actions. If researchers want to investigate the behaviour of such complex systems it is reasonable to choose an agent-based approach. This approach offers the possibility to reproduce and analyse patterns which can be observed in the real world. Agent-based modelling is a technique which was used in physics to investigate the behaviour of multi-particles or to analyse research questions in thermodynamics and which is now adopted by econophysics and social sciences.

The aim of this thesis is to investigate consumer behaviour in risky markets, especially in the case of food scares. Risk perception, trust and the role of the media will be investigated by using agent-based modelling. A multi-agent simulation will be implemented which will be used for testing different information strategies released by the media which are defined as risk communication strategies. These risk communication strategies will be evaluated by the recovery of the aggregate trust of an artificial consumer population. The artificial consumer agents follow the Bayes’ rule provided by BOECKER AND HANF (2000). The Bayes’ rule is a reinforced learning mechanism which updates the trust in a supplier of the food item under observation by considering food safety information released by the media.

The multi-agent simulation will be used to derive implications for risk communication strategies. The following research questions will be addressed by using the multi-agent simulation:

1. How does a food scare and information of a food scare released by the media influence the trust development and the behaviour of a consumer and the entire population?
2. Do different types of media have different influence on the opinion formation and the trust building of the consumer population?
3. What is the role of forgetting processes or overlaying processes of other news topics in relation of the recovery of trust?
4. Can risk communication support the recovery of trust?
5. How can effective risk communication strategies be evaluated?
6. Does the country have an effect on the development of trust?
7. What is the role of opinion leaders and which effect has the structure of the network on the diffusion of information?

The basis for these analyses is a European Union research project called “*TRUST - Food risk Communication and Consumers’ Trust in the Food Supply Chain*” (Quality of Life Programme, Key Action 1 (Food, Nutrition and Health), QLK1-CT-2002-02343) which was accomplished in Italy, France, The Netherlands, Great Britain and Germany.

The following chapters will present an insight into the field of agent-based modelling with special emphasis on the application possibilities for economic research and in particular for investigating consumer behaviour with respect to food scares and information releases by the media. Chapter 2 makes a classification of agent-based modelling in the context of scientific research in general and explains this new perspective on the object of research by comparing it with established empirical and analytical methods. In this chapter complexity and emer-

gence are described and discussed. These phenomena are of high importance for the principle understanding of real world phenomena. Chapter 3 addresses theoretical aspects of simulation theory. In particular, agent-based simulations and network theory aspects are investigated which are relevant for the multi-agent simulation explained in chapter 5. Chapter 4 is concerned with cognitive processes, perception and the influence of the media since these aspects are relevant for the modelling of the multi-agent simulation. Chapter 5 describes the multi-agent simulation which was modelled and implemented for investigating consumer response to food scares under different information scenarios. Chapter 6 is addressed to testing different information release strategies and scenarios based on the outcomes of the simulation runs of the multi-agent simulation. These results serve as evaluations of different risk communication strategies. In chapter 7 the assumptions, the research approaches and the results are summarised, drawing conclusions with respect to the underlying research questions.

2. Agent-based modelling in scientific research

Scientific research is done in various disciplines. The research methodologies are often type specific according to the object of research and depending on the coherences which are under investigation. Agent-based modelling is a relatively new research methodology especially in the economic and social sciences. Artificial agents serve as proxies for real world objects which are interrelated in an artificial environment driven from parts of the real world which shall be analysed. Complexity and emergence are phenomena which are important in this context. These phenomena and their relation to agent-based modelling will be described in this chapter. Then the conventional economic theory with its assumptions and implications will be compared to this new approach of investigating economic and social phenomena. A brief history of agent-based modelling shows the background and the development of this research methodology and finally a classification of agent-based models in the scientific space will be performed.

2.1 Complexity and emergence

Complexity and emergence are phenomena which are observable in a lot of situations ranging from chaotic systems in nature, bubbles in financial markets, trends in culture, the creation and bargaining of politics and also complexity in social networks and emergence of social networks. Often these phenomena and the implications and results are not predictable. A number of factors are influencing each other and consequently the outcomes are hard to estimate. Complexity and emergence are topics of complex systems research they will be described in the following.

Complex systems research is a field which is hard to define and to isolate. It touches all kinds of disciplines and situations that it is some kind of idiosyncratic like the way it views the world. WALDROP (1992, 9) wrote: “... *the science of complexity – a subject that is still so new and so wide-ranging that nobody knows quite how to define it, or even where its boundaries lie. But then, that is the whole point. If the field seems poorly defined at the moment, it is because complexity research is trying to grapple with questions that defy all the conventional categories.*” This statement shows the difficulties in grasping the space of complexity research. For this reason it is better to view on examples on complex phenomena. What are complex phenomena? Complex phenomena could be decentralised markets, inductive learning, consumer societies, and endogenous evolving trading networks and so on. Decentralised markets are complex adaptive systems which consist of a large number of adaptive agents which are connected to parallel local interactions (TESFATSION, 2002). These local interactions lead to macro economical regularities like behavioural norms which feedback to the determinants of local interactions. The result is a complex dynamical system of repeating causal chains which connect individual behaviour, interaction networks and social welfare.² These phenomena which result from the bottom up are guided by the ‘invisible hand’ like described in Adam SMITH’s ‘The Wealth of Nations’ (SMITH 1976).

The agent population lives in an environment and forms by interaction a complex system. This is a major point: not the system itself is complex but the interaction between the single agents or particles makes the system complex.

The question then is ‘how do complex phenomena emerge?’ One important issue to address is already mentioned in the question: emergence. Emergence means the coming up of characteristics which did not exist before qualitatively different components have been merged or divided. Consider our brain which consists of a huge number of ‘simple’ elements, the neurons. The interaction of these elements leads to an evolving of patterns which make up the brain activity: one single neuron has no thought, the brain as a whole normally has. GILBERT AND TROITZSCH (1999, 10) use another example to explain emergence. They argue that a phenomenon is emergent if the explanation of the behaviour of this phenomenon needs new categories. These were on the other hand not needed to explain the behaviour of the single components. This means that the interactions of two single objects at one layer lead to different objects on another layer. Their example is the temperature. Temperature is the emergent phenomenon which arises by the movement of atoms. The characteristic point is that only a collection of atoms possesses temperature while each single atom itself has no temperature, in this sense temperature has emergent properties.

² In this context the notion of cybernetics from WIENER (1958) should be mentioned who referred to the feedback mechanism of James Clerk MAXWELL. Cybernetics is the science of the structure of complex systems especially of communication and control of a feedback or a control circuit. Nowadays there exists a powerful mathematical system theory in control theory which allows describing the behaviour of systems.

The phenomenon ‘emergence’ is a kind of universal player. It does not care about the restrictions of any scientific discipline. Emergence is observable in many scientific fields. From this point of view it is no wonder that several scientists from different disciplines address the same question, namely the forces that drive emergence and the results that evolve under different conditions. Biologists, physicists, social scientists and also economists (and this list is not complete) discuss the common phenomenon with special reference to questions within their fields. HOLLAND (1998, 1) is of the opinion that we have to understand emergence before we can understand life³.

There is one typical assumption underlying this theory: the unpredictability of emergent properties, i.e. even if perfect knowledge with respect to the parts of a system is present some properties of the whole system are not predictable (STEPHAN 1999).

In each part of life, social life and nature there are processes involved. Most social processes are complex. An isolated observation of sub-processes is often not suited to draw conclusions of the aggregate. Interesting in this context is that the social sciences are organised in this way. This means that they are divided in fields like economics, demography, political science and so on. The counter argument of social scientists is that there is no method around which can analyse the co-evolution of these processes (EPSTEIN AND AXTELL 1996, 1). Agent-based modelling techniques however can be used as a tool for the investigation of social processes. And it also addresses the interdisciplinary aspect of this new thinking. Some concepts which were investigated with the help of agent-based simulations, for example are increasing returns (ARTHUR 1989), network externalities (KATZ AND SHAPIRO 1985 and 1986), information cascades (BIKHCHANDANI ET AL. 1992), herding behaviour (BANERJEE 1992) and information contagion (ARTHUR AND LANE 1991).

The application of artificial societies for analysing real social phenomena is a relatively new scientific instrument in social sciences. An agent-based computerised simulation model is an effective approach which differs from standard methods of analysing social phenomena. This approach can be seen as a generative method. The central point in this context is the answer to the question how decentralised local interaction lead to macroscopic phenomena like for example standards and norms or price equilibriums (EPSTEIN 1999, 1).

This last aspect compresses the complexity discussion from above. It shows that the agent-based approach is suitable for a variety of application fields which will partly be discussed in this thesis. But first some ideas and approaches about the connection of traditional economic research in comparison to the relatively new field of complexity research will be employed. The assumptions of traditional economic research contain some ideal elements and concepts

³ „Nowadays we know that genes in the seed specify a step-by-step unfolding of biochemical interactions, but only fragments of this complex process are clearly understood. Indeed, it is evident that we will not truly understand genes and chromosomes until we understand the gene specified interactions that take a seed, or a fertilized egg, to a mature organism. In short, we will not understand life and living organisms until we understand emergence.”, HOLLAND (1998), 1.

which were often criticised but which had its strength in the explanation of the basic coherences. A relaxation of the assumptions was accompanied with various problems. Complexity research offers possibilities to solve some of these problems approximately and to give explanatory support.

2.2 Is the ideal environment a specialisation of the general?

Idealisations are helpful to clarify basic coherences and to explain complex topics but often these idealisations are not to find in reality. Theory and practice differ in many cases. Ex post, theory is in most cases valid but concrete problems in present do not take care of the theory they need case specific solutions which are not always available in advance that is ex ante.

In school we learn the alphabet and the basic mathematical operations. When we start training on the job we first learn basic rules. From these ideal situations we then go to discover more detailed and complex situations and try to solve more complex problems. The same holds for students who start studying. In economic sciences the students learn about Robinson Crusoe and the basic principles of economics. Representative economic agents act according to standard economic theory like rational agents. This means they are entirely informed and they behave as objective acting and utility maximising agents. In this sense economic agents typify ideal types. Undergraduate students will, right at the beginning of their studies, be taught the concept, the assumptions and the institution of rational agents. It is necessarily justified to make these strong assumptions in order to explain the basic principles of economics.

In other scientific fields these ideal scenarios as reference scenarios also exist, for example the ideal gas, the perfect fluid or the Eulerian beam. With the help of these idealisations it is possible to get insights into the coherences and it is also possible to get some ideas about the proportions. But the major difference, with respect to reality, is that the ideal is often not real. What is meant by this statement is that for example real gases systematically differ from the ideal gas law. Similar differences can be found with fluids where the real fluid has viscosity and even for beams which exhibit buckles (AXTELL 2000, 1).

It seems that the ideal environment serves as a reference for understanding the basic coherences but beyond this sphere there are more complex dynamics at work. In the real world there can be more general events observed. Obviously the ideal environment scenario is just one possibility of all general environment scenarios and possibilities. In this sense the ideal scenario is just a specialisation of the general scenario where the underlying conditions of the ideal scenario are relaxed. The possibility space of the general also provides a combination for the ideal constellation.

Conventional economic theory postulates rational agents within their theory. But this is a strong restriction. In reality bounded rationality and incomplete information is everywhere to find. Expectations, incentives, strategic behaviour, substitution effects, moral hazard or ad-

verse selection are de facto existing. Simulation technology can deal with these features and is hence a suitable tool to investigate problems in a more realistic way.

2.3 A brief history of agent-based modelling

It was already mentioned that agent-based modelling is applied interdisciplinary. Its roots are also divers. In 1884 ABBOTT (1991) described in a science fiction roman a model in which human beings live in a two-dimensional world. They are allowed to take a look from time to time onto their world and to view their world from the outside. In the end of the 1940's V.NEUMANN (1966) and ULAM worked on abstractions of life, in form of self-reproducing automata. These models were based on cellular automata (CA). In 1949 SAKODA (1971) developed a checkerboard-model in order to investigate how members of two different groups spread over a limited area depending on their attitude towards each other. This project was related to a resettlement of the Japanese minority in the USA after the attack on Pearl Harbour. A similar approach was developed by SCHELLING (1969 and 1978). He was one of the first who used agent-based modelling for social science research. His work belongs to the basic works in this field. When he first created his simulations it was paper work, no computers were used. The aim was to show how ethnic groups develop. The result shows astonishing analogies to real world phenomena. The most conspicuous was that one group did not stop until the other group was destroyed. It was like a mob which does genocide. ALBIN (1975) implemented cellular automata for the first time. With the spread of computers in the 1970's and 1980's a multitude of application fields for CA opened up, e.g. soil erosion, collisions of galaxies, crystal growth or diffusion of fluids. CA are simple automata which interact on a grid so that patterns of behaviour at the global scale emerge. Multi-agent simulations are automata for social simulations which are somewhat more complex in their internal processing and consequently in their behaviour compared to CA.

Agent-based modelling can be found in cybernetics, connectionist cognitive science, distributed artificial intelligence, cellular automata (for example LANGTON 1989 and WOLFRAM 1986), genetic algorithms (for example HOLLAND 1975), genetic programming, artificial life, individual-based modelling in biology, condensed matter physics and co-evolution (for example AXELROD 1984). Several other fields emerged from the pioneer's works onwards.

EPSTEIN AND AXTELL (1996, 165 pp.) developed a variant of SCHELLING's segregation model which displayed the outcome of different parameter changes. The basic scenario is described in the following way: There are agents who belong either to one group (red) or to another (blue). The agents have a fixed preference for like-coloured neighbours. In this simulation the preference is just a minimum percentage. On the screen the mob is active – blue points are 'killing' red points and vice versa. This leads to a segregation of the groups. Even when it is just a computer experiment the scenario acts as a deterrent. The data packages in the agents

only follow simple rules but in the end it looks like there was just one bear in mind: to destroy the others. This digital experiment with the unexpected output is only determined by the decisions of the single agents. These single decisions led by iteration of time finally to the conflict: apartheid or segregation. It is obvious that communities organise themselves according to patterns where the single agent or member of the community is not aware of this pattern or collective behaviour although he contributes to this emergence by his behaviour.

After these first paper works of SCHELLING, scientists use modern software and computing power to create digital societies which should uncover phenomena that are observable in human societies but where the causal factors are cryptic. These multi-agent simulations follow simple rules but create after some time complex structures which are sometimes amazingly close to reality. Close enough at least to give hope for the computability of parts of human behaviour by using such models.

EPSTEIN AND AXTELL (1996) have produced a computer landscape called 'sugarscape'. In this landscape a hunter-gatherer society is searching, storing and consuming just one resource – sugar. Each agent needs an individual amount of the resource to live and he dies if he has incinerated everything by action. After certain time social netting was created in which this resource of survival was as unequally distributed as money in the real world. EPSTEIN AND AXTELL could also change the seasons and they could observe how some agents go into hibernation or how migratory birds migrated into the south.

With these possibilities of representing group behaviour in artificial societies in mind, they and others have also created simulations concerning cultures which once existed but now are disappeared (GUMERMAN ET AL. 2002). The nation of the Anasazi in the south-west of the USA disappeared mysteriously at circa 1300 A.D. The group around EPSTEIN reconstructed an artificial living space which changed climatically in the same way like the former real habitat of the Anasazi. Then they populated this artificial living space with cyber Anasazi agents. This artificial historical environment should help to discover the disappearance of the Anasazi culture. The result was that the simulation did not succeed in this point but instead in most simulation runs it created a settlement which was composed exactly at that position where the former real settlement was located and where today still ruins can be found.

HEGSELMANN (1997) tried to answer the question if solidarity between rational egoists may be possible. The results of his computer simulations were that even in a world of rational egoists which are equipped differently by nature and which look for their partners in a benefit oriented way it is possible that solidarity networks are created. HEGSELMANN states that even if these models are very simplified they provide useful insights of social phenomena. The digitalisation of the reality would be much too complicated, so that it is necessary to work with strong simplifications. In this sense especially simulations have rich advantages for the investigation of social phenomena. With the help of simulations it is possible to observe which factors are responsible for alterations in the real world by minimal changes in the parameter con-

stellation. Often it is not the big steps which lead to a turnaround but the little steps (see chapter 3.1.2). Simulations have shown that the crime rate has decreased more sustainably by selective detention than by a wave of detentions. These examples and other applications for investigating social science phenomena by means of agent-based modelling highlight the contribution of this research methodology. In the following section the agent-based methodology will be classified into the context of the research methodology space.

2.4 Classification of agent-based models in the scientific space

2.4.1 The scientific space

The scientific space comprises different sciences: natural science, philosophy, and theology (alphabetic order). Each of these sciences can look into each aspect of human life and each science will apply its significant catalogue of rules. The respective insights can not be contrary; they just display different possibilities of explanation. It is on account of this to disprove theological insights with natural means and vice versa.

Socrates was one of the first known scientists. He is related to the concept of philosophising as scrutinising the own knowledge. His student Plato perfected the concept of a dialog as a way to approximate the truth. But the first theory of science was done by Aristotle (RAPP 2004) in his script *Analytica Posteriora*. He, a student of Plato, analysed philosophy in a systematically way. Aristotle divided philosophy in theoretical science and in practical science. Theoretical science is the pursuit of knowledge while practical science is the pursuit of a good lifestyle according to Aristotle.

While Aristotle was the founder of natural philosophy, Galileo Galilei was the founder of experimental natural science. In modern times Descartes, Leibniz, Hobbes, John Locke, Hume and others caused, in consequence of their research approaches, a separation of metaphysics and a formation of natural sciences as a single research discipline.

The social and economic sciences belong to the humanitarian sciences and are closely related to the natural sciences especially in their positivistic and empirical directions. But the main difference between these sciences is determined by the fact that natural sciences focus on the object while social sciences focus on the subject. Acting subjects can change their behaviour according to a prognosis (self-fulfilling prophecy) or act in opposition (self-destroying prophecy). This implies that the empirical testing of social scientific propositions by experiments would be in some sense harder compared to natural scientific experiments.

Scientific theory

The scientific theory is part of philosophy. It is engaged in science and its functioning. The crucial aspect for the determination of a science is the question of its object and its methodological approaches. The scientific theory especially deals with the epistemology, i.e. the question how reasoning and insight can be extracted from observation. A generally accepted proceeding which has stood the test of time is called a scientific method. Due to its specific view on the reality, each scientific discipline underlies a methodological reduction. It is in the nature of models or methodologies that they have to abstract from reality and compress certain aspects otherwise they are of no use and too big to handle.

If the one-track perspective related to a single scientific research object will be ignored and if a single science area sets itself absolute by setting a part to the whole then it becomes under ideology suspicion.

There are some core questions regarding scientific theory:

- i. How does science get to new insights?
- ii. Which status do scientific insights have?

Several philosophers tried to answer these questions. In the natural sciences Karl POPPER created the 'critical rationalism' as the adequate methodology. The critical rationalism answers the questions as follows:

- i. By generating and revising of hypotheses
- ii. Insights, respectively theories maintain the character of hypotheses. One has to bargain for the falsification of a doctrine by new experiments and that new or adaptive theories may be necessary.

POPPER (1998) exposed his ideas concerning scientific theory in 'Logik der Forschung' in 1934. His idea was that scientific progress happens via the falsification of certain theories by experiments, where thesis and antithesis form synthesis. The theories which are closer to reality always win in this evolutionary selection process. This implies that there is never total knowledge; knowledge is always temporary. By the falsification of 'wrong' theories, we will come closer to the truth according to POPPER.

This approach is often regarded as unsuited to describe specific scientific problems in social and culture sciences as well as in humanities. There are other alternative starting points or claims like

- 'Gaining insights by induction because of consecutive experiments and observations',
- 'Scientific insights are true if they are in accordance with reality',
- 'Scientific insights are true due to provableness', or
- 'Explanation and prognosis capabilities of a theory are assumed'.

These conflicting positions originate among others by the different research subjects. The view of POPPER is a more general approach and is more flexible with respect of time. This means it is robust in any way because if a hypothesis is correct then it will never be rejected if it is not then it will be rejected which is exactly what POPPER had in mind.

The next sub-section is related to gain scientific insights. There will be presented a concept to gain scientific insights which is suitable in nearly every scientific discipline.

Gaining scientific insights

Scientific insights are the driving forces which are not only relevant in science but which also have impacts for societies in general. Knowledge and skills are resources and competitive factors of societies. These resources determine the position of societies with respect to other societies. The forces of nature and the competition principles govern the evolution and hence the success of the best suited organisms or in terms of civilisations the most competitive societies. Competition is a natural law for survival and evolution. The Darwinian theory of natural selection is often used by economists and social scientists. DARWIN has created a theory of natural selection where the evolution takes place by the survival of the fittest SCHMITZ (1983). Knowledge and skills are competitive advantages for societies which are better equipped with these resources than other societies. Hence scientific insights are of high interest for a society especially if they are applicable in real life situations and in technology. Researchers will be paid and honoured for scientific insights which bring the society forward. This is what drives the race to get scientific insights in all areas – in some more in others less, depending on the incentives and on the trend or the actuality.

In the beginning of each research the research question respectively the object of research has to be formulated. From this starting point on there is a general approach to get scientific insights that can be summarised by the following 5 steps:

1. Observation;
2. Model creation – in order to explain the observation;
3. Verification of the model by testing and experiments;
4. Exposing the model to public critics;
5. Changing, extending or abandoning the model depending on the result of the tests and the critics.

Scientific observation is the mindful, systematic and target-oriented perception of processes, events and behaviours of creatures (human beings or animals) in dependence of certain situations FRIEDRICHS (1985). The goal of the observation is to detect the object of interest as precise as possible. It is a basic method for data acquisition and collection of facts at the time of the events. Sources of error can be either the observer, the instrument or the situation as such.

The problem is the fact that social behaviour is viewed abstract and that the observed is not necessarily in accordance with reality.

The observation needs to be explained in some way. Model creation is such a mean to explain the observation. The model maps a part of the reality and needs to be tested if it is reliable. This can be done by experiments. If the model is reliable then it can be exposed to public critics so that it can be modified to certain needs or even falsified if it is not suitable or useful. This abstract description of getting scientific insights will be deepened in the following of this thesis on the base of a simulation. But at first the criteria for scientific tests are explained on a descriptive level at first.

Criteria for scientific tests

A scientific test is necessary to verify a model and to test if the model is reliable. The following four criteria have to be fulfilled by a scientific test:

1. Reliability of a test procedure:

A test procedure is reliable if it produces nearly the same results in repeated applications under the same initial conditions, meaning it is independent of inner and outer interference.

2. Objectivity:

An objective test is independent of the person performing the test. A test procedure must be conceived in such a manner that different investigators can achieve the same result under the same conditions.

3. Validity:

A test is valid if it assures that other not observed properties have no influence on the results of measurement.

4. Standardisation and comparability:

Results of tests are only comparable if they satisfy certain standards which have been fixed in advance.

The compliance of these criteria is necessary to guarantee that the results respectively the scientific insights are valid. They have to stand the test with the reality and they permanently have to be tested. The reason for this is that an ongoing process of evolution produces continuously changing conditions. Hence scientific insights also underlie this process; it has to be tested if they still stand to these changes in conditions.

2.4.2 Agent-based modelling in economic and social research

Social and economic research can be performed in many different ways. There are a variety of research methods that can be applied. In general there are three main methods to test hypotheses: mathematical and analytical methods, empirical and statistical methods and simulations.

Beside these quantitative methods there are also a number of qualitative methods which are not considered in the following.

Mathematical methods

Economic research is usually done in a deductive way, i.e. every economic situation is first translated into a mathematical exercise, which economic agents are supposed to solve by rigorous, analytical reasoning (WALDROP 1992, 253). The construction of a formal model and with it the building of an exact theory of the reality is to model the parts of the research object and to express the coherences in the form of a system of equations (KLUEVER 1995, 14 and 15).

Empirical and statistical methods

Empirical social and economic research offers a variety of methods to analyse and to solve social and economic problems (BACKHAUS ET AL. 2003, 2). The main factor is the connection between theory and empiricism by providing adequate methods. For the solution of social and economic problems the following factors must be fulfilled: data collection, data preparation and the implementation or the detection of a theoretical approach with quantitative methods. The quantitative methods of econometric and statistic analysis are quantifying the coherence between influencing variables and provide information regarding their statistical significance. The connection and confrontation of theory and empiricism allows on the one hand side to check empirically micro and macro economic models (deductive proceeding). On the other hand new theoretical approaches and explanations of economic and social coherences by investigating given empirical data (inductive proceeding) can be found. Statistical models are used to predict the values of dependent variables.

Simulations

Mathematical methods and empirical methods were discussed rudimentary; simulations in contrast will be discussed deeply since they are in the focus of this paper work. The simulation methodology holds an optimal position between practise and theory, although it just symbolises the reality. User of a simulation can experience the reality in a learning way by experimenting with the simulation.

In reality there are processes at work in psychology, in social relations, in technology and also in the political decision space where it would be too risky to learn or experience it by abandoning it to shocks of the reality. These processes are too important or even too serious that they should not solely be left to universities and theorist to study. Simulation can be an intermediary between practice and theory.

The time in a computer simulated system can run as fast as desired. A computer simulated system is a time lapse. The confrontation with such a time lapse system reveals failures which happen while we are working with the system (DÖRNER 1995). A simulation quickly shows the side and distant effects of plans and decisions. In this way it is possible to gain sensitivity for the reality.

Failures are important; they are a necessary transit phase for cognition, respectively to make experience and to gain insights. Working with real complex networked systems makes it more difficult to discover mistakes. They appear long after they were made and often we do not even realise them as the consequences of our behaviour. The time lapse system in form of a simulation provides solution. It shows the coincidences and it can sensitise the users for such failures.

Micro and macro simulations of administrative, economical or social action alternatives provide the effects of different policies, whereas the micro simulation especially clarifies the effects for different groups of the society. Simulations have 'inputs' entered by the researcher which are the attributes needed to make the model match up with some specific social setting and 'outputs' which are observed as the simulation runs, i.e. the behaviour of the model over time (GILBERT AND TROITZSCH 1999, 2).

There are a lot of application areas for simulations in economics. One specific type of simulation is agent-based modelling. Agent-based computational economics (ACE) is a research area where simulations are used to investigate how decentralised decision units create complex adaptive systems via parallel local interactions. TEFATSION (2002) has identified eight different application areas in economics for agent-based models (see table 1).

Table 1: Application areas for agent-based models in economics.

1. Learning and the embodied mind	There exists a broad range of algorithms which represent the learning process of computational agents, e.g. genetic algorithms.
2. Evolution of behavioural norms	Norms are generated by interaction and in social settings. AXELROD (1997, 47) uses the following definition “A norm exists in a given social setting to the extent that individuals usually act in a certain way and are often punished when seen not to be acting in this way”.
3. Bottom-up modelling of market processes	The major point in markets is the ability to perform self-organisation. Some markets follow a path dependency while others behave differently. Nearly every market can be investigated by using agent-based simulations.
4. Formation of economic networks	Economic networks play a crucial role in social and economic science. The formation of transaction networks by strategically interacting agents takes the centre stage.
5. Modelling of organisations	An organisation consists of a number of people which have an objective or performance criterion that transcends the objectives of the individuals within the group (V. ZANDT, 1998). In this sense organisations can be modelled by implementing agent-based models.
6. Design of computational agents for automated markets	This area is related to the Internet and to virtual markets. There is a number of profit oriented research on the way with continuously growing implementations in products.
7. Parallel experiments with real and computational agents	There are two main differences regarding experiments with real and computational agents: The behaviour of computational agents is determined and known in advance while it is not possible to know explicitly why real agents respectively human beings make a particular choice. Performing both experiments in parallel could support the finding of insights.
8. Building ACE computational laboratories	Work with agent-based models needs computer and programming skills. There are environments developed and still under construction which support application for non-skilled researchers. These computational laboratories permit the study of systems of multiple interacting agents by means of controlled and replicable experiments, e.g. Swarm or RePast.

Source: TESTFATSION (2002).

VRIEND (1999) has investigated information-contagious behaviour that emerges in a co-evolutionary process of interacting adaptive agents. He has shown that ACE research in general is an application of HAYEK’s methodological insights. HAYEK (1948) like Adam SMITH investigated the economy as a self-organising system, he emphasised the importance of the individual in the formation of spontaneous social products.

Simulations offer the possibility to analyse dynamics in the sense of HAYEK. Equilibriums are just temporary or can only be approximated. Some stochastic dynamic models are able to characterise an equilibrium and to reach it asymptotically but then there is nothing said about the dynamics, i.e. how it was reached. Agent-based models can give some more insights about what's beyond the equilibrium and the dynamics and this is often more interesting than an equilibrium which might never be reached. The characteristic issue with simulation technology is that it not only displays just one aspect of a solution like the stability or the equilibrium but also solution coherences. A well-working simulation can display the behaviour of a system and its development in time – beyond the equilibrium – and then it may reach equilibrium. Repeated simulations under the same initial conditions show the dependency of the parameters and the importance of the assumptions. If the code is not working adequately or if it produces artefacts then the results are of no use. The simulation and its results must always be checked for plausibility.

General systems theory

General systems theory is a universal theory which tries to develop uniform concepts and tools for the investigation and processing of appearances and laws of different kinds of systems (BERTALANFFY, 1968). It is often used as a synonym for cybernetics, the theory of self-organisation or constructivism. The general systems theory tries to find and formalise common laws in physical, biological and social systems based on the methodical holism. Principles which are found in one class of systems should also be applicable in other systems. Examples for these principles are complexity, equilibrium, feedback and self-organisation. General systems theory is not a single research discipline but more an interdisciplinary discourse. The approach provides a unique and formal representation of behavioural patterns of complex systems which can be modelled mathematically. The application of the general systems theory for social systems by LUHMANN (2002) is not undisputable among natural and social scientists. LUHMANN postulates that the last elements in social systems are not acting human beings but communication. A social system governs itself by permanently producing communications, i.e. social systems (interaction, organisation, society) can only be stimulated by communication. PARSONS (1976) in contrast states that the elements of social systems are not communications but actions. He uses the basic elements of actions to form complex structural coherences in the economy and the society.

The general systems theory is a reference for the simulation which is developed in this thesis. The next chapter thoroughly reviews simulation theory in a deeper sense and provides foundation for the applied simulation model in chapter 5.

3. Simulation theory

The close relation between natural sciences and social sciences with respect to evolutionary models will also find its place in this chapter. The reason is that both disciplines use the same methodology to explain processes.

In social and economic sciences there are a number of analytical methods. It was already mentioned that besides theoretical and empirical methods the simulation method becomes more relevant. Since the 1990s and due to the ongoing technical development in the computer and software technology the field of research applications for simulations grew rapidly. Multi-agent models offer the possibility to simulate autonomous individuals and the interaction between them. These opportunities became available from imported techniques from the study of nonlinear dynamics and from artificial intelligence research.

Complex phenomena such as the formation of social networks, economic cycles and social conflicts can be analysed as well as interactions between voters and political parties or the development of cities.

3.1 Social sciences and natural sciences: different uses of simulation

This sub-section is directed to two different research disciplines: social sciences and natural sciences. Both are using simulation techniques to explain phenomena in their fields. But it is important to mention that social sciences deal with human beings while natural sciences deal with natural phenomena. An important fact which illustrates the basic difference between the two objects of research might be this: an electron for example can not think while human beings can do so and can behave predictable or unpredictable.

An important question in science is the question of the causality. The answer to the question about the direction of causality between individuals and social groupings, i.e. “which must come first, individuals or social groupings”, is “neither”. Individuals and social groupings co-evolve together, like in the real world. In natural sciences this question is often easier to answer.

Explaining and understanding are two concepts which have determined the methodological discussion in the social sciences since the 19th century. They are the result of two different traditions of thinking – natural science vs. humanities – and also of two different notions of the object area - object vs. subject (LAMNEK 1995, 219). The aim of natural sciences is to understand certain appearances as effects of certain causes, i.e. to discover causal relationships between appearances. These detections should be collected together so that universal propositions in form of laws are resulting. These laws can then be used to explain new observable appearances (KONEGEN AND SONDERGELD 1985, 65).

Social and economic sciences deal with people while natural sciences are engaged in animate and inanimate nature. This also implies that different issues are important in modelling societies compared to modelling, for example, aggregates of physical particles. Some issues are specific to social sciences.

Explanation is related to the methodology of the natural sciences and therefore it disregards the social constitution of the reality, i.e. social life is related to subjective constitutions and creative human beings (FILSTEAD 1979, 37). In this sense human organisations seem to be like animal societies such as ants' nests (DROGOUL AND FERBER 1994). But ants build a nest according to their instincts, while people have the ability to reason and react. GILBERT (1995) calls the emergence of such reflexive institutions 'second-order-emergence'. The agents themselves can distinguish patterns of collective action and therefore their actions can be affected by these patterns. This reflexive character of human interaction is known as autopoietic or self-organisation theory (VARELA ET AL. 1991).

Natural scientific analyses would neglect this mind component and would display the social reality reduced to the object. Hence social action would be comprehended incorrect. The main argument not to use the natural science approach is that social issues are not composed of facts or material things but of meanings (GIESEN AND SCHMID 1976, 182). Agent-based modelling belongs to a new paradigm which is related to complexity research. The paradigm concept traces back to KUHN (1970) who accentuated the reciprocal relations of social and cognitive phenomena and who penetrated the dominance of the pure epistemic oriented logic of science driven by POPPER (see above).

The following paragraph shows part of a discussion between economists and physicists at the Santa Fe Institute (SFI) who try to find similarities regarding complex phenomena in their respective field. This discussion gives some insights which are important for the boundaries of the traditional economic theory with respect to reality and for the possibility space of agent-based modelling in economic and social sciences.

Agent-based simulation technology was first used in physics where agents operate in an inductive way, in which they try to reason from fragmentary data to a useful internal model. Induction is what allows us to survive in an unpredictable and often incomprehensible world. It is like playing chess: *"The players have fragmentary information about their opponents' intentions and abilities. And to fill the gaps, they do indeed use logical, deductive reasoning. But they can only use it to look a few moves ahead, at most. Much more often the players operate in a world of induction. They try to fill in the gaps on the fly by forming hypotheses, by making analogies, by drawing from past experience, by using heuristic rules of thumb. Whatever works, works – even if they do not understand why. And for that very reason, induction can not depend upon precise, deductive logic"* (WALDROP 1992, 253). The main point with respect to conventional economic theory is that usually an economic problem has to be well defined before talking about it; if this isn't the case then logic couldn't be applied. *"But in*

cases where the problem context isn't well defined, and the environment isn't stationary over time then the agents have to be adaptive otherwise they won't survive, i.e. evolution does not care whether a problem is well defined or not" (HOLLAND, cited in WALDROP 1992, 254). Adaptive agents are just responding to a reward. They do not have to make assumptions about where the reward is coming from. A system with adapting agents is always testing those hypotheses to find out which ones were useful and led to rewards, it could continue to learn even in the face of incomplete information – and even while the environment is changing in unexpected ways. Economists could now complain that this behaviour is not optimal because a rational agent is one who optimizes his utility function. But then the counter argument is “optimal relative to what?” i.e. *“in any real environment, the space of possibilities is so huge that there is no way an agent can find the optimum – or even recognize it. And that is before you take into account the fact that the environment might be changing in unforeseen ways”* (HOLLAND, cited in WALDROP 1992, 254).⁴ This would imply there is no equilibrium in the economy at all. *“The economy would be like the biosphere: always evolving, always changing, and always exploring new territory. The problem with this statement is that it does not seem possible to do economics in that case because economics had come to mean the investigation of equilibriums. That is, if things are not repeating, if things are not in equilibrium, what can we, as economists, say? How could you predict anything? How could you have a science?”* (HAHN, cited in WALDROP 1992, 255). A simple comparison from a natural science which uses simulation methods could help to answer these questions: meteorology. The weather never settles down. It never repeats itself exactly. It is essentially unpredictable more than a week or so in advance. And yet we can comprehend and explain almost everything that we see up there. We can identify important features such as weather fronts, jet streams, and high-pressure systems. We can understand their dynamics. We can understand how they interact to produce weather on a local and regional scale. In short, we have a real science of weather – without full predictability. And we can do it because prediction isn't the essence of science. The essence is comprehension and explanation. In this way it is possible to do economics without equilibrium.

This kind of thinking about economics is quite different from the conventional perspective on economic theory; this is a new attitude, a new approach and a whole new world view.

There are a number of types of problems and purposes for which simulation is best suited.

⁴ ARTHUR cited in WALDROP 1992, 254: *“This whole induction business fascinated me,” says Arthur. “Here you could think about doing economics where the problem facing economic agent was not even well defined, where the environment is not well defined, where the environment might be changing, where the changes were totally unknown. And, of course, you just had to think for about a tenth of a second to realize, that is what life is all about. People routinely make decisions in contexts that are not well defined, without even realizing it. You muddle through, you adapt ideas, you copy, you try what worked in the past, you try out things. And, in fact, economists had talked about this kind of behaviour before. But we were finding ways to make it analytically precise, to build it into the heart of the theory.”*

3.2 Simulation application fields

Besides ACE application fields there are a number of other application fields for simulations. Simulation is an approach to analyse dynamical systems, it often replaces an experiment if this can not be carried out because of ethical, practical or financial reasons. A car crash test is a simulation model for real traffic situations where a car is involved in a traffic accident. The preliminary events leading up to the accident, the traffic situation and the exact consistence of the other party will be radically simplified so that just the main factors can be analysed. Another advantage is that there are no persons involved but crash test dummies which have similar mechanical properties like human beings. Hence a simulation model has just certain aspects in common with real accidents. Which aspects these are, depends on the question which should be answered by performing this simulation. The following table displays some reasons and application fields for simulations.

Table 2: Simulation application areas and motivations.

Reasons for the application of simulations:	Examples:
Investigation in a real system would be too elaborate, too expensive, ethically not justifiable or too dangerous	<ul style="list-style-type: none"> ➔ Crash test (too dangerous in reality) ➔ Simulation of industrial facilities (repeated rebuilding of the facility would be too elaborate or too expensive)
The real system is not (yet) existing	<ul style="list-style-type: none"> ➔ Wind tunnel experiments with models of airplanes before the airplane will be produced
The real system can not be observed directly	<ul style="list-style-type: none"> ➔ Depending on the system. Example: simulation of single molecules in a fluidity ➔ The real system works to rapid. Example: simulation of circuits ➔ The real system works to slow. Example: simulation of geologic processes
A simulation model can be much easier modified than the real system with respect to experiments	<ul style="list-style-type: none"> ➔ Modelling city planning
Risk less and cost-efficient training	<ul style="list-style-type: none"> ➔ Flight simulation
Game programming	<ul style="list-style-type: none"> ➔ SimCity

Besides a better understanding of some features of the world, the classical use of simulation is prediction. That is if the model faithfully reproduces the dynamics of some behaviour, it may be possible to make some predictions, e.g. for evaluating risk communication strategies.

GILBERT AND TROITZSCH (1999, 13) emphasised the similarity to experimental methodology. If a simulation model will be executed many times and if different conditions will be tested then it is possible to discover the effects of different parameters. But there is a slight difference between experiments and simulation: in an experiment, one is controlling the actual object of interest, while in a simulation one is experimenting with a model rather than the phenomenon itself.

AXTELL (2000, 6) differentiates between three agent modeling approaches. One approach is closely related to operations research simulations, i.e. it will be used if equations can be for-

mulated which completely describe a social process and if the whole system can be solved explicitly. The second approach is a complement for the mathematical model if the equilibrium is unknown, the stability of the equilibrium is not determined or the dependency of the parameters is opaque. The third approach is finally directed to apply agent-based simulations if mathematical models can be formulated but can not be solved.

GILBERT AND TROITZSCH (1999, 13) have identified some factors which tag simulation as more appropriate to social science than mathematics:

- Programming languages are more expressive and less abstract than most mathematical techniques.
- A program deals more easily with parallel processes and processes without a well-defined order of actions than systems of mathematical equations.
- Programs could be modular, major changes can be made in one part without the need to change other parts of the program.
- Simulation systems can include heterogeneous agents.
- The main advantages of using simulations are the possibilities for doing experiments, proofs and discovery.

As a matter of principle one has to distinguish between simulation with and without computer. A simulation is an as-if act made up out of processes. This can be done with and without a computer. Nowadays usually computer simulations are meant.

A computer simulation is basically a program. In this program there will be defined the rules of the processes. Analogue to behavioural equations in mathematical systems in computer simulations there are behavioural algorithms. Models can be invented ad hoc but they can also be derived from empirical findings or from theories, e.g. weather models are derived from the theory of hydro dynamics.

3.3 Basic concepts

The basic idea with respect to the formulation of a scientific model is the reduction of complexity: one tries to make reality describable and understandable by simplifying it. If the model can be quantitatively formulated and described by a closed set of equations then it is a mathematical model. If the model is too complex that it can just be evaluated by numerical methods then it is a computer model respectively a simulation. A so called computer model is nothing else then a mathematical model which will be evaluated with the computer. A computer simulation is then the evaluation of a mathematical model.

Most of the basic concepts in agent-based simulation theory and implementation were developed in the fields of computer science especially in artificial intelligence and in the field of nonlinear dynamics. They play an important role in the development of simulations. In the following basic core concepts of these fields will be presented roughly.

3.3.1 Artificial intelligence (AI)

Artificial intelligence is a research discipline which is closely connected to computer science. The self-conception of artificial intelligence is as hard to define as the concept of complexity. The matters of AI-research are the analysis and the construction of cognitive systems. These cognitive systems are able to do intelligent efforts. The concept 'intelligence' withdraws from all-embracing explanation. There is a distinction between 'hard' AI-research and 'weak' AI-research. Hard AI-research is concerned with the computer theory of the mind while weak AI-research defines its objective of research as follows: clearly definable parts of human intelligence which can be instantiated in automatic systems. In science, just the latter abilities are granted to AI-systems and not general human properties.

AI deals with 'machine learning' (MICHALSKI ET AL. 1983). Computer programs can increase their knowledge and their procedural skills by learning from experience. The simulation of cognitive processes can be supported by this learning technique.

The methods of AI offer a big variety of tools to investigate these complicated mechanisms. Simulation runs generate results and could serve to get a deeper insight into the processes that drive evolving phenomena. Computational laboratories allow investigating under controlled experimental conditions how for example consumer populations decide or how consumer populations might be influenced by information.

3.3.2 Nonlinear dynamics and chaos

Simple things can create very complex situations just by interaction. Even when agents just have some simple rules the aggregate behaviour can become very complex. Chaos theory is dealing with this subject; it is part of mathematics and physics. Certain nonlinear dynamic systems which possess a number of phenomena that lead to chaos are the basic topics of interest in chaos theory. Chaos theory was among others originated by Lorenz, Mandelbrot and Poincaré. A popular example is the butterfly effect discovered by Edward N. LORENZ, a meteorologist at the MIT institute. LORENZ has modelled a meteorological computer simulation and he ran the simulation for days. Once he wanted to investigate how the simulation behaves for a longer run time, so he continued with computations which he computed in another run. These numbers were the new starting values in the same experiment in order to save time. But instead of reproducing the same result, the computer produced results which were completely different from the results of the other runs although the computer produced in the beginning the same pattern. The reason for this divergence was that LORENZ marginally changed the numbers. The computer has saved numbers with six digits but the printer has just printed the first three digits so that there was a marginal change in the numbers. LORENZ has inserted the abbreviated numbers and the thousandth part was enough to change the outcome of the simulation completely. This effect was called the butterfly effect because the sheet flutter of a but-

terfly could cause minimal atmospheric changes so that somewhere else the atmosphere was influenced in the sense of producing a tornado which would not have happened if the butterfly were of no influence (STEPHAN 1999, 243 and 244).

LORENZ started a new kind of thinking which is related to deterministic non-periodic flow in chaos theory. He summed up his results like follows: *“Finite systems of deterministic ordinary nonlinear differential equations may be designed to represent forced dissipative hydrodynamic flow. Solutions of these equations can be identified with trajectories in phase space. [...] A simple system representing cellular convection is solved numerically. All of the solutions are found to be unstable, and almost all of them are non-periodic. The feasibility of very long-range weather prediction is examined in the light of these results”* (cited in STEWART 1989, 133). Chaos is not the common idea of disorder but the temporal behaviour of a system, its dynamics. Chaotic behaviour emerges in the strict sense if the changes of the initial conditions and the resulting differences in the development of the system grow exponentially in time instead of linear or polynomial given that the system is limited so that the differences are within certain boundaries. Nonlinear respectively chaotic systems and their system status can not be expressed in linear equations. Until now nonlinear equations which are used to analyse and describe dynamical systems are hard or only numerically solvable. Although these systems are in principle deterministic it is not possible to perform a useful forecast for a longer time. If one observes the climate then one needs to include an infinite number of state variables, e.g. weather cycles, which influence the climate. The forecast of the weather is in this sense depending on an infinite number of known and unknown functional chains and therefore unpredictable in the long run.

‘Feedback’, which was already mentioned above, is another influencing factor. These hard to detect systemic reciprocities are expressed in chaos theory as ‘Everything is connected with everything’. The sheet flutter of a butterfly in the Amazon region, representative for minimal changes in one factor in the beginning, could invoke a thunder storm in Europe as a great effect in the end value. Each marginal change in the initial conditions of a system leads to new states or even new initial states of the system which on their part lead to further unpredictable dynamics of the system; this is the iteration or feedback effect. The causality of such phenomena is largely unexplored. At this point there should just be mentioned that the model of the phase space is used to describe nonlinear systems. The phase space maps the chronology of specific combinations measured from the state variables respectively the parameters, this means that specific system states can be grasped on a timeline. Each measurable state marks a point respectively a combination of state variables in the phase space. These points are called attractors which are temporal states of equilibriums in the phase space like for example the initial and the end states of a dynamical system. The directions of effect of the attractors are driven by the trajectories which are the track curves of non-overlapping temporal states of equilibriums.

Due to the extreme requirements with respect to the exactness of the initial conditions there is a relation to quantum theory. HEISENBERG's uncertainty principle indicates that the place and the velocity of a particle can not be defined exactly at the same time. This constraint is in general only relevant in the micro cosmos but the predictability of macroscopic chaotic systems also touches the frontier of the uncertainty principle. Hence chaotic systems are in reference to their deterministic character quantum mechanical systems. This implies that they are in principle not deterministic due to restricted validity of classical physics.

Coming back to the application field in social and economic research it is first to mention that often conventional statistical methods are used to analyse data on social systems. The problem with these methods is that they are based on assumptions of linear relationships between variables. Complexity theory deals with nonlinear systems (WALDROP 1992, KAUFMAN 1995) which seem to be more relevant for social and economic research. GILBERT AND TROITZSCH (1999, 10) use a plastic example. They are considering a steady stream of sand out of a pipe which mounts up into a pyramid. As more sand pours out of the pipe there will be a little landslide down the side of the pile. And while the pyramidal shape of the pile and the angle of the pile are predictable, the timing, location and scale of the landslides are unpredictable because the slippage is nonlinear, that is once a grain of sand starts sliding, it pulls others along with it and there is positive feedback to a mass of sand slipping. If one considers stock market crashes then there might be similar nonlinearities be responsible to cause the markets to crash. One lesson to learn from these nonlinear systems is that it is not possible to make predictions. The models which deal with complexity theory are very well suited to analyse and to explain coherences but they are not able to predict future behaviour in a deterministic way. Transferred to social science means that it is even harder to perform predictions. Social action is already complex but individual cognition, e.g. under bounded rationality, which is underlying the social action is also complex (CONTE AND CASTELFRANCHI 1995). If an atom could think like human beings then physics would probably get into trouble.

3.4 Modelling approaches

The word 'model' has its origin in the Italian renaissance (*modello*, coming from *modulo* the scale in architecture). The appearance and the diffusion of the term 'model' started in the beginning of the 1920s with the atomic model. Meanwhile it is commonly known that science uses models to understand phenomena. A model has to be simple in relation to reality otherwise it is not flexible enough and no conclusion can be drawn. Mathematicians, among them James D. MURRAY, have developed a 'divorce formula'⁵ which helped predicting a hit rate of 94% if a couple gets separated or not. The method is based on a simple computation of the ra-

⁵ <http://www.spiegel.de/wissenschaft/mensch/0,1518,286112,00.html>

tio between nice and not so nice sections in a marital disputation. The success of the model was based on simple mathematics and produced relatively good predictions. Hence a model should be able to map simple causal coherences and to make under certain realistic assumptions good propositions of future events.

STACHOWIAK (1973) proposed a general theory of modelling. The general concept of 'a model' is not dependent to a specific scientific discipline. A model is characterised by three features:

1. Mapping: A model is always a map of something; it is a representation of natural or artificial originals which in turn could be models.
2. Reduction: A model does not cover all attributes of the original but only those which seem relevant for the modeller, respectively the user of the model.
3. Pragmatism: Pragmatism means orientation with respect to usefulness. A model is not the end in itself with regard to the original. The assignment of a model to the original is governed by the questions *for whom?*, *why?* and *what for?*. A model will be used by the modeller, respectively the user for a certain time and for a certain purpose representative for the original. The model has to be interpreted.

The main feature of a model is abstraction, i.e. the aware negligence of certain attributes in order to highlight the main properties of real world within the model.

A mathematical model tries to include the essential parameters of natural phenomena. These parameters will then be used in computable systems of equations, differential equation systems or similar to make prognosis for the observed system. Computability means the analytical investigation as well as the approximation by means of numerical procedures. As a general rule the so called physical models are also mathematical models but based on physical laws. Likewise mathematical models are used in economic science, e.g. for the calculation of business cycles. These models are not abstracting from nature but from economic or social systems.

3.4.1 Modelling procedure for simulation research

A model serves as a basis for discussion; it does not map the reality in a one to one manner. The 'target' is the presentation of a real world phenomenon (DORAN AND GILBERT 1994; ZEIGLER 1976) within a model. In the following a modelling approach of GILBERT AND TROITZSCH (1999, 14) will be described.

1. Methodology of simulation research:

The model of a target needs to be much simpler than the real world phenomenon itself. The idea behind this reduction is that insights from the model and its behaviour should be drawn which are also valid for the real world phenomenon the target represents. Hence the model

must also map and include the dynamics which are observable in the behaviour of the target. This means the changing in time and the reaction to the environment. Furthermore the model must also have the same structure and behaviour like the target. The conclusions can then be drawn by investigating and analysing the behaviour of the simulation over time.

2. The logic of simulation as a method:

A model in social science is based on social processes; in this case the model is a computer simulation. The simulation will be run and its behaviour will be measured. The simulation will be used to generate simulated data. These data will then be compared with observed empirical data. It will be investigated, if the generated data are conform with the observed data in the real world (see figure 1).

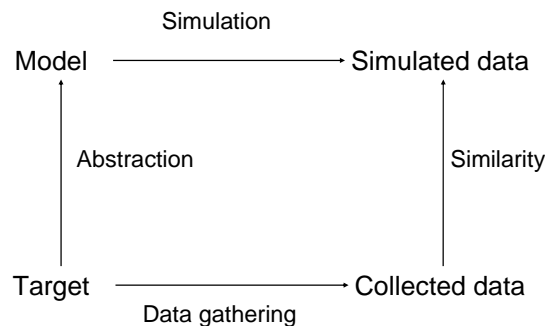


Figure 1: The logic of simulation as a method (Source: GILBERT AND TROITZSCH 1999, 16)

3. The stages of simulation-based research:

- i. Research objective – identifying the questions that should be answered.
- ii. Definition of the target to be modelled.
- iii. Identifying the parameters and initial conditions – by means of observations of the target.
- iv. Programming the model – object oriented programming is well suited for agent-based simulations.
- v. Execution of the simulation and data recording.
- vi. Verification – each model must be checked whether it works correct and as intended, i.e. debugging.
- vii. Validation – the behaviour of the model must be conform to the behaviour of the target. A pattern observed in reality must be reproducible within the simulation.
- viii. Sensitivity analysis – observing the effects of slight changes in the parameter space and initial conditions.

After this basic description of the modelling of a simulation, the agents will be described in the following sub-section.

3.4.2 Agents

Agent-based simulations are simulations where an agent acts on behalf of someone else's interests. Hence an agent is a proxy for an object. In AI-research and in complex science, agents are human beings, animals and artificial beings. They can be modelled as real world objects which have certain capabilities.

FERBER (2001) defines an agent as a physical or virtual entity which:

- i. acts autonomous in an environment,
- ii. can communicate directly with other agents,
- iii. is driven by a set of intentions,
- iv. possesses own resources,
- v. is able to perceive its environment (but to a certain extend),
- vi. just owns a partial representation of its environment,
- vii. possesses certain skills and can offer special services,
- viii. can reproduce itself if necessary and
- ix. who's behaviour is directed to fulfil aims given their resources and skills and relying on their perception, internal models and communication with other agents.

Technically agents are self-contained programs which can control their own actions based on their perceptions of their operating environment (HUHNS AND SINGH 1998). Often they are programmed in an object oriented way.

Agents are connected via networks. On the Internet there are an increasing number of applications where agents act as commercial robots (MAES 1994). These are distributed and practical applications which are related to distributed artificial intelligence (DAI). Besides these commercial applications there are a number of different scientific branches which analyse network structures and network effects using agent-based modelling. Networks have a significant impact on the aggregated outcomes at the macroscopic level. The agents are part of the network and influence each other via communication and action. They are either individually and/or collectively responsible for network effects.

3.4.3 Networks

Networks play a crucial role in economics and social science. Networks are the basic infrastructure for individual entities to interact; they are structures or systems which can be modelled with mathematical graphs. A network consists according to graph theory of a set of elements (nodes) which are connected by relations (links). A prominent and one of the first applications of graph theory is the 'Königsberger Brückenproblem' by EULER. The city of Königsberg had seven bridges (a to g) crossing the river Pregel (see figure 2).

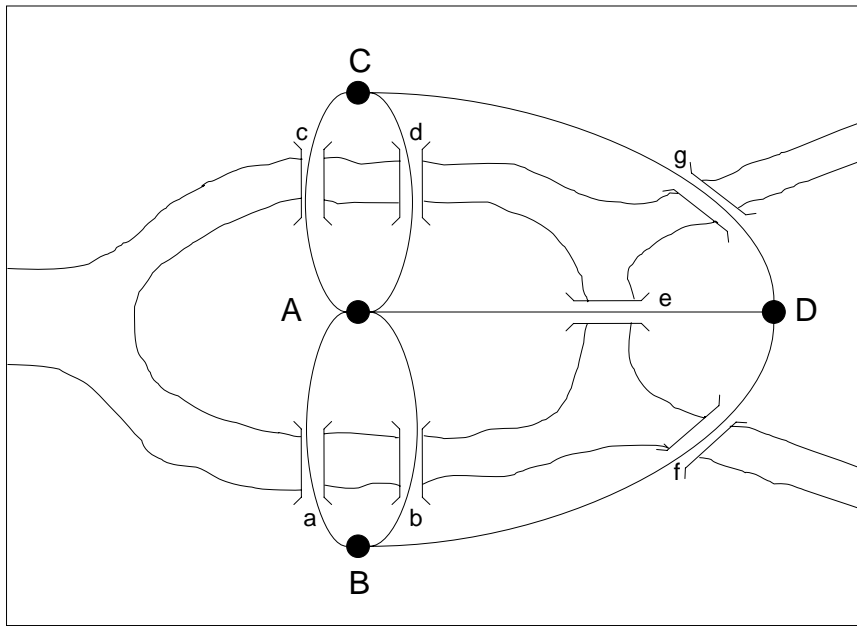


Figure 2: Bridges of Königsberg before 1875 (Source: BARABÁSI 2003, 11)

There is an island (A) in the Pregel called Kneiphof island and also a land area (D) which is situated between the two branches of the Pregel river. The city of Königsberg was asking if there exist a loop road in the sense “*of finding a route around the city that would require a person to cross the bridge only once*” (BARABÁSI 2003, 11). EULER has proofed mathematically by implementing and using graph theory that there is no possibility of finding a loop way. He introduced the notions of nodes and links and he claimed that a loop way would exist when no node has an odd number of links, which wasn't the case in Königsberg. This cycle is called an Euler cycle and is in general admitted in graph theory.

There are many areas where networks are found. Examples are computer networks where single computers are linked among each other by communication connections or road networks where locations are represented by nodes and streets are represented by links and then there are also social networks with persons and their relations. Everywhere where human beings are connected in any form there are also social networks. The focus in social network research lies on the social entities and their relations, e.g. communication between members of a group, economic transactions between enterprises, trade between nations or contract negotiations.

Social network analysis (SNA) is a research discipline which is engaged in patterns and implications based on relations, e.g. the measurement of structure variables. SNA is a distinct research perspective within the social and behavioural sciences. The main features of SNA are methods and models for analysing social network data. WASSERMAN AND FAUST (1997, 169) describe several measures for social network analysis. One of the most important questions

‘who are the most important actors in a social network?’ is addressed by several measures with regard to the location of the actor within a social network. These actors are usually located in strategic positions within the network. Mathematical measures of SNA are for example degree, closeness, betweenness, information and the rank of an actor (JANSEN 2003). Often social networks are structured in ‘Small Worlds’ where the maximal distance between the single entities are small (MILGRAM 1967). MILGRAM’s ‘six degrees of separation’ paradigm fits to these findings. The connection topology of networks is somewhere in between completely regular or completely random (WATTS AND STROGATZ 1998, 440). ERDÖS AND RÉNYI (1960) have introduced random networks. These networks emerge if pairs of nodes will be connected randomly together. If a critical number of links were placed then tiny isolated clusters will melt together in a giant cluster where almost every node is connected (BARABÁSI 2003, 18). But real networks are supposed to have organising principles that distinguish them from the random network model. WATTS AND STROGATZ have ‘rewired’ regular networks. They discovered systems which were highly clustered just like regular networks but with small characteristic path lengths like in random networks. They have called them ‘small-world’ networks (see figure 3).

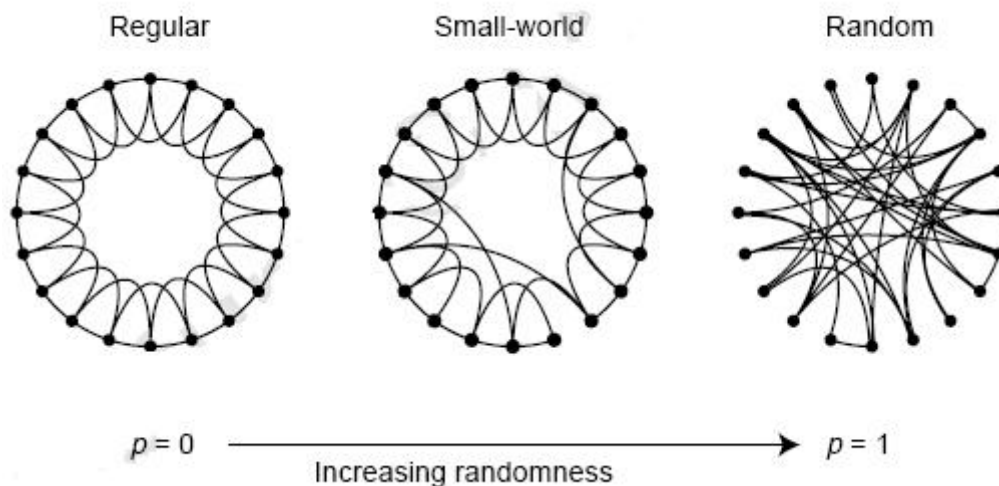


Figure 3: Network types (Source: WATTS AND STROGATZ 1998, 441)

GRANOVETTER (1973) investigated job networks, he discovered that weak ties to acquaintances are more important than strong relationships. He described an ordinary person called Ego who is part of a social network. Ego has a social network of strong relations to a collection of close friends and then he also has relations to acquaintances where few of which know each other. The acquaintances have also closer friends but different ones. It was shown that these weak ties play a crucial role with respect to the communication to the outside world. This would imply that often close friends can just help a little, while weak ties offer richer possibilities in getting opportunities.

The above described aspects are directed to the organisation of the individuals and their sustainable influences on aggregated outcomes. The network aspect as the main resource for the transition from the individual to the aggregate level is in the focus of current research. This does not imply that the micro level is of no interest but the organisation of the individuals and the interaction processes are responsible for the emerging outcomes.

The consideration of networks as a complexity creator offers the possibility to reduce the capability claims for the agents compared to standard economic theory. This means aggregation itself leads to structure (KIRMAN 2003, 274). The ways in which networks are organised determine the access to information. In this way it is also possible to explain how information asymmetries arise. Agents have limited access to the network due to limited connections to other agents. This leads to information asymmetries.

In conventional economic theory there are two economic models which mark the extreme positions. The classical Walrasian standard model is based on individuals who are completely independent and isolated. These individuals are coordinated by market signals. Whereas the individuals in a game theoretic model are in contrast completely interconnected and are fully dependent on each other. They have complete information and they are completely rational, i.e. they know the behaviour patterns of the other agents. In reality in contrast to both described models there are often situations in which agents are just partially interconnected. In these situations local interactions emerge (KIRMAN 2003, 275). Interactions of agent $i \in J$ with other agents $j \neq i$ are restricted to agents m who are in i 's network $m \subseteq J$. Due to this fact, changes will not be updated simultaneously. The network as the underlying infrastructure is the limiting respectively the regulating factor regarding the type and speed of diffusion. The emerging aggregate results depend considerably on the underlying communication infrastructure. The degree of the connectivity is responsible for the speed of the diffusion of information via the network. This also implies that this degree is also responsible for how fast an opinion spreads through the network. The aggregated effects of a local interaction depend strongly on the structure of the network.

Commonly there are two types of networks: deterministic and stochastic networks.

A network is deterministic once there is a fix communication network. Often these networks are represented in a graph where the neighbourhood is predefined. The links to the related agents are set up and unchangeable. The analysis in this case is uncomplicated.

Once the graph respectively the network is specified then the neighbourhoods are defined in the sense that agent i is influenced by his neighbours $N(i)$. The probability of agent i being in a state s is conditioned by the states of his neighbours. Thus one specifies the dependence between individuals and then sees what may happen on the aggregate level.

The network set-up can partially be deterministic and partially random but once it is set up it is deterministic.

Stochastic networks are harder to analyse. KIRMAN (2003, 278) differentiate two types of stochastic networks.

1. A network which is fixed and determined but where the interaction is stochastic. The state of an agent i depends on the states of his related agents respectively neighbours $N(i)$.
2. The other alternative is a graph or a network which is random itself. This means the upsetting of the network follows random distributions. But once the network is set up it produces a dedicated result. The choice of the random link distribution also leads to a random result.

Both types are exogenously given. The evolution of network structures in contrast is in the actual discussion. This endogenous formation of networks is technically difficult to analyse. One starting point is to look for so called 'rest-points' which maintain as stable organisations of individuals during the dynamic process of network evolution (KIRMAN 2003, 282). This research field is currently developing rapidly. EBEL ET AL. (2002) have analysed a model which deals with dynamics in social networks. Their assumption was that complex real world networks evolve not in an engineered architecture but as self-organised by agent to agent actions. An acquaintance network was modelled where the evolving of the network happens via the formation of new links between new acquaintances or people joining or leaving the network. The model showed that small world networks arose with highly clustered networks. These kinds of networks are very often observable in the real world. Besides small world networks there are a lot of other networks analysed (BOLLOBÁS AND RIORDAN 2003) for example scale-free random networks, e.g. the Internet.

In the actual discussion there are two distinct research directions to find. One addresses the strategic choice of relations while the other aims at the enforcement of relations which were well experienced by their users. The research concerning these endogenous network types and their implication for the investigation of real world phenomena enrich the discussion about the relevance of networks with respect to different outcomes.

JANSSEN AND JAGER (2001, 745) have implemented a multi-agent simulation to investigate the dynamics of different markets. They were interested to see why some markets are dominated by just a little number of products while products on other markets are changing permanently. They found out that the implemented behavioural rules were responsible for fashions, lock-ins and unstable renewals. But one of the most important influencing factors is the structure of the network. In a further paper JANSSEN AND JAGER (2003, 344) have tested different network structures. They have implemented a WATTS AND STROGATZ small world network and a scale-free power distribution network for the node connectivity. The latter network type showed that the market is dominated by a little number of products. This network type implies for the market dynamics that a small number of consumers have a far reaching influence on the consumptive behaviour of the other agents in the network. They are the hubs, respectively the

early adopters which initiate the diffusion of news or trends. Small world networks in contrast led to a higher number of products in the market. The comparison of different types of networks shows that the network structure is one of the driving forces for the formation of different outcomes.

The interesting aspect with respect to the hubs is ‘who are the hubs?’ and ‘how do they emerge?’. SNA for example can help identifying important network components. KIRMAN (2003, 292) also addresses this problem. The aggregate outcome results from the aggregated or collective behaviour. These coherences lead to the question ‘who or what are the driving forces?’ this is the identification problem. MANSKI (1995) wrote that this collective behaviour is difficult to check empirically. He identified three different explanation approaches for correlated behaviour in networks:

- Contagious effects – an individual behaves like the group;
- Exogenous (contextual) effects – depending on the exogenous properties of the group;
- Correlated effects – individuals in a group have similar attributes or are in a similar environment.

Agents are somehow influenced in their decision making by their neighbours. The influencing means are their expectations, their decisions or in another way their direct interaction. This leads to the question “*How can we distinguish what appears to be a clear case of contagion from a situation in which individuals choose independently but share some characteristics which makes them choose similarly?*” KIRMAN (2003, 292). An answer to this question is very difficult; research in this area is still in the beginning (BROCK AND DURLAUF, 2001).

3.4.4 Multi-agent simulations

It was already mentioned that agents can be proxies for ‘real world persons or objects’. These agents can be connected together in networks. Multi-agent simulations (MAS) technically offer these properties.

A MAS is a system which consists of the following elements (FERBER 2001):

1. An environment E .
2. A set of objects O . These objects are situated, i.e. at each point in time they can be assigned to a position in E . Objects can be perceived, created, modified and erased by agents.
3. A set of agents A which represent the active objects ($A \subseteq O$) of the system.
4. A set of relations R which interconnect the objects.
5. A set of operations Op so that agents can receive, create, consume, change or erase objects.
6. Operators which are the ‘laws of the defined universe’.

Virtual societies can be modelled with the help of MAS. They are much more flexible than cellular automata for example. Besides the possibility to form networks, MAS offer a rich bandwidth of application fields. The agents can communicate with each other and therefore they need a common language. Although there is no uniform language around at the time, there are two approaches which provide some basic features: ACL (agent communication language) and KQML (knowledge query manipulation language). The common basic vocabulary is based on methods like ‘request’, ‘tell’, ‘ask’ and ‘reply’. But most often the modellers create their own communication methods.

MAS are very useful to analyse phenomena in behavioural sciences. Agents can be modelled like persons in a social network. It is to acknowledge that they are highly simplified but if they are equipped with the core elements and the basic methods to deal with social processes then they are a useful tool to investigate social phenomena. This method will later on be applied to a behavioural problem in consumer research where consumers face risky situations in which the media releases information about contaminated food. This scenario is well-suited to implement a MAS and to investigate the behaviour of the artificial consumer population which partially allows inferences to the reality. The next chapter is concerned with information processing on the micro respectively the individual level and also on the macro level.

4. Cognitive processes, perception and the media

The aim of this chapter is directed to highlight the main factors of consumer behaviour in risky markets. This is necessary to provide the background for the modelling of the multi-agent simulation and to identify the relevant aspects for the behaviour of the artificial consumer agents. Special emphasis is lying on the coherences of cognitive processes and perception of the consumers as individuals and influencing capacities of the media by releasing information since this is one of the main issues which should be simulated with the multi-agent simulation.

This chapter is partitioned in seven sections. The first section is concerned with the information processing of the individuals as consumers. The second section presents artificial neural networks. This is an excursion which is needed to make a linkage between biological learning and information processing of the individuals on the one hand and agent-based updating of new information in the multi-agent simulation on the other hand. The third and the fourth sections are directed to give an overview over the perception and evaluation of products and over the decision behaviour and product selection. In these two sections a lot of aspects concerning consumer behaviour are mentioned the reason is that the bandwidth of this topic should be presented in advance since the multi-agent simulation is reduced to the Bayesian updating of new information as an approximation of the s-curves which are observable in the real world behaviour of the consumers. All the steps and aspects which will be presented in the third and

fourth sections are hard to map in a simulation instead the focus lies on the approximation of the observed processes and patterns which can adequately be matched by implying the Bayes' rule (BOECKER AND HANF 2000). The fifth section is directed to present the theoretical background of the multi-agent simulation presented in chapter 5. This section lays special emphasis on the connection between trust and the factors which lead to a buying intention, respectively to the buying decision. The sixth section highlights the communication processes which influence the consumers in their decision making. Information and influence of the media are of high importance with respect to the manipulation possibilities regarding the formation of opinions and especially the trust development in questions of food safety. Section seven of this chapter then picks up the aspects of the previous sections and explains the coherences of risk perception, trust and risk communication based on an example of food scares which is the BSE-crisis in Germany. The eighth section finally leads over to the cognitive processes modelled in the multi-agent simulation which will afterwards be presented.

4.1 Information processing

Information and knowledge are important factors for consumers who have to do buying decisions. Knowledge can be developed by using information which is necessary for the trust building in products (here food) and institutions (firms, suppliers, authorities or even cultivation methods) (HINRICHS 2004, 78). Individuals in reality face a complex environment, especially consumers in buying decisions. Each individual has to do several decisions in daily life. They are influenced by a variety of factors: personal relations, the media, information and so on. They often rely on experience in order to master daily life situations and new challenges. Information is a key element in decision finding and decision making. Cognitive processes, perception and the media are factors which influence and determine each individual to a certain extend in his information processing. Information asymmetries and information overload is nowadays in an ever-growing complex life a permanent attendant of the individuals. The complexity will often be reduced by using cues which are key information that densify complexity and supports the decision making. In many cases the reduction leads to biases in the perception of the reality. It is commonly known that risk can be reduced by additional information. On the other hand more information causes an overload of information. This will then be counterbalanced by using heuristics which came from experience and which were successful in the past. The individuals are building models of the reality in order to negotiate their way. This in turn offers the possibility to influence the individuals in their view on the world. Interest groups have the possibility to systematically influence certain target groups with respect to certain goals. Often the media is used for these manipulation activities since they are the medium to distribute and diffuse information. Cognitive processes and perception are im-

portant factors with respect to the information processing which in its part influences decision making.

The information processing from the reception of information to the application of information can be characterised by the following five steps (WILDNER 2001, 37):

1. Reception of information;
2. Storing of information;
3. Processing of information;
4. Restoring of information;
5. Application of information.

Information is not perceived objectively by the individuals. Each individual associates different issues relative to new information. The reception situation also plays an important role in the perception and the information processing, e.g. the way in which information is presented (objectively or emotional). This is commonly the working point which marketing, respectively advertising uses to influence consumers choice or the method how politicians or other interest groups try to convince people to follow their politics.

Technically information reception includes the processes which lead to the adoption of information into the short-term memory. Information can be retrieved externally and internally (see figure 4). The internal information is stored in the long-term memory and must be 'loaded' to the short-term memory. This means that the 'processor' must have all relevant information to perform a certain task.

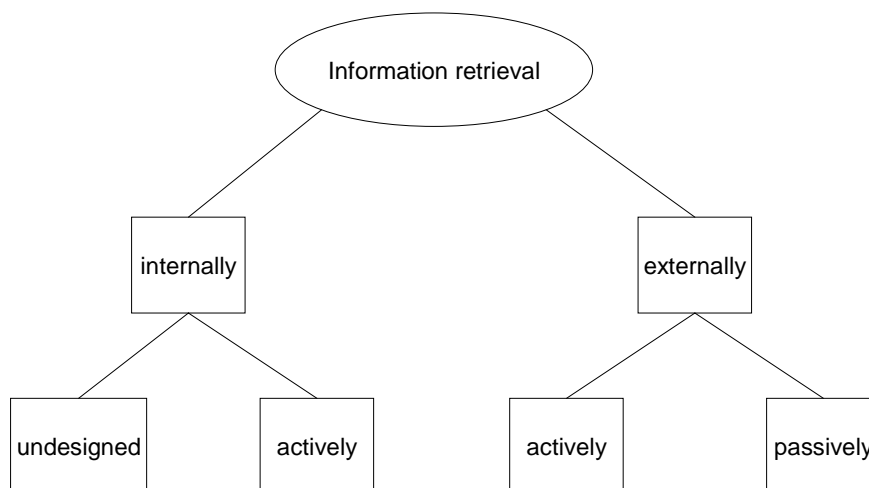


Figure 4: Information retrieval (Source: KROEBER-RIEL AND WEINBERG 2003, 246)

Internal information is stored information which results from former experiences and decision processes and represents the consumer's knowledge, e.g. information about former food scares regarding a certain product. External information is retrieved by searching and retrieving information via prices, product properties, brands, advertisement etc.

Each individual is different and so is his information behaviour. But technically the biophysical processes are the same in every human brain. Learning (processing and restoring of information) is the changing of behaviour of an individual. An individual learns based on experiences. There are several theories of learning in the literature. Neurobiological theories like proposed by VESTER (2001) for example aim at the chemical and biological procedures in the brain while people are learning. Besides this natural science approach there are psychological theories and experiments which are related to elementary theory and to complex theory.

Elementary theories are mainly stimulus-response (SR) theories (see figure 5).

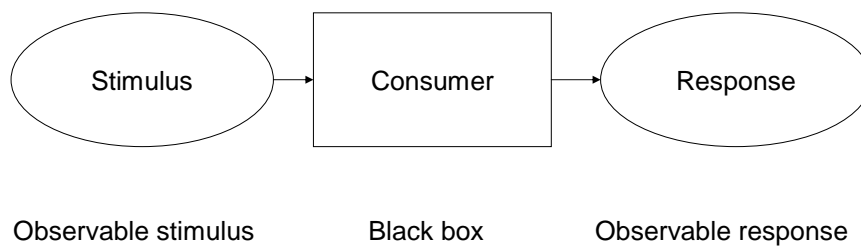


Figure 5: S-R-Theories (Source: SOLOMON ET AL. 2001, 90)

The information processing and storing in the brains of human beings takes place in three types of memories. These three components are responsible for mind processing of stimuli: sensory memory (ultra short-term memory, USM), short-term memory (STM) and long-term memory (LTM). Figure 6 displays the cooperation of these memory components with regard to stimuli processing.

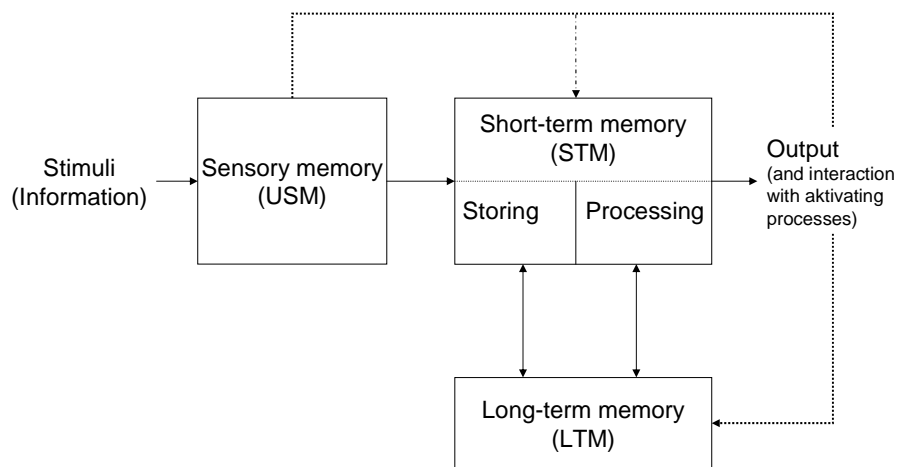


Figure 6: Information processing and storing (Source: KROEBER-RIEL AND WEINBERG 2003, 226)

The USM stores new information for a very short time in the retina. It has a high capacity, e.g. like a mirror after picture response, but the duration of storing is very short (0.1 – 1 second). The eye is scanning the environment and thereby bioelectric impulses are produced. The STM is the ‘processor’, i.e. the central unit of information processing. It is the active memory. Depending on the activation potential of the stimuli, it adopts a part of the information which comes from the USM. This memory has a longer storing time (5 seconds); it decodes, organises and interprets the incoming information. STM connects these information units with the LTM, e.g. via flavour or experience. In comparison to the USM the STM has a more limited processing capacity. It can assimilate up to 20 information units within a short period under observation (5 seconds). The LTM is the ‘memory’. It is responsible for the long time storage of processed information. The LTM is structured by biochemical memory molecules which can not be erased, but interferences (overlying effects) are possible (VESTER 2001).

As an example of how this information processing and storing works, a mathematical task, which should be solved by the brain, is presented in the following (KUSS AND TOMCZAK 2000, 27): The equation $8+7*3=?$ will be read by the USM. The single numbers and signs are read each by each and to each of these symbols meanings will be assigned which will then be stored in the memory. The STM contacts the LTM and gets out arithmetic rules in order to solve the task. These rules will be applied sequentially and the result will be stored or written down somewhere. During the solving process the USM can be used to check from time to time the mathematical task respectively the equation. This basic information processing and

storing is the same for each human being but the single components, experiences and biological equipments are different for each individual. Moreover there are different learning types and hence also different influencing possibilities: some people are more open and sensible for new information while others are not.

Automatic learning is one aspect in SR-theories. This concept implies that behaviour results from a series of stimulus constellations. This kind of learning is passive uncontrolled learning which is not done by intention. It is often used in marketing strategies. Cognitive effusion leads to a periphery information acquisition with a low involvement of the target persons. Frequent repetitions of stimuli are stored in LTM unconsciously. This often leads to an unpremeditated buying. Additionally there is mere exposure which means that the more often a person is in contact with an issue the more positive he evaluates it. This mere exposure often leads to a reactance of the target persons; they are disgusted with this penetration.

Another aspect of learning is conditioning. A distinction is drawn between classical conditioning and instrumental conditioning. Learning in classical conditioning is the result of joint occurrence of two stimuli. This is often referred to as contiguity principle. Technically a stimulus is activating a reaction with another stimulus which alone wouldn't cause this reaction, i.e. the combination of both stimuli has an effect on the perception and learning.

In contrast instrumental conditioning means that learning happens according to the strengthener's principle. The probability that behaviour occurs depends on the consequences which entails this behaviour (reward/penalisation). Penalisation is more effective than rewards regarding the controlling of the behaviour. Besides these learning aspects there is complex learning with two other approaches. One is learning by imitation (learning by example), e.g. children adopt behaviour pattern by parents. The other is cognitive rational learning, e.g. studying for an examination.

The information reception is influenced by the quantity of information (necessary information vs. information overload), the information sources (and the influence capacities of the communicators), object related information and the order of information.

The quantity of information is a critical factor. Additional information can reduce risk and can support the decision finding and making. Also too many information can lead to an information overload. In this case the complexity of the information processing will be reduced by using cues or information chunks.

The quantity of information which will be grasped depends on the number of information chunks which will be pulled up for a decision. This depends on various factors like for example quantity and kind of stored information, involvement and perceived buying risk, complexity of the decision, cognitive capabilities, cost and benefit for the information gathering.

The involvement is the degree of perceived personal importance respectively interest which will be invoked by a stimulus in a certain situation. The more an individual is involved, the higher is the interest in getting new information. The involvement as well as the other influ-

encing factors varies from person to person. In this sense, it can happen that the quantity of information by an external source might be too little for one person, while it might be too much for another person, so that one will be activated, while the other one is no more interested in gathering new information.

Information sources have different influence on the receptors. They also have different intentions regarding their aim of releasing information. Some are just objectively informing the public or other interest groups, other in contrast have influencing intentions which directly address specific groups or people. Hence the perception of the individuals varies from one information source to another.

Trust is one of the main aspects concerning perception of information coming from different sources⁶. Trust also differs from person to person and depends on a variety of factors among them are personal experience and basic attitude. There is a close relation between trust and risk attitude. Trust is the subjective belief in the correctness, respectively the truth of actions and insights of another or of oneself (self-confidence). The persuasion of the possibility of actions and the persuasion to be able to do these actions also belong to trust.

Trust is a phenomenon which appears in uncertain situations: the one who feels confident does not need to trust. Trust is even more than belief or hope because it needs a fundament ('trust fundament'). This can be experiences, but also trust in a person who is trusted by oneself (trust is partly transferable).

In economic sciences trust only has its place after the revision of the homo economicus axiom. Since the 1980s a lot of research has been conducted around the concept of trust, in the field of organisational behaviour for example NOOTEBOOM AND SIX (2003) and in a more comprehensive sense KHALIL (2003). But up to now there are inconsistencies in the definitions, in the usages of terms, in the akin constructs and in the implicit mechanisms. This prevents the formation of a uniform theory of trust in the economics sciences. In this thesis trust plays a crucial role especially with respect to information sources. A deeper notion for trust which will be used here will be presented in chapter 5.

The relation between information sources and the trust in them is important for the perception and the effect on the recipients of information. In general there are three types of information sources for consumers: direct observation, neutral third persons and supplier side oriented information sources.

Direct observation gives the consumers the opportunity to experience the properties of the good. The consumer respectively the decision maker can actively investigate the problems and questions which arise if a consuming decision has to be done.

Neutral third persons are trusted more in general than representatives of interest groups – given that the audience knows that the communicators are neutral third persons. The last type of information sources for consumers are the supplier side oriented information sources. They

are in general less trusted since they represent a lobby with specific interests. By definition this group has to spread information which are biased towards the interest of the lobby – at least the public perception appears to be like that.

Each object or product is an individual case and for this reason it is also dependent on the object which information are relevant. But for nearly every object or product the price is relevant for the buying decision. Beyond it, consumers often apply key information in order to reduce extensive search of information. Besides object related information the order of information is also relevant for information processing and the results, respectively the effects on the individuals.

Most people have an order concerning the most important criteria. The order is an indicator for the perceived importance. Attitudes and experiences determine these criteria (and also the perception of new information). If attitude and experience can be influenced then information processing and decision making can also be influenced.

4.2 Artificial neural networks (ANN)

The biological learning serves as an archetype for artificial neural networks (ANN). ANN were originally developed to understand the nervous system of human beings. Meanwhile there exists a variety of application fields because the properties and the mode of action of ANN are applicable for manifold purposes.

Communication and learning in the human brain happens in a dense network of neurons. Signals are transmitted and processed by a multitude of neurons. Figure 7 displays a simplified representation of a single human neuron.

⁶ See Annex A.1 Cross-Country comparison within five countries of the EU.

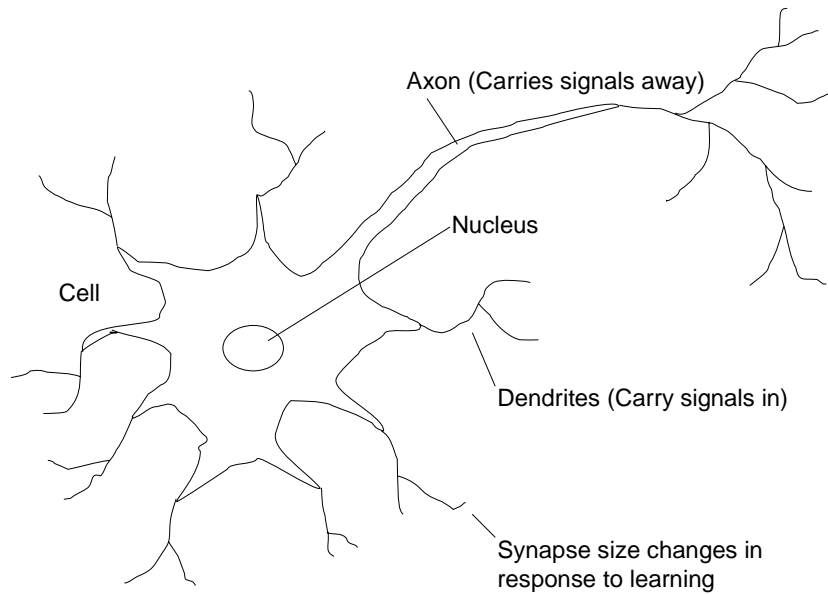


Figure 7: A neuron (Source: DAMASIO 1997)

A neuron consists of three central components: the nucleus (soma), the axon and the dendrites. Figure 8 shows a synaptic connection between neurons. The neuron receives arousing, respectively repressive signals by the dendrites which are connected to various other sending neurons. The submission of information is done by electrochemical impulses. These signals will be compressed into one aggregate signal. The nucleus evaluates and processes these signals before they will be forwarded to the following neurons by the axon. If the stimulating input is strong enough then the neuron ‘shoots’ an impulse into the direction of the other connected neurons; this will be done by the synaptic connections. Biological learning happens if two neurons shoot in parallel and thereby strengthen their connection.

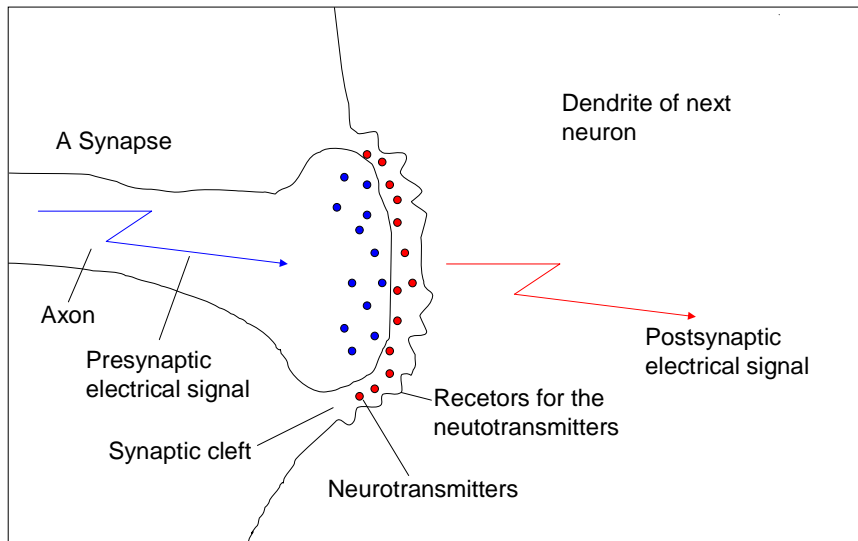


Figure 8: Synapse connection (Source: DAMASIO 1997)⁷

The moment in which the nucleus will be activated by the incoming signals is reached when a certain threshold will be exceeded. Then the nucleus generates a temporary electrical impulse which arrives at the synaptic connection via the axon. The synapse reacts by pouring out messengers (BACKHAUS ET AL. 2003, 739). These are called neurotransmitters. The adjustment of the connections between the neurons lead to learning processes in the human brain.

ANN try to copy the biological paradigm, they consist of a multitude of simple elements. These elements are also called neurons. The human brain consists of approximately 100 million neurons however ANN are strongly simplified compared to the human brain. With not more then 50 units a ANN is already able to 'learn' to a certain extend. The artificial neurons are interconnected via directed connections and they are able to exchange information (see figure 9).

⁷ http://zope.iuk.hdm-stuttgart.de/iwm/roswitha_projekt_wissen_emotion/damasio/damasio_05.htm

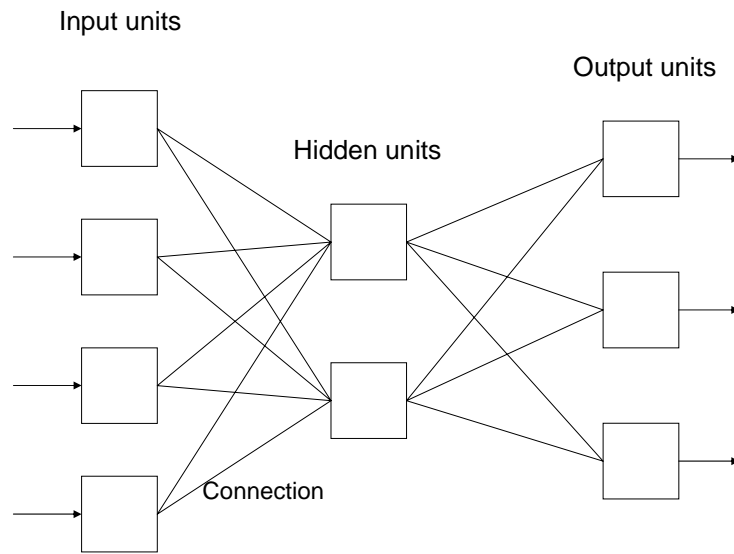


Figure 9: Artificial neural network

Each connection has a numerical weight. The input happens by stimuli and the output by emitting response to the network. Each input unit receives a certain signal which is the pattern of the stimuli of the input units. The hidden units take these signals and process them. Then it generates an output signal which will be sent to the following layer. The strength of the output of one unit is called its ‘activation’. The strength of the connections between the neurons will be determined by learning respectively training of the net. ANN normally are learning on the basis of input values which are related to known output values. Trained ANN are able to map linear and non-linear functions (STOLZKE 2000, 19).

One of the main features of ANN is that they react (response) to their environment (stimuli). In this sense they are like the human paradigm a stimulus-organism-response schema (SOR-model). Like the biological nervous system, respectively the brain, ANN also process and stores information and ‘knowledge’. There are similar analogies at work (BACKHAUS ET AL. 2003, 740):

1. Stimulus effects from the outside are extrinsic information which are the initial point for the information processing;
2. The information processing are carried out by a multitude of simple networked elements, the neurons;
3. Knowledge will be acquired by learning processes;
4. The actual standard of knowledge will be represented by the strength of the connections between the single processing units (neurons);
5. The information processing is not carried out strictly sequential but in parallel.

In biological neural networks the biochemical processes are the basis for the information processing. In ANN in contrast, suitable mathematical arithmetic operations are applied for the processing of information. These will be executed in the cells respectively the neurons of the ANN. The artificial consumer agents also implement such a mathematical arithmetic operation which will be used as a reinforced learning mechanism for the updating of trust in single suppliers based on new information which are diffused via the network of the artificial consumer agent population. The updating mechanism will be performed by the Bayes' rule which will be explained later on in this thesis.

Similar to a biological neuron a cell can receive a multitude of input signals of the preliminary cells. It compresses these input signals according to their strength (weight) into a uniform input value of the neuron. Afterwards the so called activation function determines if the neuron is activated and if it should send a signal or not. As well as the nervous system respectively the brain the single neurons are connected and together they process the information. The learning process in ANN is primary determined by the way in which the weights, i.e. the strength of the connections between the single neurons, are determined and in which way they can be influenced.

The typical application fields for ANN are pattern recognition, information retrieval, prediction of time series and controlling of robots or processes. Especially the analysis of the information processing in the human brains can be supported by using ANN. In this thesis, parts of their functionality will be applied for the multi-agent simulation especially the reinforced learning mechanism and the network aspects.

4.3 Perception and evaluation of products

This section gives an overview over the main concepts of perception and evaluation of products by consumers. The concepts presented here refer to KUSS AND TOMCZAK (2000), KROEBER-RIEL AND WEINBERG (2003) and TROMMSDORFF (2003). These sources also provide deeper insights into this field of research.

Perception is a complex cognitive process which is connected to other cognitive processes like attention, thinking and memory. It is nearly impossible to circumscribe and to analyse perception as an independent process. Perception helps the individual to recognise itself in its environment. The determining characteristics of the perception process are subjectivity, selectivity and activity.

- Subjectivity: The perception will be influenced by experiences, valuations and the capability to process sensory stimuli 'correctly'.
- Selectivity: Human information processing is limited, hence stimuli can just be perceived and processed selectively, i.e. the consumer particularly perceives stimuli which are closely related to his needs and wishes.

- Activity: Perception is not only a passive reception of stimuli from the outside but also the activity regarding the interpretation and selection of the stimuli is important, i.e. each individual constructs its own subjective environment respectively a model of the perceived reality.

The form of these characteristics again differs between the individuals. This can lead to a bias between subjective perception of issues and objective characteristics of these issues. But nevertheless a unique perception process can be identified, which is similar for each individual.

4.3.1 The perception process

The perception process presented here is based on KUSS AND TOMCZAK (2000, 31.). Figure 10 displays the single components.

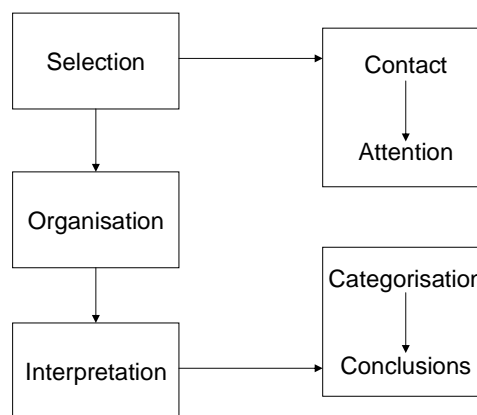


Figure 10: Perception process (Source: KUSS AND TOMCZAK 2000, 31)

The selection phase determines which of the manifold environmental stimuli enter into the perception process. Precondition for the selection phase is that a contact via the senses was established. This is the door for influencing strategies. The consumer agents in the multi-agent simulation receive information signals by the media and by their social networks. Their perception is reduced to these sources and to the information of the topic under consideration, i.e. the safety of the product under investigation.

The senses are closely related to perception. People can be influenced by a variety of stimuli which are addressed to the senses. Depending on the aim of the influencing strategy, the design of the means to influence people varies and is a case related. In the multi-agent simula-

tion the influencing strategy are information distributions which are released by the media agents. These information distributions are time series of positive and negative news regarding the safety of the food under investigation.

After the selection phase the single information units will be summarised to a meaningful whole, e.g. an impression of a product will be created by the properties which are known about the product for example by advertisement or experience. This is the organisation phase. The artificial consumer agents of the multi-agent simulation process the information coming from the media and their social network in a predefined way which will explicitly be described in chapter 5. Finally the interpretation phase marks the frontier to the information processing. Information will be interpreted and connected by categorisations, this leads to conclusions regarding the perceived issue. The organisation of the incoming and selected information and the interpretation of this information in the multi-agent simulation follow an algorithm which is implemented on each consumer agent. This will also be described in chapter 5. The product evaluation, in this case the safety of a food item, is closely related to perception and information processing, the next sub-section refers to this issue.

4.3.2 Information processing and product evaluation

Product evaluation is a part of perception. There are two phases of the information processing regarding product evaluation (KROEBER-RIEL AND WEINBERG, 2003):

1. Product perception – the cognition of a product by processing the perceived stimuli (product properties) and the decoding and mind processing.
2. Product evaluation – Arranging and evaluating of the available product information.

The result of the product evaluation is the perceived quality of a product.

The product evaluation relies on two kinds of information, one which is already stored by experience and one which is actually around and coming from external sources (see figure 11).

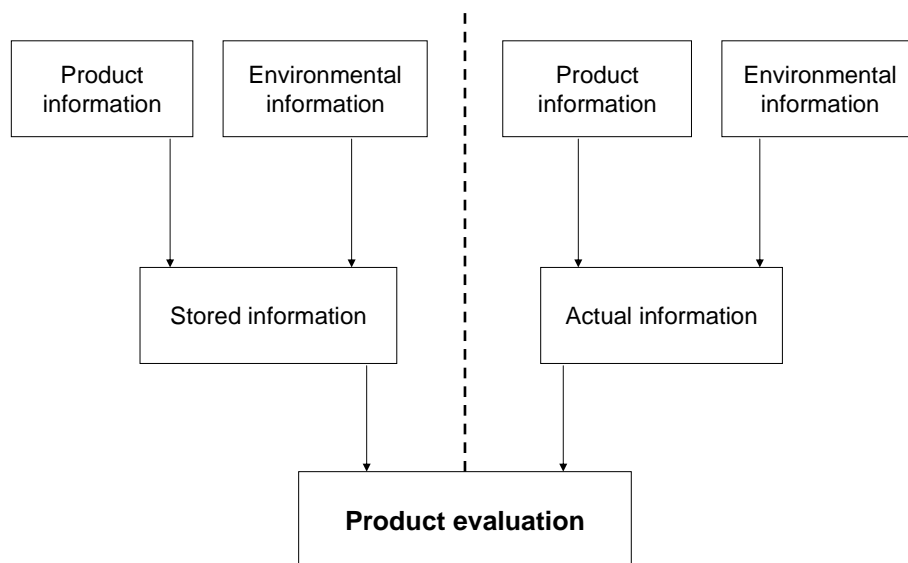


Figure 11: Information and product evaluation (Source: KROEBER-RIEL AND WEINBERG 2003, 280)

Stored and actual information can both be divided into product information and environmental information. Actual information is information which is in the actual public discussion, e.g. direct product information. This can be perceived physical-technical properties of the product like colour or shape, or other perceived properties like price or activated guarantee. People use only a little part of the offered information for the product evaluation; they use key information in order to reduce complexity. Key information is information which is crucial for the product evaluation process. It substitutes or bunches other information units.

The consumer knowledge is the stored information regarding the respective food item. ENGEL ET AL. (1995), 338 differentiate the consumer knowledge, which is relevant for the buying decision of food products, into the product knowledge, buying knowledge and application knowledge. Especially product knowledge and buying knowledge are of interest concerning the safety and quality of food (HINRICHS 2004, 80). The product knowledge refers to the high profile and the image of products like described above. The buying knowledge refers to the knowledge of the buying sources of the products. This includes also the knowledge of the advantageous point in time of buying these products with respect to special offers and possibly the knowledge which of the shopping places have been associated with food scares. The consumer receives the information for this knowledge by the media, by organisations for consumer protection and other organisations and sources. This is also implemented in the multi-agent simulation. The artificial consumer agents are connected to these information sources and they will be informed about the safety of the respective food item.

Stored information are manifold, they range from environmental incidents up to specific signals regarding the perceived issue. The perception of products and brands for example depends on the product or brand schemata which come from the experience of the consumer concerning the product. The consumer agents have past knowledge of the safety of the respective food item; they update this knowledge based on new information coming in from the media agents and the social networks. The real world consumer connects the new information with the knowledge of the effects which implicates the consumption of contaminated food with respect to the human organism. In this way he extends his knowledge so that he knows that the contaminated food item can be harmful which leads to the consequences that he stops buying this suspicious food item. The artificial consumer agents are acting similarly. They revise the trust in the suppliers of these products by considering the new food safety information.

Schema conform information are correlated with a faster information processing, a facilitation of the perception of a product and a better reminder, e.g. an established brand activates a brand schema, it automatically influences the whole product perception. Often key information is used to influence consumers' decision making. Key information can be price, brand, quality mark, adjustment of a test institute, adjustment of acquaintance or experts or appearance. The complex decision situations evoke reduction mechanisms which supports the consumers in their decision making. Often they use templates of thinking as heuristics for the decision making in order to reduce complexity.

4.3.3 Templates of thinking

Templates of thinking are simplified cognitive evaluation programs. These templates are used to simplify information processing and they are applied like quasi automatic thinking patterns. These templates of thinking are generated by reduced information perception via dominance of attributes (key information or cues), irradiation or halo-effect (V. ALVENSLEBEN 2001, 3; FRITZ AND THIESS 1986, 146). The dominance of attributes implies, that a single attribute is a proxy for the whole product quality, e.g. often the price is a placeholder for the quality of a product. Irradiation in contrast implies that a single attribute governs the implication that another attribute is correlated, e.g. colour of a product may imply the taste of this product. The halo-effect means that a specific attribute is outshining all other attributes.

The evaluation for the over-all quality created by these templates of thinking influences on the other hand the perception of the other attributes. This implies that if a positive product image was created then the individual also prefers a perception of positive properties and vice versa. This can be reasoned by the pursuit of cognitive consistency. Templates of thinking are hard to change. Furthermore the influencing capacities are different for every individual which implies that different strategies have to be implemented if changes should be precipitated.

The consumer agents also implement templates of thinking by using cues. They reduce the complexity by referring only to the available information of the media and the social networks. The information released by the media represents the direction of the information in the sense of positive and negative information and it also represents the intensity which is an indicator for the importance and the strength of the news. Based on this information the updating to the trust in the suppliers of the suspicious food will be performed.

4.4 Decision behaviour, trust and product selection

The consumer behaviour and the product selection are strongly related to the information processing, the perception, the consumer knowledge and the available information concerning the safety of the food under investigation. This section is directed to explore the general decision process and especially to address the buying decision process. Like the previous section, this section also gives an overview of the basic concepts of decision behaviour and product selection. KUSS AND TOMCZAK (2000), KROEBER-RIEL AND WEINBERG (2003) and TROMMSDORFF (2003) provide further insights in this topics.

In general the factors which determine the buying decision are the product, the constellation of stimuli during the choice (buying situation) and the personal predisposition and the price. The phases of the decision making displayed in figure 12 are not only bounded to product selection but are also valid in general decision situations.

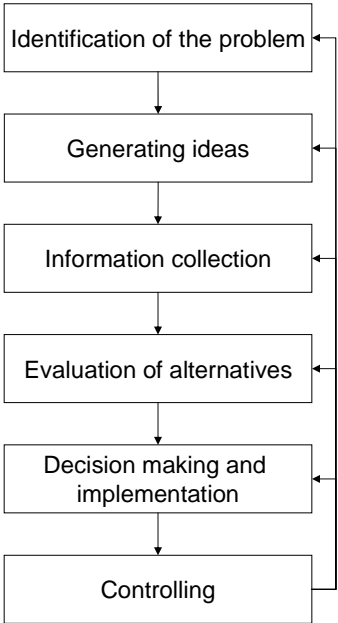


Figure 12: Decision process

First of all the decision problem has to be identified. Then ideas regarding the solution of the problem are generated, these are followed by the information collection in order to discover the space of alternatives. These alternatives will then be evaluated and then the 'best' suited alternative will be selected. This alternative will then be implemented. Finally there is the controlling process which implies a permanent checking and intervening if necessary.

This general decision process is implemented differently by the individuals. In principle each individual follows this approach but with different strategies and hence with different success. This is especially in buying decision situations the case. The determining component is the cognitive control which will be explained in the following.

Types of buying decisions

Buying decisions depend on the type of product, the situation and other factors. The involvement of the deciders, i.e. the activation degree, is of high importance for the decision process, especially the cognitive involvement. There are two main differentiations: decisions with strong cognitive control and decisions with low cognitive control. Beforehand it is to mention that there are floating boundaries between these two decision types.

Decisions with strong cognitive control

The extensive (rational) decisions appear in complex or innovative decision situations. The decider is strongly affected and needs strong cognitive efforts to come to a decision. These decisions often bear a high risk potential and are critical for the decider. On the other hand there are limited (simplified) decisions; here the individual criteria formation is widely done due to former experiences. The choice is merely done between limited alternatives. The cognitive effort is limited and affective and reactive conclusions are of little importance. The decider evokes a set of limited and clearly defined cues which simplify the buying decision process characteristically.

The simplifications happen by limiting the alternatives already in the beginning of the decision process. This will be done on the base of existing preferences or attitudes, by replacing the own decision by recommendation of the environment or by reducing the aspiration level for the next best alternative.

Decisions with low cognitive control

In habitual decision situations the decider resorts to routine behaviour. The choices are well known and the experience is far reaching. The decisions have to be done frequently so that the decider has old habits and often proceed according to decision patterns. The behaviour in these decision situations is consolidated.

There exist a number of hypotheses explaining brand loyalty. Older persons are often more brand loyal compared to younger people and they are often less flexible with a lower risk attitude. Brand loyalty is stronger if the social status is low. One of the reasons for this hypothesis is less information processing capacities of these people and larger uncertainty with respect to the buying decision. Other reasons for brand loyalty are high buying risks in the sense of 'no experiments' and prestige.

In impulse (stimulus driven) decision situations the decider reacts spontaneously without information collection and information processing. A strong emotional impulse connected with little cognitive control and impetuous action marks this decision situation. KUSS AND TOMCZAK (2000, 137) differentiate between different types of unplanned buying decisions:

- Memory effect – the presentation of products in a store reminds the consumer that he needs the product;
- Planned impulse – shopping as hobby without a concrete buying intention;
- Recommendation effect – the demonstration of the capabilities of the product convinces the consumer;
- Pure impulse – characterised by a large spontaneity.

TROMMSDORFF (2003, 307) enumerates motives for impulse buying decisions:

- As a mean of conflict avoidance;
- Dominance of amusement/excitation;
- Dominance of pressure of time/stress;
- Habituation/satisfaction;
- As personality attribute.

The types of buying decisions presented here, shows the manifold situations in which consumers can be and where they have to make decisions. Again, the individual determines which reaction will be selected and executed.

Extensive vs. routine decisions

KUSS AND TOMCZAK (2000) differentiate between extensive and routine decisions. Extensive buying decisions are more capacious problem solving processes which run in parallel when a new situation is perceived which invokes a problem that has to be solved. Routine buying decisions, in contrast, are associated with a habitual behaviour or a behaviour which is not reflected. Along the way will be given a short overview about different influencing factors and their relation to the different types of decisions (see figure 13).

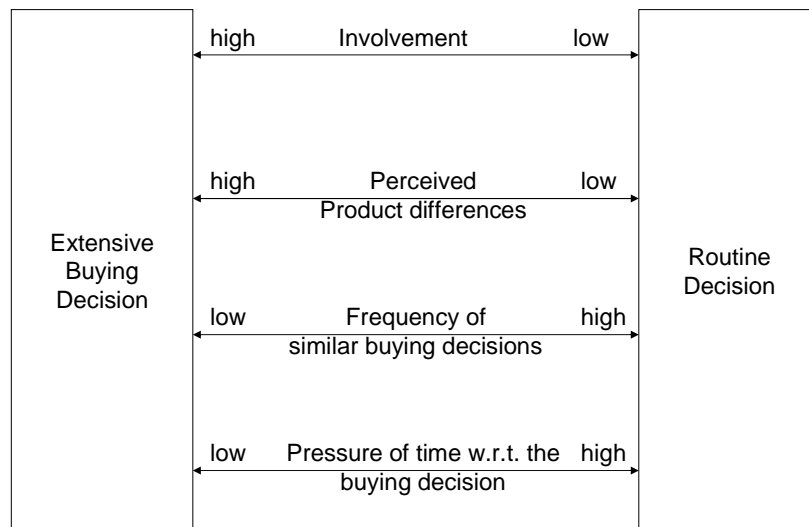


Figure 13: Decision behaviour (Source: KUSS AND TOMCZAK 2000, 101)

Involvement is low in routine decisions, most processes run automatically. In extensive buying decisions however, involvement is very high because there are a lot of mind processing capacities needed.

Perceived product differences are low in routine decisions since the attention is less intense in these decision situations. This is different in extensive buying decisions. Here the perceived product differences have a main influence on the buying decision.

The frequency of similar buying decisions is low in extensive buying decisions, whereas it is high in routine decisions. The pressure of time concerning the buying decision is high in routine decisions but it is low in extensive buying decision situations since these decisions need, given by their nature, a larger time for the evaluation of the situation.

Another way of to explain the buying behaviour of consumers is provided by an information economic approach. This approach is partially adopted by the multi-agent simulation. In this information economic approach, the properties of the products will be differentiated and estimated by the consumer. The buying behaviour results by assessing the information regarding the product which the consumer has already collected. These properties can be differentiated into search properties, experience properties and trust properties. Figure 14 displays a classification of these properties.

		Point in time of the evaluation of the property	
		Before buying	After buying
Possibility of evaluating performance property	Possible	Search properties	Experience properties
	Not possible	Experience respectively trust properties	Trust properties

Figure 14: Classification of search-, experience- and trust properties (Source: KUSS AND TOMCZAK 2000, 105)

Search properties are product properties which are obvious for the consumers. They are of no relevance with respect to the safety of food. Experience properties are product properties which are less obvious than search properties but the consumer has ‘tested’ these products formerly hence he has experienced the properties and knows the characteristics of the product. These experience properties influence the habitual buying behaviour described above. The trust properties are not obvious for the consumer. The consumer is not able to check these properties neither before buying nor after buying. Especially food products exhibit these trust properties. The multi-agent simulation is directed to the development of trust both on the individual level and on the aggregate level. The connection between trust in food safety respectively suppliers and information is explicitly modelled in the multi-agent simulation. HANF (2000), 266 has differentiated two groups of trust properties for food: metaphysical properties (e.g. ‘organic production’ or ‘appropriate to the species’) and risk properties (‘free of salmonella’ or ‘free of poisonous residues’). The risk properties possess a higher relevance in cases of food scares. Risk perception is closely related to trust. The multi-agent simulation implicitly covers risk perception, i.e. the consumer agents react according to food safety information released by the media and updated their trust in suppliers of this food item accordingly. They are in a risky market since most of the food products have this trust property. Trust is a state between knowing and ignorance (SIMMEL 1983, 263; HINRICHS 2004, 85). The confider is reliant that he will gain an advantage by buying a specific food item, on the other hand he disposes into risk to be harmed by a possible contaminated food item whether he knows it or not.

Trust has to be learned and it can also be unlearned (HALK 1993, 21). Trust is build up slowly but can quickly be destroyed if it will be disappointed or if the expectation of the confider was too high. Mistrust emerges if discrepancies in familiar situations appear suddenly or if certain undesirable properties of products exceed the individual threshold of tolerance (LUHMANN 1989, 78; HINRICHS 2004, 85). Simplification or reduction of complexity is also relevant for both trust and mistrust. This means that the consumers try to collect information which support the actual direction. The multi-agent simulation implements this mechanism while the consumer agents update the trust respectively the mistrust in the supplier of the suspicious food item depending on the direction of the news or the information which are released by the media agents and the general discussion in the social networks. It also takes care of the asymmetry in the speed of the trust building and the destroying of trust, respectively the 'building' of mistrust. The Bayes' rule which will be implemented is the responsible updating mechanism which maps exactly this process. It will also be shown that information, which should support the trust building, have little effects on the recovery of trust of mistrusting consumers. The only way to rebuild or recover the trust is that the consumers learn to trust again in the suppliers, respectively in the producers and the product. The learning process was already described above. The consumer can only rebuild the trust by learning to trust if he collects enough information that the product is safe again or if forgetting processes combined with no negative news reportage on the safety of this food item are active. The artificial consumer agents in the multi-agent simulation have implemented a reinforcement learning mechanism which reproduces the observed pattern of loss of trust and slow recovery of trust in time.

Firms which have caused a food scare loose the positive image of producing safe products. This implies that the consumers react with buying reticence of their product which leads to a reduction in sales. The firm has to invest in regaining the trust of the consumer if it does not want to risk more economic losses or even to become insolvent. Hence the firm has to do a good crisis management and to communicate the attempted arrangements to produce safe food again credibly to the consumers. Risk communication and the implementation of quality assurance systems are adequate means to perform these tasks. These issues will be discussed in 4.6 but first the next section will be addressed to the theoretical background of the multi-agent simulation with special emphasis on the connection of trust and the intention to buy, respectively the actual buying decision.

4.5 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour was developed in the field of psychology by Icek AJZEN (1991). It is concerned with the factors which influence the behaviour of human beings. The TPB is an extension of the theory of reasoned action (FISHBEIN AND AJZEN 1975; AJZEN AND

FISHBEIN 1980). It incorporates attitude, intention and behaviour in one context (see figure 15).

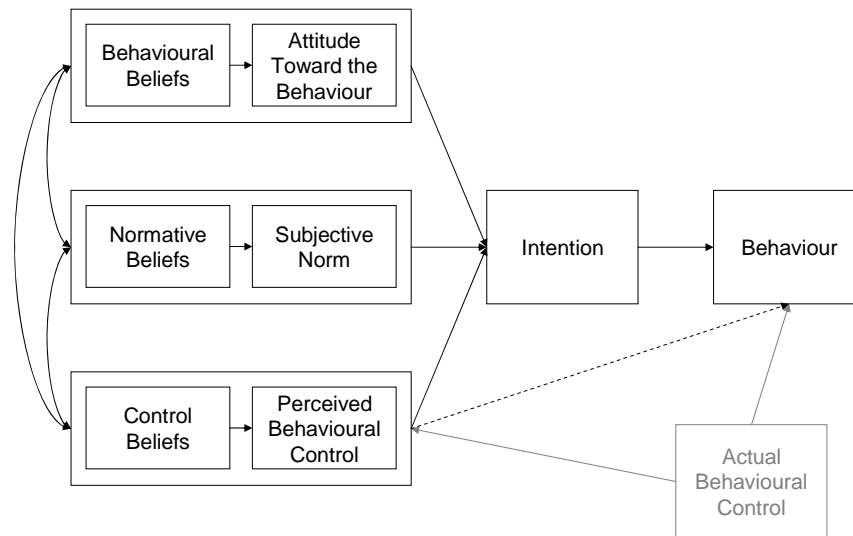


Figure 15: The Theory of Planned Behaviour (Source: AJZEN 1991)

According to the TPB human action and behaviour is guided by three different considerations. One is related with the beliefs about the likely outcomes of the behaviour and the evaluation of these outcomes. These are the behavioural beliefs they produce a favourable or unfavourable attitude toward the behaviour. The second consideration is related to beliefs about the normative expectations of others and the motivation to comply with these expectations. These are the normative beliefs, they result in perceived social pressure or subjective norm. The last consideration is concerned with the beliefs about the presence of factors that may facilitate or impede performance of the behaviour and the perceived power of these factors. These are the control beliefs they give rise to perceived behavioural control.

A behavioural intention is the result of the attitude toward the behaviour, the subjective norm and perception of behavioural control. The intention is not yet the behaviour; it is more an indication of a person's readiness to perform a given behaviour. The strength of the intention can be derived from the above mentioned considerations. A general rule for the strength of the intention is: the more favourable the attitude and the subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question. People are expected to carry out their intentions when the opportunity arises given a sufficient degree of actual control over the behaviour. The actual behavioural control refers to the extend to which a person has the skills, resources and other prerequisites needed to perform the behaviour.

The SPARTA model is an extension of the TPB. It was developed by MAZZOCCHI ET AL. (2004b) to integrate the factors perceived risk and trust into the framework of the TPB and to consider the influence of different individual characteristics. SPARTA is an acronym for Subjective Norm (S), Perceived Behavioural Control (P), Attitudes (A), Risk perception (R), and Trust (T) as well as Alia (A_L). The interaction between these components is depicted in figure 16. The assumed relationship between risk perception on the one and trust on the other side can be tested statistically within the SPARTA framework.

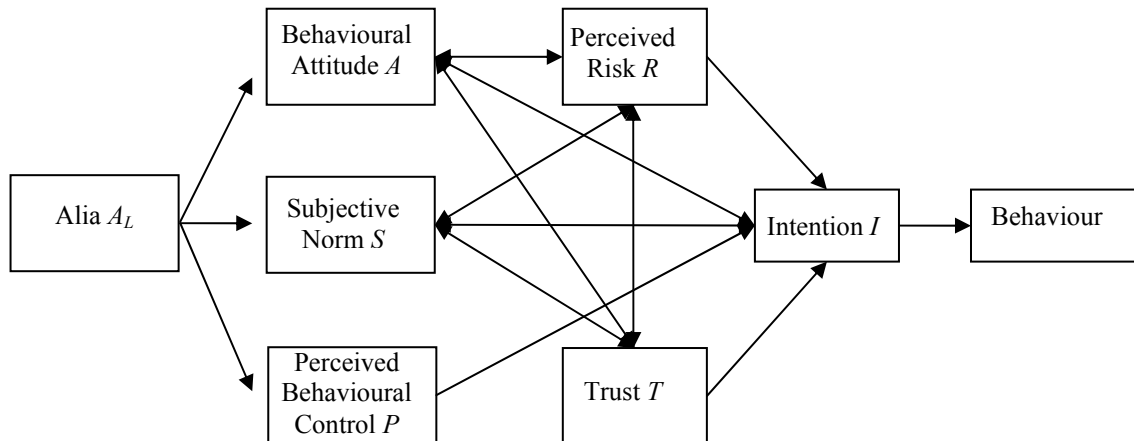


Figure 16: The SPARTA model (MAZZOCCHI ET AL., 2004b., 4)

The SPARTA framework has served for the design of the EU-survey within the TRUST-Project. Some data gathered by this survey and the analysis of this survey are used for the calibration of the multi-agent simulation (especially the network weights of the different information sources were extracted, see 5.2.3). The multi-agent simulation proposed here implements as an updating mechanism for the trust the Bayes' rule. The agents are interconnected in networks so that the subjective norm aspect is especially relevant for the direction of the trust updating.

ROMANO ET AL. (2005), 1 assume that *“in case of a food scare or poisoning outbreak, both consumer trust in risk information sources and effective communication are likely to play a significant role in bringing back perceived risk to the ‘normal’ level existing before the crisis occurred. Perceived risk, in turn, influences the way in which demand re-adjusts after the drop occurred as a consequence of the crisis”*, i.e. the authors assume that trust and demand are ceteris paribus correlated. This is also the case in the SPARTA framework where the trust influences the intention which on her part influences the behaviour, here the buying behaviour. This simplified assumption that trust and demand are running in parallel leads to the assumption that trust in this case can serve as a proxy for demand. An exact calculation of the demand and the consumer behaviour would require a further step, i.e. a partial market model would be necessary to draw conclusions regarding the actual consumer behaviour. This partial

market model must include the price in order to make propositions concerning the development of the actual demand. Nevertheless the focus in this thesis lies on the development of the trust assuming that there is a correlation with the actual behaviour and the demand.

The decision behaviour of the consumers can strategically be influenced by communication. This is of interest for creating effective risk communication strategies. The media are the communication means, their influence on the behaviour of the consumers will also be analysed by the multi-agent simulation. The following section addresses this aspect and provides the relevant concepts for the multi-agent simulation which will be described in the next chapter.

4.6 Communication – information and manipulation of consumers

The role of the media is important in the formation of the public opinion; especially the mass media has high influencing capacities (MEYN 1999, 33). The flood of information implies for the media to process the information hence they have to concentrate only on a little number of information which they communicate to the public. In this sense they are a gatekeeper (WHITE 1950). The media construct a ‘reality’ because it is not possible to create a complete map of the reality due to different limited capacities (KALTENBRUNNER 1976, 9).

Communication (lat., *communicare*: share, inform, let take part) is one central aspect in daily life of human existence. Communication means the exchange of ideas in language, scripture or picture. Communication is closely related to interaction. A well-established description of communication is the ‘sender-receiver-model’ which means that communication only happens if there are at least two participants taking part in the communication whereas both act reciprocal as sender and receiver (LASSWELL 1948). The sender and receiver must be at one with each other concerning the coding of the information in order to interpret correctly the received signals.

Communication is a crucial mean of gaining insights and knowledge. The collection of data of the environment allows an individual (or a machine) to create a model of the environment and to put new information into a context so that it gets meaning, i.e. each individual creates its own reality (WATZLAWICK 2001). The notion of communication can even be enlarged so that there is no individual or intentional sender presupposed. Then communication is the only way of learning because each perception is part of a communicating procedure. In the broader sense behaviour will be understood as a reaction of communication; the reason is that each reactive behaviour has a notification character (interaction).

On an abstract level communication is the procedure of connecting at least two systems. In the area of interpersonal communication but also in some technical and natural scientific coherences the interaction character of communication can be clarified as follows:

Communicative interacting systems (persons, high-tech IT, cells etc.) must always be exerted to create information in other systems if they want to function. In order to do this they use the media. The media is used to transport their information. This can be done in various ways, e.g. via contact, electromagnetic waves (radio, light, heat...), electric current, sound respectively speech, enzyme exchange etc. The main factor of success is that information will be decoded. In short words: communication is the main element of systems, i.e. without communication no system exists.

This section highlights the communication and its relation to the behaviour of consumers. In the first sub-section a simple communication model will be described. In the second sub-section the impact of the media with respect to the communication processes and the influencing capacities on the opinion of the population will be deeper explored. The opinion formation and the opinion dynamics of the population and within the population will be investigated with special emphasis on the possibilities to use agent-based modelling. The opinion formation process regarding the safety of a food item under observation will also be used in the multi-agent simulation in chapter 5. The third sub-section is directed to explain diffusion processes within the population which has some implications for the modelling of the multi-agent simulation.

4.6.1 Lasswell formula – a simple communication model

LASSWELL (1948) has developed a model for the communication process: ‘Who says what in which channel to whom with what effect’. The following figure 17 displays the single elements of this formula.

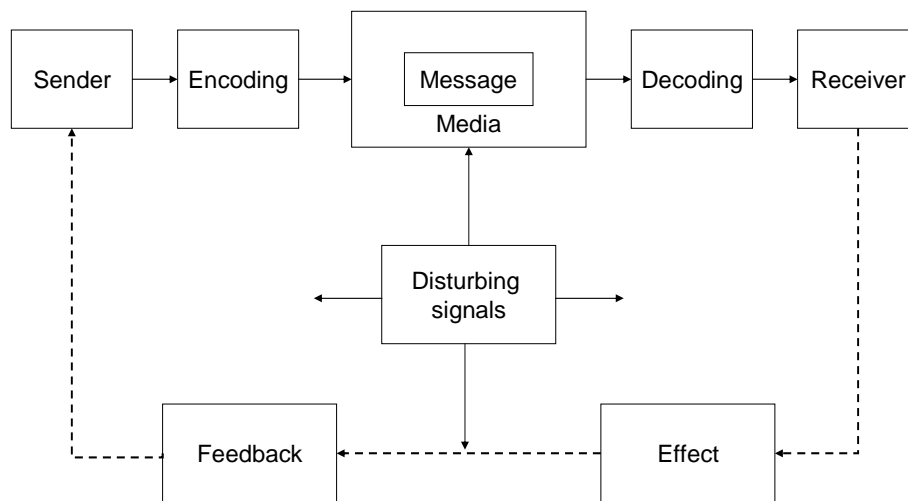


Figure 17: Communication process (Source: KOTLER AND BLIEMEL 1993, 830)

The main components of the communication process are:

- Sender – one part of the communication process who wants to send a message to another part (source or communicator);
- Encoding – process of compilation of an idea into a transmittable representation;
- Message – the entirety of symbolic representations which is sent by the communicator via the media;
- Media – means of communication which serve as a carrier to transmit the message from the sender to the receiver;
- Decoding – process of compilation of the transmitted symbolic representation into meaningful content;
- Receiver – the part of the process who receives the transmitted message;
- Effect – the entirety of reactions of the receiver after the contact with the message;
- Feedback – the part of the receiver reaction which will be retransmitted to the sender;
- Disturbing signals – unplanned effects with disturbing or distorting effect on the process.

There are three reasons why members of the target audience are not reached by the message (these are the disturbing effects): selective perception, i.e. they do not perceive all submitted stimuli; selective distortion, i.e. they form the message like they want it to be and they just perceive what they want to perceive; selective remembrance, i.e. they just store a part of the message in their memory (KOTLER AND BLIEMEL 1993, 831).

Selective distortion occurs if the receiver has preconceived attitudes which lead to certain expectations what the message should mean or show. The receivers will hear what they want to hear and which is conform to their beliefs. As a result they tend to add something to the message or to leave out something. In order to change attitude it is necessary that the receiver repeatedly checks his body of thought. Consequently the changing of the attitude relies to a great extent on the process of self-conviction.

The effect of a message depends on different factors (FISKE AND HARTLEY 1996, 79):

- The more distinct the position of the communication source is, the larger is the triggered change or effect at the receiver,
- The communicative effect is greatest if the transmitted message is conform with the existing opinions, beliefs and affinity of the receiver,
- The message can lead to effective changes in the attitude in subjects which are not in the centre of the value system of the receiver and where he is not familiar with or where he is less interested in,
- The message is more effective if the bearer is supposed to be competent, has a high status, is objective or is en vogue. However most important point is if he is powerful and if one can identify with him,
- The social context and the social or reference group is participated in the reception of the message and influences its acceptance or refusal.

Messages are distributed and communicated via the media. The impact of the media for the communication process and the corresponding effects on the participants will be discussed in the following section.

4.6.2 Media, communication and opinion formation

The public opinion consists of a multitude of single opinions regarding a concrete topic. The formation of a public opinion is based on private experiences and on extrinsic experiences. The extrinsic experiences are communicated by the media. Hence the media is part of the public opinion (NOELLE-NEUMANN 1996, 229). The media plays a crucial role in the communication process. The way in which human beings deal with social communication means, among them are media, can involve positive or negative effects. Although it is commonly said that 'the media' can do this or that, they are no blind natural sources which are out of human control. The communication events may have unintended consequences however finally it depends on the decision of human beings in which way they want to use the media.

These decisions will not only be done by the communication receivers who are the consumers of messages but in particular by those who control the media and who are responsible for their structures, their policy and their content. Those are office-bearers and board of directors, business managers, members of governmental organisations, owners of media enterprises,

publishers, editors, directors of radio and TV stations, editorial journalists and chief editors of newspapers, producers, authors, correspondents and others. The responsible persons who own or control the media have the agenda-setting power (COHEN 1963; MCCOMBS AND SHAW 1972, 177). The influence of the media is immense. At this marketplace people meet other people and events and here opinions are generated and formed. By means of this media not only information and ideas will be conveyed but the people also learn about life by experiences which were transmitted via the media.

The technological change supports the dominant position regarding influencing capacities of the media. The emergence of the information society is a cultural revolution. The impressive improvements of the twentieth century are likely to be a prologue of what comes in the twenty first century.

The dispersion and the variety of the media which are open to the people of rich countries is large: books and periodicals, TV and radio, movies and videos, audios and sound recordings, via radio, cable, satellite or Internet transmitted electronic communication. The matters of this massive stream of communication range from pure news up to pure entertainment, from a prayer up to pornography, from contemplation up to violence. Depending on the media they choose, the people can either grow their mercy and compassion ability or they can live in a totally isolated and ego-centred world which is fully equipped with nearly anaesthetic stimuli. Even people who completely avoid media can't evade contact to other people who are deeply influenced by the media. This aspect is explicitly modelled in the multi-agent simulation. The artificial consumer agents are interconnected in social networks where they exchange information.

Personal communication is more credible than mass media (KROEBER-RIEL AND WEINBERG 2003, 510). The reasons are a high credibility of the communicator, a better selective perception by the communicant and a larger flexibility with respect to the communication, i.e. feedback is possible. The direction and the way of communication are important factors for the success of the communication intention. There is

- direct communication – immediate contact between sender and receiver;
- indirect communication – no immediate contact between sender and receiver but communicative activity via media;
- unidirectional communication – there exists just one communicator and there is no possibility of feedback for the receiver;
- bilateral communication – the communicator and the receiver are in an interaction relation, i.e. the dialog form (BRUHN 1997, 173).

Direct communication is implemented in the multi-agent simulation as the connection of consumer agents in social networks. In these networks the agents communicate about the safety of a food item. The media agents are connected to the consumer agents in a unidirectional communication way, i.e. they exogenously send information to the artificial consumer popula-

tion and they receive no feedback since exogenous information strategies should be tested. Some segments of the artificial consumer population can be connected to segment specific information sources. Only these agents receive information from the segment specific information sources but these agents are in turn connected to other consumer agents via their social networks. The agents in this segment are intermediaries they transfer the information coming from the segment specific information sources and influence in this way the opinion formation.

Mass communication is public and the number of receivers is unlimited. Precondition for mass communication is that there must be technical media. The mass communication happens indirect and is targeted at a disperse audience. The effects of mass communication can be distinguished by information effects (intermediation of knowledge), manipulation effects (strengthening of opinions) and persuasion effects (changing of attitudes).

Multi-level communication systems can be characterised by the following aspects:

- no immediate relation between sender and receiver;
- elements (e.g. opinion leader) as intermediary;
- the receiver does not receive the information directly but via multiple level and as the case may be in modified form by the communication sender (BRUHN 1997, 20).

The multi-agent simulation has implemented such multi-level communication, i.e. not every consumer agent is connected to all exogenous information sources. The information will be processed by the consumer agents and will then be transmitted to their connected agents in the social networks.

The concepts described above are closely related to the concept of opinion formation. Opinion formation is a precondition for the decision making. Several processes are connected to the opinion formation.

Opinion formation

The free formation of opinion is a central element for the efficiency of a democratic society. The opinion formation is generated locally on the level of the single individual which is part of the whole society. The public opinion emerges as the aggregate of the individual opinion formation and which in turn retroact to this so that the whole process is a reciprocal dynamic system. Similar processes take place in the multi-agent simulation. The single agents are updating the trust in the suppliers of a possibly contaminated food item. Their opinion respectively their trust development is influenced by the information coming from the media and from their social networks. On the aggregate level of the artificial consumer population an aggregate trust level is developing which is depending on the information released by the media.

The media is one key player in the process of opinion formation. Like already stated above they influence the individuals by the content and the type of news and information which they diffuse. Information are the operating units which are characterised by three factors: direction, intensity and information content. Media are different; this implies that they have a different weight in the opinion formation process. The three factors of information can, depending on the type of media, be influenced differently. They affect the sender-receiver-relation of a single individual within a society and thereby in the aggregate of the society as a whole. The source of the information and the media which submits the information or modified versions of it are two different elements of the information processing and opinion formation process.

The opinion formation however not only happens by the exogenous media but also by social contacts and networks. The most important aspect also in this endogenous form of information processing is again the communication. Communication is the mean to grasp information which then will be used to reappraise decision situations. Thus a manipulation of the opinion formation takes place, either confirming and strengthening the predominating opinion or it comes to a revision of the opinion. The changing of an opinion must not necessary lead to a changing in the decision if there are sufficient other factors which determine the decision.

Both types of information sources, exogenous media and endogenous social contacts and networks, have their own influencing mechanisms. But the exogenous media also influences the endogenous information processing. In the previous section multi-level communication system were already mentioned. The concept of the opinion leader combines the personal communication with the mass communication (LAZARSELD ET AL. 1948, cited in BONFADELLI 1999, 136). The opinion leader occupies a key position in a group. He carries out a personal influence on the other members of the group, the opinion followers. The opinion leader usually has more contacts than other group members. He owns the activation function for the opinions and implicitly the decisions of the others.

The two level communication starts with ideas coming from the mass media which will be taken over and partially processed by the opinion leader. The opinion followers are the less active parts of the population. In the second level the opinion leader influences the less active members of the group because he is more informed than the followers. The opinion leaders transmit the information orally; this implies that there is an immediate contact between the opinion leader and the social group – they are connected in a social network.

In general an opinion is the subjective view or attitude of a human being regarding states, events or other persons. Opinions emerge on the basis of own experience and own knowledge. A human being undergoes every day different situations and impressions. He sees, hears, reads, feels and/or experiences something familiar or something new and he thinks about different situations, e.g.

- What do I think about that?
- Do I agree about that?

- Do I believe that?
- How or what do I feel about that?

Depending on the interest concerning a certain situation he needs a specific time to collect information from others about this situation, to balance and compare the experienced and to talk again with others about the situation. This time is defined as the opinion formation process. At the end of this process there was a picture of ideas generated which is the own opinion regarding the situation under investigation. Hence an opinion is a mental generated state. The human being won't change his opinion with regard to a certain situation unless he is uncertain; then he will start a new process of finding and collecting information. The result will then be a modified or even a new opinion will be generated.

The opinion formation process often depends on the character of a person. If a person needs a long time to form an opinion regarding a certain situation, then he is often said to be uncertain or uninterested because he is still searching. If a person permanently insists on the same opinion regarding a certain situation, then it is under certain conditions said to be wrong-headed or incorrigible and he is not adaptive. If a person always adopts his opinion to his surrounding and if he does not understand the coherences then he is called a follower.

The degree of concernment serves as a measure of manipulation. The concernment of a topic varies from person to person, thus it also influences in a different manner the perception of topics and events (KOLMER 2000, cited in HAGENHOFF 2003, 19). The higher the degree of concernment the more information regard this topic will be collected by the affected people (LOGES 1994, 16). Hence these people increasingly use the media. Figure 18 displays the flow of information of one topic.

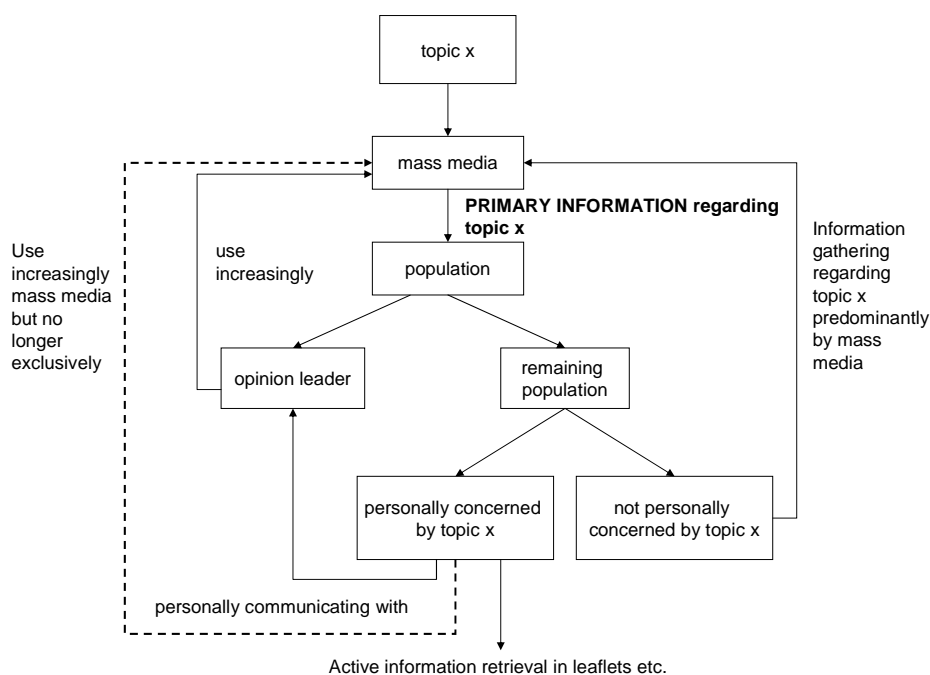


Figure 18: Flow of information of one topic (Source: HAGENHOFF 2003, 20)

The personally concerned people are interested in a substantial perspective on the topic. Hence they try to get a deeper access into the topic, among others, by personal communication with the opinion leader. A less degree of concernment often implies that it is sufficient for the individuals only to be informed for this purpose they principally rely on the media.

Opinion dynamics

Beside the formation of opinions on a descriptive level, it is interesting to focus on a technical issue of opinion dynamics, i.e. how do opinions evolve by aggregating opinions from related agents. This network perspective can be well analysed by using agent-based modelling. HEGSELMANN AND KRAUSE (2004) have investigated how opinion dynamics develop under different averaging regimes. They refer to a previous work on opinion dynamics and bounded confidence (HEGSELMANN AND KRAUSE 2002) where they set up the basic model. In this model the agents assign different weights for different opinions coming from their neighbourhood. In the later work they have employed on the level of the individual agents different possibilities of aggregating means for the aggregation of opinions: an arithmetic mean, a geometric mean, a power mean or a random mean. The authors have shown that the dynamics driven by the averaging opinions always stabilise in certain pattern of opinions. They could show that people tend to become more alike but they could also show that not all differences disappear because of partial means which was introduced in order to model bounded confidence. Further research on opinion dynamics and network effects especially connected with the concept of the opinion leader and the relation to the media is of high interest in social science. The diffusion process in the social networks is closely related to this.

4.6.3 Diffusion processes

The theoretical concepts of diffusion and adoption are the foundation of diffusion theory. Diffusion theory is engaged in the temporal development of dissemination of innovation or information in a social system. Starting point of the considerations is the adoption theory. On the level of the individual the adoption theory describes the factors which lead to an adoption or a rejection of an innovation. There are five groups of adopters (FILL 2001, 57):

1. Innovators
2. Early adopters
3. Early majority
4. Late majority
5. Stragglers

The innovators are persons which like to take high risk and being the first. They are followed by the early adopters with a large quote of opinion leaders which accelerate the diffusion

process. Early adopters are people with a lot of links and a high status in the social network ROGERS (1995). The early majority are the opinion followers who rely on informal information sources. The late majority is sceptical vis-à-vis new ideas; they often accept alterations only because of social pressure. The stragglers are suspiciously against innovations. They are inflexible in their opinions.

In 3.4.2 the investigation of different network types and their effect on the aggregated outcomes have been discussed. The work of JANSSEN AND JAGER (2001 and 2003) has shown that the network types have a significant influence on the dynamics and the results of the interactions of agent-based simulations. Their research question was why different types of markets emerge. Some markets are stable where a little number of products is negotiated. These markets exhibit only little dynamics, they are called lock-in markets. While other markets possess a frequent change of products and the dynamics of such markets are high. They often follow trends.

JANSSEN AND JAGER (2003) assume that the price may not be the only factor which is responsible for these differences; they draw on social processes which might be of high influence concerning these dynamics. Examples for such social processes are imitation, prestige or status seeking. Herding effects are another example of social processes which are investigated in financial markets. JAGER (2000) has identified two basic mechanisms which underlie such social processes on these markets. The first mechanism is the product choice of others as a heuristic which serves as a mean to narrow the variety of products down. This is especially observable in situations of uncertainty. The second mechanism is related to social needs. This means that human beings are always situated in a social environment which influences their behaviour. This determines their group membership and their status. Both mechanisms are working together and they are dependent on the topology of the underlying networks in which the information flows. The network effect is dependent on the structure of the network since this structure influences the diffusion processes and the market dynamics.

REINGEN ET AL. (1984) have investigated the relation between social networks and the choice of brands. They have drawn the conclusion that people who are in a cohesive group which is characterised by strong relations are more frequently buying the same product than other consumers. Thus closer social networks see to it that there is an incentive to create a higher homogeneity in the consumption.

The basic assumption in the model of JANSSEN AND JAGER (2003) is that consumers are organised in different networks and that they take part in different markets. This implies that different products are assigned to different agents. The differences of the agents in the network is characterised by different preferences for the products, i.e. some agents have for some products a much higher number of links or contacts to other agents than the average of the other agents. These agents are multipliers (like hubs – e.g. Google in the Internet) which are in the centre of these networks. They have a disproportionate influence on the behaviour of

the other consumers – like opinion leaders. The influence of these people often has the power to initiate a word-of-mouth recommendation ROSEN (2000). The strength of these network members then leads to a propagation and diffusion of this information through the network (SAGGAU, 2004).

The model of JANSSEN AND JAGER (2003) consists of a population of N agents. Each agent decides in each period which of the M product he wants to consume. The agents are connected to in average k other agents. The products differ in a dimension d in the range between 0 and 1. The utility of a product has two components: an individual part and a social part. This refers to the two above described mechanisms. The individual part expresses the individual preferences for one product and the social part expresses that the utility of the product increases if more friends consume the same product. Both parts are weighted; the sum is equal to 1. If the individual part has a higher weight then the agent is more an innovator, if it is reverse then the agent is more a follower with a high social need.

The decisions of the agents are closely related to the structure of the social network. The small-world networks of WATTS AND STROGATZ possess the small-world effect (MILGRAMS, 1967) like described above and the clustering effect (NEWMAN, 1999). The clustering effect refers to clusters which exist in social networks and the circles of friends tend to overlap in wide ranges. Besides the small-world network scale-free networks are considered in recent years. Scale-free networks are for example the Internet. Their common property is that the node connections follow a power-law distribution (BARABÁSI AND ALBERT, 1999). JANSSEN AND JAGER (2003) assume that this kind of distribution is also the underlying distribution of consumer networks. They use the model of BARABÁSI AND ALBERT (1999) and adapt it for their model. The scale-free network increases in continuing time by adding new nodes, respectively agents. These new agents tend to connect to agents who are already well connected in the network. Hence the influence of the agents (hubs) increases. AMARAL ET AL. (2000) have analysed scale-free networks which followed the power-law connected with a sharp cut-off. An example can be that a highly connected node or agent refuses new connections because his capacities are reached or even a highly connected node may die out, respectively drop out. They have proposed an adjustment of the BARABÁSI AND ALBERT model. The adjustment contains an option which provides the probability that a node in the network may become inactive. And since new nodes can only be connected to active nodes, AMARAL ET AL. are able to show that different classes of network could be reproduced. This property was used by JANSSEN AND JAGER (2003). They have shown that the structure of the social networks have an effect on the dominance of products. A regular grid in a small-world network never has a degree of dominance of specific products. The reason is that the clusters make sure that the decisions are local, i.e. the structure of the network reduces the diffusion of the information within the network. In most cases the degree of dominance of specific products is greatest in scale-free networks. The hubs make for a fast diffusion of information. They lead

to a more homogenous choice of products. Moreover they can fast recognise if another agent uses an attractive product because of easy access to this information.

The results of JANSSEN AND JAGER (2003) point out that the market organisation depends not only on the psychological needs and decision processes but also on the size and the structure of the included networks.

A central question with respect to the decision making of daily consumption is the actual relevance of networks regarding these consumption decisions. In certain markets the role of the networks may be marginal while in other markets the people strongly rely on information which comes from the networks. In these markets the size and the structure of the network may depend on the product. JANSSEN AND JAGER (2003) give some examples for these different products and their implications for the market structure. If the consumption is concerned with status relevant products then the people may focus on the part of the network which owns a high social status. If a new computer shall be bought then the agent would only ask the agents who are familiar with computers independently of their social status. And if clothes shall be bought then one would ask the people who have the same opinion. In some cases the number of other users is low (e.g. purchase of computer) while in other cases the number of users is high (e.g. fashion).

The consumption of food and the trust in the safety of food, respectively the reliability of the suppliers and producers is of special interest in cases of a food scare. The trust building and the development of trust depends on the news reportage of the media regarding the safety of the food which is under observation. The following section is directed to explore these coherences based on the example of the BSE-crisis in Germany.

4.7 Risk perception, trust and risk communication – the case of food scares

Consumers have a need for trust and straightforwardness. Each individual undergoes different kinds of risks each and every day. Uncertainty accompanies the people in a lot of decision situations. In decision theory, uncertainty characterises future states for which there are no probabilities available. Uncertainty is divided into suspense, risk and ignorance. In suspense situations the possible consequences are known but there are no information concerning the occurrence probability available. Risk is similar but as additional information there is the occurrence probability available but not the occurrence time. And if finally the consequences of the action alternatives are unknown then ignorance is met.

Bounded rationality is an aspect which has to be taken into account when looking at consumers which have to take decisions. The Prospect Theory of KAHNEMAN AND TVERSKY (1979) refers to that issue. Consumers evaluate negative information relative to a reference point higher than positive information, i.e. negative information has a higher weight than positive

information. This point has to be taken into account with respect to information releases by centralized information sources.

Health risks meet the people immediately and they compromise the people in their existence, therefore they are treated respectfully. Food, for example, is a daily necessity. Hence consumers are worried about residues in food. The consumers often can not evaluate the objective risk regarding the safety of food. In most cases they rely on an intuitive risk evaluation which is the perceived risk (KAFKA 1999, 5). FIFE-SHAW AND ROWE (1996) divide risk perception by consumers into two dimensions: the severity of a hazard and the awareness of the hazard. KAPLAN AND GARRICK (1993, 93) state that risk is never zero. Risk, according to JUNGERMANN AND SLOVIC (1993, 169) can be expressed in different ways, one common expression is the probability of a harm.

Consumers have incomplete information on food supply. Alongside they have also limited information processing capacities. Based on bounded rationality they often show a shopping behaviour which is circumscribed as 'routine response behaviour' (HOWARD 1977, 10; KAAS, 1982).

The question of the appropriateness regarding the respect of the health risk is admittedly often neglected. In a lot of cases there is a discrepancy between subjective perceived and objective risk. The perception of risk can be divided into two levels: experts vs. laymen. The perspective of the experts defines risk as a loss or damage which occurs with a certain probability and which leads to a certain quantitative extent of negative consequences. The probabilities in the perspective of the laymen whereas play a subordinate role, the surrounding field in contrast is much more weighted. Aspects like the awfulness of an event, the exposure, the voluntariness, the publicity and the controllability are the main factors which influence the laymen most (V. ALVENSLEBEN AND KAFKA 1999). In this context the threat and the exposure are of a matter of particular interest. In situations where risk is overestimated, there is a low exposure connected with high threat whereas in situations where risk is underestimated, there is a high exposure connected with a low threat which economically leads to a higher welfare loss (HEINZOW 2003, 119). On this account comparisons to motoring or smoking will not be accepted because they are voluntary, day-to-day, less dreaded and controllable. Already now it is to say that this implies for risk communication to have two tasks: compose in cases of low risks and warn in cases of substantial risks.

Health risks, like stated above, refer to consumers briefly. The mad cow disease, the Bovine Spongiforme Enzephalopathie (BSE) was a special food scare. Its outbreak in Germany and the nature of this disease connected with the news reportage led to significant changes in the demand, especially in the short term. It caused reactions in the whole supply chain and also in the political market in Germany. The minister of agriculture in Germany had to leave his chair and a minister of the green party took his chair and changed the name of the ministry together with whole political direction – from agriculture oriented to nutrition and consumer oriented.

Food safety and quality are very interesting for the media. Except food products, there is no other product group where once a quality problem appears, the notion of scandal will be used inflationary. Events like for example nematodes in fish (1987), nitrofen in ecological food products (2002) and the mad cow disease BSE became only food scares after negative news reportage by the media (KUTSCH 1992; MEYER-HULLMANN 1999, 19).

History of a risk topic:

A risk topic can be assigned to a history which exhibits certain phases. In the centre there is a pattern which reflects the changing of the public attention in time. The course can be divided into four phases (see figure 19).

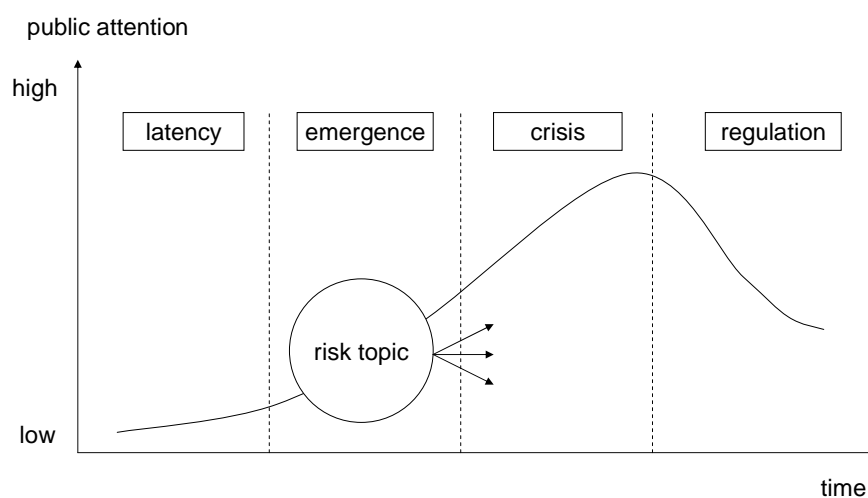


Figure 19: History of a risk topic (Source: WIEDEMANN ET AL. 2000)

In the first phase the topic is latently around, in proceeding time the risk topic emerges into the attention of the public supported by the media until it comes to a crisis. After the peak of the crisis the public attention decreases, e.g. because other topics become more relevant or the perceived risk decreases; this is the regulation phase. This pattern offers possibilities for a timely and cost adequate reaction regarding the developments which could lead to a threat. The design of risk communication strategies should take care for this pattern and its implications in order to grasp adequate arrangements to avoid a threat.

The concern of the consumers is closely related to the media presence. Especially food scares generate a high degree of concern compared to other incidences. The reason is that everybody has to consume food and is therefore highly involved.

Negative news reportage is not the only source for consumer uncertainty but it is also a result of it. Media companies underlie, like every other firm in a market economy, an ongoing com-

petition; hence they also underlie the market forces. As a result if they want to survive they have to adapt to the needs of their customers. The decreasing valuation of food increases the interest of the consumers regarding information which confirm the negative prejudice. This is the strengtheners' effect of the media. General information overload enforce the consumers to perform a selective perception so that they are registering preferred negative properties and news. The media fulfil this need of information of the consumers. This coherence is called the 'vicious circle of selective perception' (see figure 20). Thus the frequency of negative news will not only be determined by the actual scandal frequency but also from the demand for scandal information (v. ALVENSLEBEN 1998, 1 and 9).

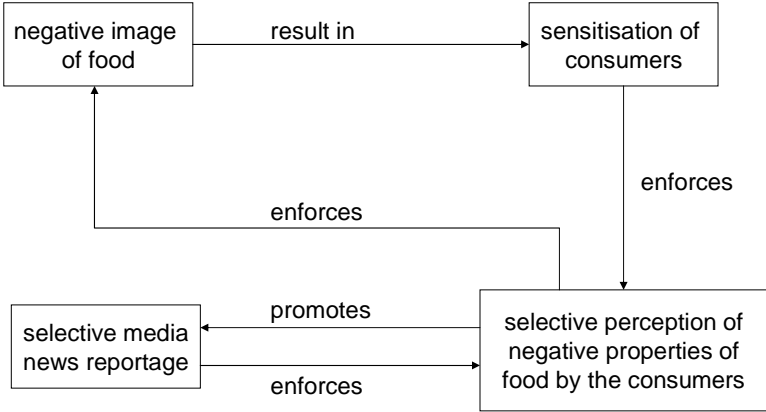


Figure 20: Vicious circle of selective perception (Source: v. ALVENSLEBEN 1998)

It was already mentioned above that consumers underlie systematic perception biases by the estimation of risks. Risks which are connected to food consumption normally have properties which lead to an overestimation of the risks by the consumers. The subjective risk perception of the population is often far away from the objective evaluation of experts. BSE for example is evaluated as more dangerous as smoking which can be explained among others by the voluntariness of these risks: Smoking is a voluntary taken risk while BSE will be perceived as an inflicted risk (v. ALVENSLEBEN 1998, 8; WIEGARD AND BRAUN 1994, 298).

After disclosure of a food scare the consumers react in with buying restraints. The demand of the food product under observation will be partly or even completely stopped while substitutes will be bought increasingly. In the 1980s for example the glycol wine scandal led to an incursion of the German wine consumption. In parallel the beer consumption increased. Beer as a substitute of wine could improve, at least in the short run, its relative competition position

against wine based on the mistrust of the consumers regarding wine (ECKERT 1997, 9). Similar tendencies could also be observed in the development of the beef demand during the BSE-crisis in Germany (EGENOLF 2004). In November 2000 the first BSE case was confirmed in Germany, the media news reportage concerning BSE increased rapidly (see chapter 5) and the consumers' trust in the beef production decreased accordingly. Together with the decreasing trust, also the demand for beef decreased. It came to a switch in the demand from beef to the as safe perceived poultry meat (see figure 21). After the food scare the demand for beef recovered slowly.

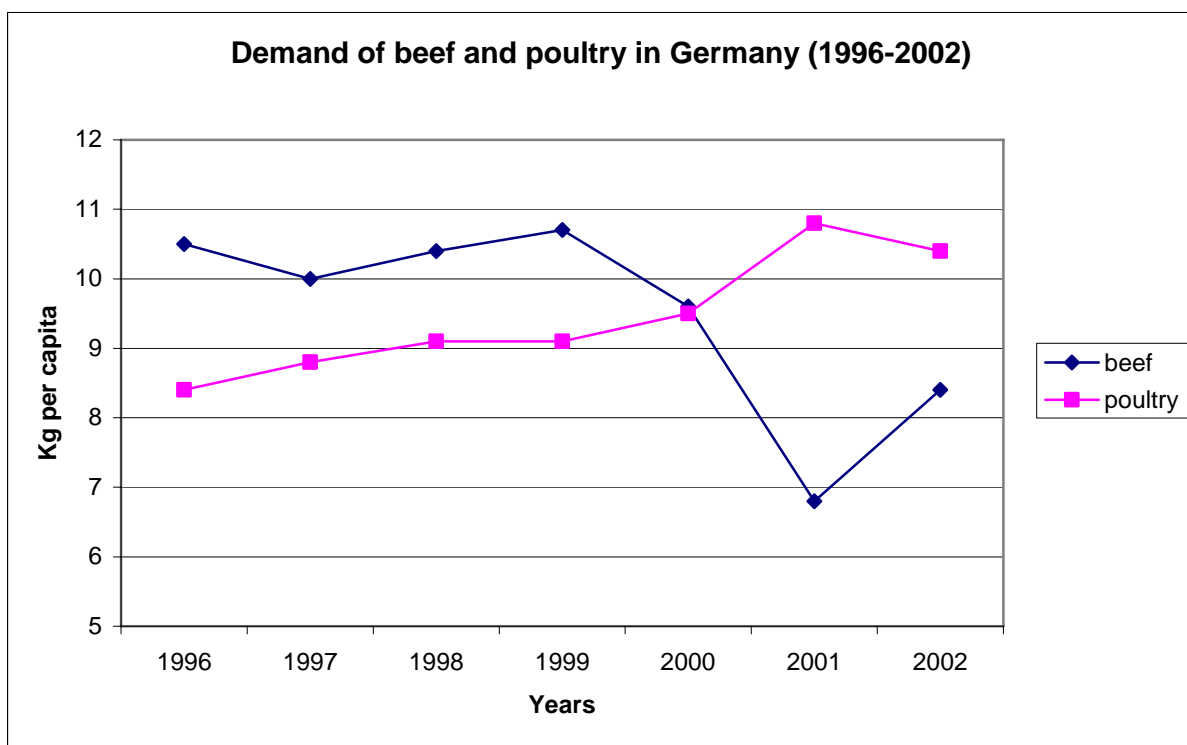


Figure 21: Demand of beef and poultry in Germany (1996-2002) (Source: ZMP)

Besides these substitution processes there is another risk minimising strategy: the consumers have partly changed their buying behaviour, i.e. they changed from the supermarkets respectively the discounters to the local butcher since he is trusted more. The direct selling gained new impulses by the appearance of negative news concerning food safety (KUTSCH 1992, 148). Especially in times of a crisis, trust in different supplier types plays a crucial role. The disclosure of a food scare induces aware buying behaviour of the consumers. A motivation to safety leads consumers to pay more for safe food especially in times of a crisis. V. RAVENSWAAY AND HOEHN (1991, 156 and 157) have confirmed this hypothesis by a study which was related to the willingness to pay for Alar-free apples. The background for this study was the discussion in the USA concerning the chemical growth regulator Alar, which was used in apple cultivation and which was under suspicion to invoke cancer. It was shown that the will-

ingness to pay for Alar-free apples during the period of investigation increased: 1984 the consumers would have paid 11,5 % more for a pound of Alar-free apples and in 1989 they would have paid even 31,8 % more for a pound of Alar-free apples. The increase of the willingness to pay over time can be traced back on the increase of the media reportage regarding risks with Alar. The example shows that consumers who are anxious about their health are willing to pay a higher price if they would get a higher food safety. This is especially the case if negative news reportage about food safety of a certain product leads to distrust in the safety of this product under investigation. In this light also the behaviour of the German consumers who preferred to buy beef during the BSE-crisis from the local butcher rather than cheap offers of supermarkets or discounters is comprehensible.

The uncertainty within the population is strongly related to intense media reportage in the beginning of a food scare. Shortly after the peak of the news reportage however these topics loose their news value for the media and it will be overlaid by other news. In the course of this recessive stimulus intensity forgetting processes set in, so that the consumers find after some weeks of partly panic reactions with respect to the scandal news back to their habitual behaviour patterns. This was also the case in the German BSE-crisis in the winter between 2000 and 2001. In the beginning after the first mad cow case in Germany was discovered, this case was intensely discussed by the media. HAGENHOFF (2003, 269-272) has analysed how the impact of the media reportage concerning BSE in the print media has influenced the opinion of the population in Germany. She counted the number of articles regarding BSE for a representative number of German newspapers within the years 1990 until 2001. With these numbers it is possible to display the distribution of articles (information releases) over this period (see figure 22).

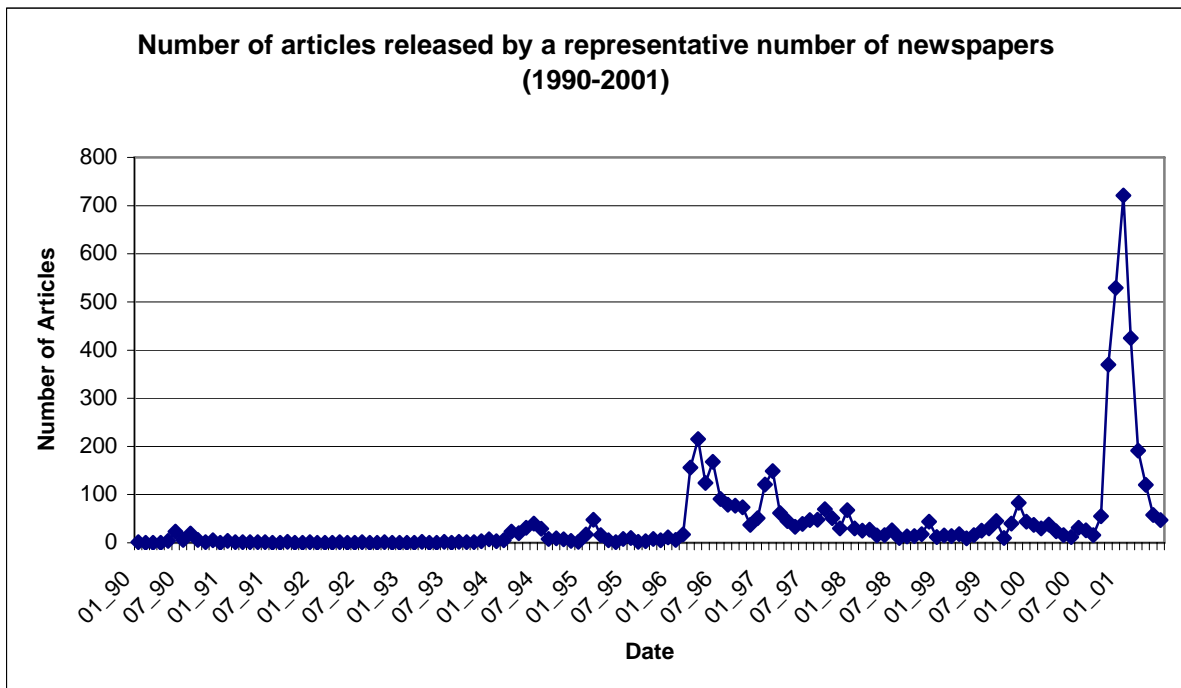


Figure 22: Newspaper reportage concerning BSE (HAGENHOFF 2003, 269-272)

The intensity of the BSE news reportage reached its peak in December 2000 and in January 2001. After that the number of BSE articles decreased rapidly. Beyond the peak, forgetting processes which were accompanied by declining BSE news reportage set in, so that the share of the anxious people nearly decreased back to the level before the BSE-crisis in Germany occurred (BRUHN 2001, 5). BRUHN (2001, 30) found that already seven month after the first discovered BSE cases in Germany the consumers came by the majority back to their former attitude and behaviour patterns. At that time (middle of 2001) there was no fracturing of trust with the German population as a consequence of the BSE cases to detect. This issue can serve as an indicator of the ephemerality of food scares.

The element trust with respect to perception and behaviour is also relevant. It was already mentioned above that trust in information sources is one of the determining factors which influences the behaviour of the individuals in connection with information releases regarding certain topics. Risk communication is one mean to reduce potential risks and which can thereby support the trust building of the consumers. Risk communication is one element of risk management (WIEDEMANN 1999, 4). Risk communication can be differentiated into target-oriented risk communication and into 'free-floating' risk communication (KRIMSKY AND PLOUGH 1988 according to WIEDEMANN 1999, 1). 'Free-floating' risk communication is basic in communication processes of modern societies. This can happen by rumours, press reportage, PR-campaigns, as information by firms or even the absence of this information (WIEDEMANN 1999, 1). Risk communication in this form has often no certain aim and no certain target group. It derives from different sources. Target-oriented risk communication is directed

and refers to certain communication processes. *“Risk communication is the process of exchange about how best to assess and manage risks among academics, regulatory, practitioners, interest groups and the general public”* (POWELL AND LEISS 1997, cited in WIEDEMANN 1999, 1). And furthermore *“risk communication is an interactive process of exchange of information and opinion among individuals, groups and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risks, that express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management”* (NRC 1989, cited in WIEDEMANN 1999, 1). This differentiation is later important for the scenario testing of the multi-agent simulation where different risk communication strategies will be tested with respect to the recovery rate of the aggregate trust of the artificial consumer population. Trust of the consumers is not only determined by risk communication but also, or even more, by the successful operation of the product and the control systems. If the consumer should trust in the quality of food and its harmlessness concerning health then a precondition the product and the control systems in the food industry are working successfully (HALK 1993, 28). Quality assurance systems are, besides effective risk communication, important means in the trust building of the consumers. The consumer relies on an effective control of the quality and the safety of the supply and value chain (HINRICHS 2004, 93). The objective quality includes product oriented quality as well as process oriented quality (GRUNERT ET AL. 1996, 78). This is especially relevant for food supply chains which consist of several levels which have to be controlled. The consumer trusts not only the producers of a food item but also the controllers which have to check and control the whole production and supply process. Hence the means to build up and maintain trust in food and its production are effective quality assurance systems which integrate and control the whole production and supply process based on binding contracts. These contracts must be equipped with incentives and sanctions which lead to the maintenance of the contracts (HINRICHS 2004, 93). Along with the implementation of effective quality assurance systems, target-oriented and effective risk communication supports the communication of these quality assuring arrangements. In case of food scares the consumers are interested in new information regarding the safety of the suspicious food item. Risk communication which can communicate the arrangements of the quality assurance systems, can support the recovery of trust in the quality of the food and the reliability of the suppliers. Quality assurance systems and effective risk communication can reduce the perceived risk of the consumers to be harmed (PENNINGS ET AL. 2002). BOECKER AND HANF (2000) state that besides the perceived severity of a food hazard also the perceived differences in the reliability of different types of suppliers have an influence on the trust and the buying decision of the consumers. Hence suppliers which have implemented quality assurance systems have a higher probability to be reliable than suppliers who did not invest in this effort. This assumption will be used in the Bayes’ rule for the trust updating of the single consumer agents in the next section.

4.8 Cognitive processes in the multi-agent simulation

The cognitive processes which are active in the mind of the actual consumers and which were described in the sections above are complex and need a lot of steps to be performed. The multi-agent simulation has to reduce these processes since it is hard to map all elements of these cognitive processes due to a lack of quantitative information and due to technical reasons. These cognitive processes are reduced and simplified in the multi-agent simulation by implementing the Bayes' rule (BOECKER AND HANF 2000). This can be reasoned by the fact that the Bayes' rule or the Bayesian updating approximates the observed pattern of the aggregate trust when consumers are committed with a food scare where the aggregate trust rapidly declines after disclosure of the food scare followed by a slow recovery of the trust in the following. This s-curve can be adapted due to the mechanisms of the Bayes' rule. This simplification of the actual cognitive processes is implemented on each consumer agent. The artificial consumer population in turn is interconnected in different networks where they can communicate about the safety of the suspicious food item. Information distributions by the media influence the development of the aggregate trust, i.e. the cognitive processing on the basis of each consumer agent and the communication with the related agents leads to a change of the trust in the suppliers of this food item.

The following chapter displays an approach to model consumer behaviour respectively trust according to food safety information released by the media which is related to a food safety incident. Therefore a multi-agent simulation will be modelled in order to create an artificial consumer population which is connected to media agents. Different information scenarios will be evaluated based on this model, so that risk communication strategies can be evaluated regarding the recovery rate of trust.

5. Consumer response to food scares – a multi-agent simulation

Consumers are active in a lot of different markets. Often they do not know how products are processed and produced. Especially food and the quality of food often can't be controlled. Some properties of food can be experienced, whereas others have to be trusted because there is no way to check the quality property. Hence consumers are often in uncertain situations regarding food consumption. In buying decisions the trust in the harmlessness of the food products, respectively the reliability of suppliers (trust property) is primary relevant. The fact that consumers are less good informed concerning the food quality than the producers is called in information economics as asymmetric information distribution (AKERLOF 1970). The risk is always around and therefore the people are vulnerable with respect to news which indicates that there are problems with food safety.

In this chapter a multi-agent simulation will be presented which models the diffusion of trust in food respectively suppliers based on food safety information from the media and its impact on demand in the environment of a food safety incidence. Hence, it offers the opportunity to illustrate the variability of trust in the course of time and can provide valuable information about recovery process of trust and the time that has to elapse before pre-incidence sales are obtained, again.

As depicted in figure 23, the simulation comprises three interdependent spheres. These are firstly a set of n individual consumers who update their trust in suppliers of a specific food item. The updating is based on a Bayesian updating considering the special features of the agent's affiliation to a consumer group, the current state of the agent's information about food safety and risk, and the corresponding trust in food chain actors. Secondly, the n individual consumers are summarised into a demographic network and into social networks in which they exchange information about food safety issues. Finally, a set of m media agents that supplies the consumers' network with either positive or negative information about the food under investigation is introduced. The impact of information on the consumers is assumed to depend on the formers addressees, their position within the network, and the media's trustworthiness represented by the specific network weight of the information source (the media agent), apparently.

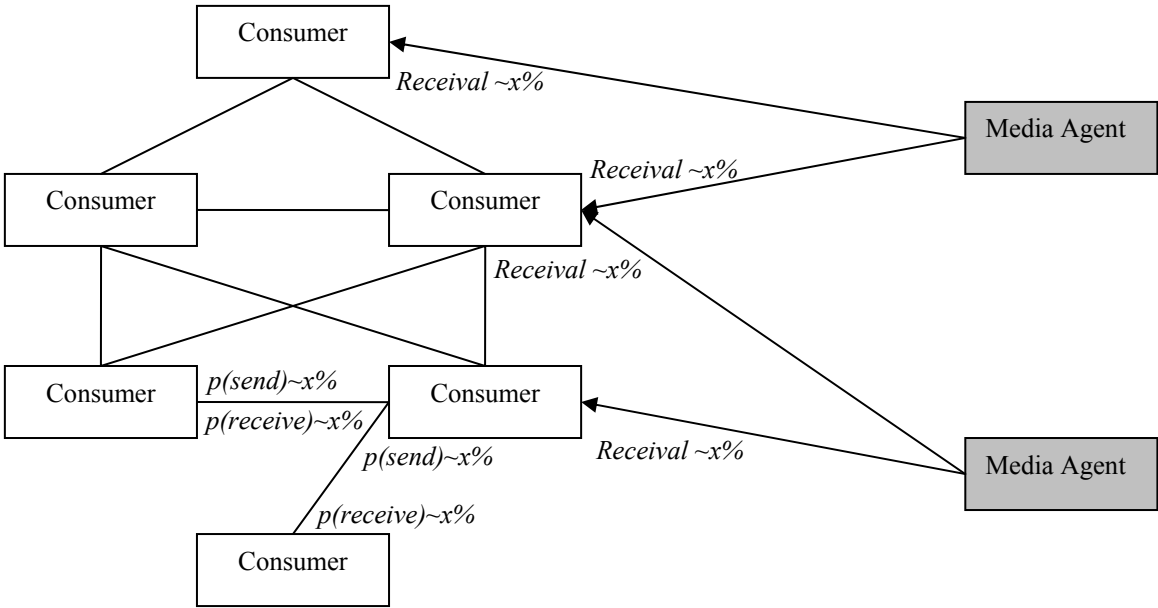


Figure 23: The Distribution of Food Safety Information within the Demographic Network and the Social Networks

The task of the consumer agents is to transfer this information to trust. Hence, these artificial agents must have been constructed in a way that they are able to transfer food risk and safety

information into trust. As the transformation process certainly varies from person to person the artificial consumer agents had to be modelled that they correspond in their structural and behavioural characteristics to different consumer segments.

The multi-agent simulation in this case is a computer program. Here it is an object oriented approach written in *Java* where a certain number of repeated interactions between parts of the program generate a complex systems structure.

5.1 The object paradigm and the impact of processes

The design of a multi-agent system is of high importance for its performance, flexibility and robustness. There are various computational aspects to consider in order covering these features. First the researcher has to decide if he wants to develop the system from scratch or if he uses existing tools. Therefore the requirements of the system have to be previously identified. One method in software engineering fits adequately for the modelling of a multi-agent simulation: object oriented software development. This method is a conceptual modelling technique and is widely used in various disciplines.

Natural sciences investigate natural objects and appearances while artificial objects with planned properties are the research objects of the ‘Sciences of the Artificial’ (SIMON 1994). Herbert SIMONS architecture of the complex and his principle of the quasi decomposability offers the possibility to decompose conceptually complex processes.

The object paradigm is closely related to a general design theory especially with respect to the representation of real world objects (QUIBELDEY-CIRKEL 1994, 194). The development comprises three consecutive phases: analysis, design and implementation.

The object oriented software engineering process builds the basis for the development of the system. Object oriented analysis (OOA) and object oriented design (OOD) follow an iterative way from the requirements analysis over the utilization of activity diagrams up to the class design. SIMON has identified three important technical aspects: modularisation, hierarchy and representation. These technical aspects allow a flexible use and reuse of the simulation model. Social life is often determined by processes. Individual cognition comes first before social action follows. The same object can be perceived differently by different people. In social situations it is even more divers. In social life the main interacting elements are processes which run in between people or groups of people and these relations and processes are subject of permanent metamorphosis. Social networks are also relevant for the formation of social processes.

A process in the general systems theory is a dynamic sequence of states of a system. A deterministic process is where each state results explicitly by its previous state. A stochastic process is characterised if each state results with a certain probability by its previous states. Deterministic processes are only idealisations of real processes. The reason is that each process

ultimately represents a unit of inevitable and stochastic changes, i.e. it is in principle stochastic. Deterministic processes in the sense of classical mechanical theory are an exception even in physics. These remarks regarding the character of processes confirm that each process is an entity of necessity and chance which emphasises the stochastic element in processes.

In practical science it is tempted to convert stochastic processes into deterministic processes approximately by various theoretical and mathematical means. The reason is that deterministic approaches are easier to treat technically.

A social process is a notion which comes from sociology. It denotes a change of social and societal circumstances. The dependency of an individual from its social environment forms its consciousness. Social processes permanently pass off in all social areas. They do not always lead to a change in the sense of a developing evolution, but it is also possible that they lead to declining changes or adjustment processes within a system.

Simulation technology offers an appropriate environment to model and analyse social processes. Object oriented software development is based on the identification of processes with relation to objects. Social processes can partially be described by mathematical relations. This kind of thinking is the starting point for the modelling of a multi-agent simulation. Object oriented programming is best suited to represent multi-agent models. The objects are self-contained, they may be designed to convey information (answer questions) from other objects and they can also retain, categorize, and summarize information.

The basic processes (business processes) are derived from the requirement analysis (SAGGAU 2003). They are a collection of organisational and technical interrelated activities. These processes will be sub-processed into use cases (single processes in software development), so that a definite set of use cases form a business process. The interaction of the use cases can be illustrated in a use case diagram. The use cases are then decomposed using activity diagrams, which show sequences of actions forming these use cases. Parallel to this sub-processing the class design (the different objects and their relations) is developed iteratively⁸ (Oesterreich 2001). At last, the messaging concept is formulated which makes the objects, respectively the agents communicate and thereby create a complex system. Using this multi-agent system, simulations can be run to help explaining aggregate outcomes.

5.2 The model

The motivation for the development of a multi-agent simulation is lying on the questions ‘How does a food scare and information of a food scare influence the trust of one single agent and the changes on the aggregate level?’ and ‘How can risk communication strategies be evaluated?’. An artificial society of consumers which have their own decision functions is

⁸ The documentation of the underlying classes respectively objects are represented in the unified modelling language (UML) format; see Annex A.5 for the UML-modelling of this simulation software.

used to observe how new information about food safety influences the behaviour of each consumer agent and the population as a whole. This multi-agent simulation can be used to investigate how different information releases and decision functions influence the aggregated outcomes. The agents get information from the networks in which they are present. This information will be processed, the trust regarding the food item under investigation will be updated and taken into account for the own decision. The intention is to measure how different risk communication strategies influence the aggregated trust. For this purpose a multi-agent simulation is used in order to follow a bottom up approach where each agent acts individually. The interaction between the agents leads to an emergence of an aggregated trust level which comes from the bottom up. Each agent follows its internal updating and decision algorithms so that on the aggregate level the trust changes according to the outcomes of the interactions and its related updating processes. After the communication phases the aggregation of the outcomes of each agent shows the result of the information strategy that was selected. In this way it is possible to test and investigate different risk communication strategies and evaluate these information policies, more precisely the benefits of a risk communication strategy can be evaluated with this multi-agent approach.

Regarding the diffusion process, the model is able to illustrate both the decline and recovery of consumers' trust in food. Various processes that range from the rapid spread of distrust after a food scare to time consuming process in the build up and recovery of trust are considered.

The modelling starts with the construction of an economy which consists of an initial population of N consumer agents. Besides these primary agents there are auxiliary agents which represent different social and model environmental objects, e.g. media agents.

First the initial state of the economy has to be specified, i.e. the agents will be equipped with their initial attributes. These attributes are type characteristics, internal behavioural norms and internal information about themselves and other agents like the network connections.

The development of the economy happens in time by interaction and updating of internal states of the agents, i.e. updating the trust value for a specific good, respectively supplier. The simulation model implements a Bayesian updating process for the trust updating based on new food safety information according to the specifications made by BOECKER AND HANF (2000). The Bayesian updating process is the core of the decision making of the consumer agents. Consumer agents in this model update their trust in different kinds of suppliers of the product under investigation by processing new information concerning the reliability of these suppliers. The consumer agents are organised in a network structure.

5.2.1 The networks and the information sources

The model consists of several networks which serve as information sources for the agents (SAGGAU AND PATELLI 2004, 2). There are decentralized and centralized networks. Both types of networks serve as information sources for the agents. The decentralized networks are social networks which again are several sub-networks like the demographic network or friend's networks. These networks are endogenous, more precisely the information processing is endogenous. The centralized networks are exogenous in the sense of releasing information exogenously. They spread information regarding food safety from one single information source via the population of consumer agents.

The N consumer agents are connected to the networks. They communicate information about the safety of the food item which is under suspicion to be unsafe. There are two, respectively three kinds of social networks. Each network serves as an information source for the agents. The networks are differentiated by unique identifiers ID_k where k denotes the network, so that the information sources are well known to the agents.

The demographic network

In the demographic network each agent of the population finds its place in a family structure. This network type is deterministic in the sense that it is once set up in the beginning of each simulation run. The demographic network consists of three generations: the grandparent generation g_1 , the parent generation g_2 and the children generation g_3 . The agents are consistently assigned to this network, i.e. the family relations are kept, and there are no inconsistent states (see figure 24).

The demographic network can be varied by changing three parameters: the population size N , the average number of offspring in the second generation o_1 and the average number of offspring in the third generation o_2 .

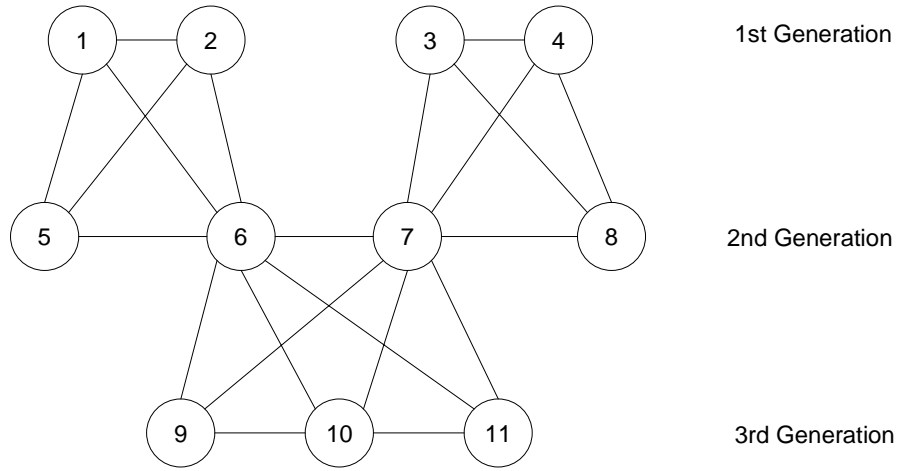


Figure 24: Demographic network

The population size N determines the size of the adjacency matrix which will be used as the connections matrix $D(n,n)$. This connections matrix is quadratic and the size corresponds to the number of agents in the population N . This matrix will initially be filled with zeros. The zeros change to one when the generations will be upset and only if the connections are determined. $d_{i,j}$ denotes the relation between agent i and agent j with $i \neq j$, where $d_{i,j} = 0$ denotes that there is no relation between the agents and $d_{i,j} = 1$ denotes that there exists a relation between agent i and agent j . During this phase the initial parameters for the agents will be set.

The algorithm for the creation of the demographic network:

1. First the connection matrix for the demographic network will be filled with zeros. This means there is no linkage between the agents.
2. Next there will be set up three vectors g_l with $l \in \{1,2,3\}$ where each vector will be equipped with the agents in the respective generation.
3. The size of the first generation s_1 results from the quotient of the population N divided by the product of the average number of the 2nd generation o_1 and the 3rd generation o_2 with $o_1, o_2 \geq 1$.

$$s_1 = \frac{N}{o_1 * o_2} \tag{1}$$

The first part of the agents of the population will be filled into the first generation vector g_l and each of them together with a connection vector.

4. The size of the second generation s_2 is the product of the number of the first generation s_1 and the average number of children per family in the second generation o_1 .

$$s_2 = s_1 * o_1 \quad (2)$$

A part of the remaining agents of the population will then be assigned to the second generation vector g_2 likewise each with a connection vector.

5. The size of the third generation s_3 is the result of the subtraction of the population size N minus the size of the first generation s_1 and minus the size of the second generation s_2 .

$$s_3 = N - s_2 - s_1 \quad (3)$$

The remaining agents of the population will finally be assigned to the third generation vector g_3 and each also with a connection vector.

6. The ‘marriage’ in the first generation will be done by another algorithm which overwrites the zeros in the connections matrix by a one if two partners are found. In the next step another algorithm generates the offspring of the first generation and connects this second generation with the first generation.
7. The marriage in the second generation is a little bit more complicated because it has to be excluded that there are no brothers and sisters marrying each other.
8. Finally the grandchildren have to be included into the family structure, i.e. the third generation will be assigned to the second generation.

All these connections will be done in one adjacency matrix by overwriting the zeros by ones. In this way the demographic network will be set up; in parallel the agents will be initialised and assigned to the network.

The social networks

Besides a family network each agent can also be part of other social network, here they are called friend's networks. These networks are stochastic, that is they are random networks which are not determined like the family network. Each agent randomly receives a variable number of links which connects him to agents who are not members of the family. The members of these social networks are again the members of the agent population, which already form the family (demographic) network. The connections to other agents can be chosen differently. It is possible to choose between different distributions of the links to the friends. The uniform distribution for example sets up a connection matrix where the number of connections results from the product of the average connections and the population size. An algorithm then sets up the connections matrix according to the uniform distribution. Figure 25 displays a possible structure of this network.

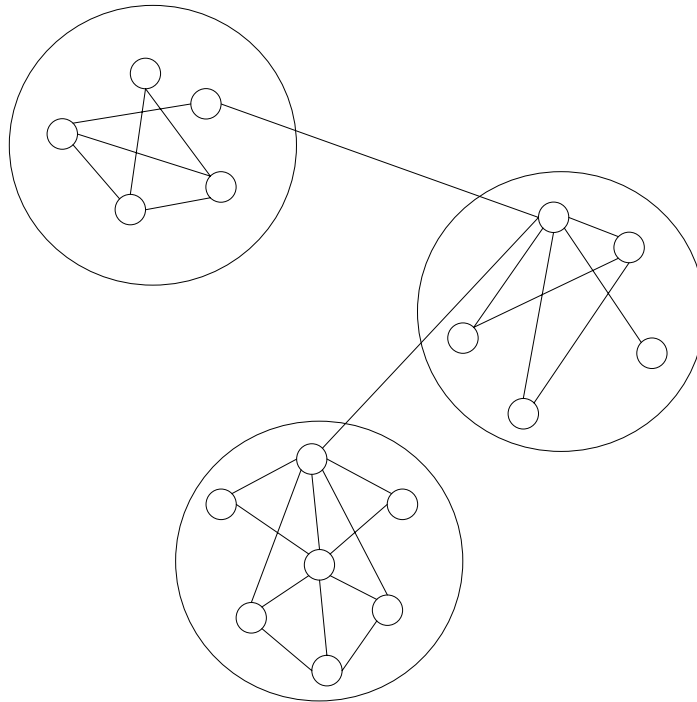


Figure 25: Social networks

Agents can be related in groups respectively clusters, where the nodes or agents are interconnected in a bidirectional way. Some agents have links to agents which are outside of the cluster but again in another cluster. In this way the friend's networks can be created. The stochastic element is the random distribution of links. It can vary in each simulation run but it is also possible to perform different simulation runs under the same random conditions.

The creation of the social networks is a bit different compared to the set up of the demographic network. There will also be set up a connections matrix for the social networks $S(n,n)$. This happens by an algorithm which randomly connects the agents by using the selected random distribution together with the specified parameters for the respective distribution. The connection matrix will then be converted into a list; this list is a vector in which each agent is placed as an element of the list and each agent himself has a vector of other agents which are his friend or social contacts.

The centralised networks

The centralized networks can be the media, the government or other centralised organisations which can reach consumers. The consumer population can be segmented into three trust segments, so that there is a differentiation between global centralised and segment centralised networks. In the global centralised networks each agent receives a message which is released by these information sources (see figure 26), that is the global media agents are connected to

every consumer agent. Whereas the segment centralised networks are just segment specific and segment exclusive. They are specified and segment directed centralised media.

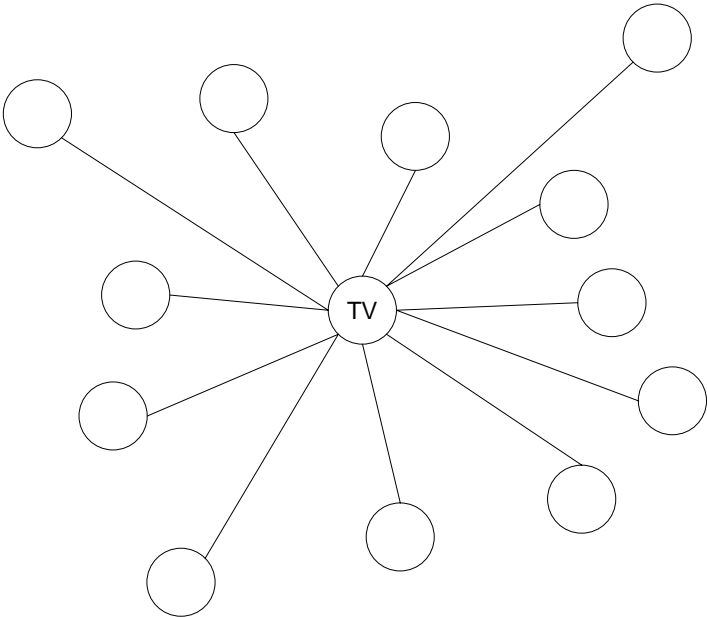


Figure 26: Centralized networks

The segment centralized networks refer to specific segments of the population. The data analysis of the Trust-survey (CAVICCHI ET AL. 2005) has identified three consumer segments: ‘Trusters’, ‘Mixed-trusters’ and ‘Non-Trusters’. A cross country comparison within five EU-countries (United Kingdom, Italy, Netherlands, France and Germany) was made. These three consumer segments regarding trust were discovered, they are differentially distributed within the analysed countries hence this implies a different percentage distribution within the population.

The population of consumer agents will be assigned to the segments according to the respective percentage distribution. There are m media objects which are the global centralised and the segment centralised networks. In particular there are $m_a \subset m$ global centralised media agents and $m_b \subset m$ local or segment centralised media agents. Each media agent can implement different kinds of information distributions. The centralised information source panel from the graphical user interface of the multi-agent simulation displays the properties of the media agent, i.e. the media and the parameter setting area for the properties of the information releases (see figure 27).

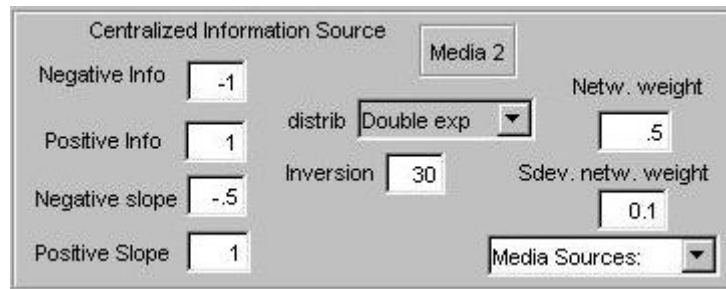


Figure 27: Centralised information source panel

In this panel the intensity of the information which will be released can be set explicitly, i.e. negative information can have a different intensity than positive information. The inversion text field offers the possibility to set the changing of the sign, i.e. when negative information becomes positive (food is not safe – food is safe). Another feature is the possibility to choose different information release distributions: exponential, double exponential, imported empirical data distribution as information release strategies. The slope of the curves can also explicitly be set and finally the weight of the network for the agents can be set explicitly.

The information release distribution is a time related distribution. Here one iteration corresponds to one day. The information which come from the media or the centralised networks are numerical values. They range from 1 for positive information to -1 for negative information regarding food safety in this case. It is important to know that the absolute value is an indicator for the intensity of the information, i.e. -1 (e.g. prime time news reportage in the main TV channel) is much more negative intense information than -0.1 (e.g. article on page 3 of a local newspaper) for example. The following table 3 displays the parameter fields of the simulation for one global media source.

Table 3: Parameter description of a global centralised media source.

Parameter:	Meaning and implication:
<i>Negative Info</i>	This is the starting value for two kinds of predefined information release distributions: double exponential distribution and exponential distribution, i.e. starting in the first iteration (day) with a negative information with the intensity -1 (e.g. first page of a newspaper with a picture of harmed people) and then continuing with less intense negative information regarding the safety of the food item under investigation.
<i>Positive Info</i>	The same holds for positive information but only for double exponential, since plain exponential is just a distribution of negative information releases.
<i>Distrib</i>	You can choose between two predefined information release distributions and one manual distribution. If choosing predefined distributions you will have the opportunities between ‘Double exponential’ distribution and ‘exponential distribution’. For these distributions you can also modify the following parameter.
<i>Inversion</i>	This text field offers the possibility to set explicitly the day when the news release changes its sign, i.e. when negative information (food is unsafe) changes to positive information (food is safe).
<i>Negative slope</i>	The negative slope is the curve of the negative exponential distribution, i.e. here the user can change the intensity of the information release values in time by changing the slope (a smaller value decreases the curve and keeps thereby the decreasing of the intensity slower in time and vice versa).
<i>Positive slope</i>	The same holds for the positive slope but also just for the double exponential distribution since the plain exponential distribution just has negative information values.
<i>Netw. weight</i>	This value is the trust value for the media source, i.e. the relative weight for this information source which influences the aggregated information value.
<i>Sdev.netw. weight</i>	This is the standard deviation for the network weight of this information source. Each agent belongs to a segment or will randomly be equipped with an initial trust value. This initial trust value comes from a random distribution where the network weight enters as a mean value and the standard deviation as the second moment.

Each global centralised information source can implement different information distributions which can be influenced and set explicitly: exponential, double exponential and manual distribution.

1. Exponential distribution:

The exponential distribution only provides a distribution of negative numerical information values. The shape follows an exponential curve which starts with the highest negative information value which can be chosen in the ‘*Negative Info*’ field and whose absolute values decrease in time depending on the slope of the curve. The simulation offers the possibility to choose a number of control parameters which can influence the shape and the duration of the negative exponential information distribution (see table 3). In this way it is possible to implement different negative exponential information distribution scenarios.

2. Double exponential distribution:

The double exponential distribution in contrast also offers the possibility to release positive information regarding the safety of food. The shape of this distribution is in the beginning that is in the first part like the exponential distribution. It starts with negative information which is reasonable because the effects of negative news reportage regarding a food safety incident shall be investigated. The negative information values also decrease

over time. In a certain point in time, it is called the inversion day, the negative information changes its sign and becomes positive. After the changing of the sign the news reportage starts with the highest positive information value (set in the parameter field '*Positive Info*') and continues with decreasing but positive information values. The shape is also exponential but this time coming from higher positive values and approximating the zero line. In the theoretical part in 4.6.4 it was already mentioned that forgetting effects are setting in after a time and other news are overlapping the news reportage of this food safety incident. Both the exponential and the double exponential distribution are allowing for this reasoning by their shapes. There are also a number of influencing parameters for the shape and the duration of the information release distribution in the double exponential distribution.

3. Manual distribution: '*import distr.*':

The manual distribution finally offers the highest degree of freedom for implementing a certain distribution of numerical information values. An Excel-file can be opened where the numerical information values can be set explicitly in an Excel-sheet. The respective file is filled with zeros, this means that the media which implements this distribution simply does not report about this food safety incident in any way. By replacing the zeros by other numerical values between 1 and -1 the distribution can be set up. Each cell beginning by A1 is the information release value for one iteration respectively for one day, e.g. -0.3 at C1 means for example a negative article with no picture on page 1 of a global centralised newspaper on day 3. In this way a personalised information distribution can be built and addressed to a single information source. The Excel-file will then be stored as an ASCII-file and the multi-agent simulation software translates this file into the information release distribution for the respective media during run time.

The global centralised networks can implement one of these options as information distribution possibilities while the segment centralised networks only can implement the import distribution option respectively the manual distribution.

The multi-agent simulation offers different types of media sources. Depending on the media source the data from the survey will be loaded into the text field which will be taken over by the agents. These parameters are the network weights for the respective media.

Information sources for the consumer agents

Information sources, especially media, and their impact on the consumers were already discussed in 4.6.2; these information sources are centralised exogenous information sources. The multi-agent simulation whereas implements two types of information sources: the exogenous centralised networks and the endogenous decentralised networks.

Media agents are newspapers, television, Internet and radio. They are the exogenous centralised networks. The structure of these centralised networks is different from the endogenous networks. One reason is that they are responsible for the initial information release which will be diffused via the agent population and processed by each agent.

The intensity of the information received from the different centralised networks is also different, depending on the information distribution of each media. Furthermore the influence on the agents depends on the information type, the information source (the weight of the network) and other environmental influences.

The social networks and the family network are completely decentralised. Only the members of the single social and family networks will be informed within these networks. They communicate the single actual information status of each member. But the agents in these networks also receive exogenous information from the centralised media which will also be processed and communicated so that it influences the endogenous information communication.

Technically a vector \underline{p} will be instantiated in which the information sources will be written, i.e. the different networks. Each information source respectively network also receives a unique identifier ID_k . This will also be written into the vector. First the demographic network will be written in \underline{p} which is a graph that connects all the members of the population, i.e.

$$\underline{p}(0) = G_{n,M_0} \quad (4)$$

This is the first element in the information source vector \underline{p} with $M_0 = \#$ of links between the agents in the demographic network. The social network will also be handed over to the information source vector \underline{p} , i.e.

$$\underline{p}(1) = G_{n,M_1} \quad (5)$$

This is the second element in the information source vector \underline{p} with $M_1 = \#$ of links between the agents in the social network. The same holds for the different implemented centralised information sources.

Then each information source also receives a network weight which determines the influence in the information processing of the agents. The connection of the centralised media agents to the agents of the population is different from the set up of the demographic and the social networks. Each centralised information source (*cis*) receives a vector of all agents of the population:

$$\forall cis \leftarrow \underline{n} \quad (6)$$

with \underline{n} as the vector of agents of the consumer population. Then all *cis* will be added to \underline{p} and finally each *cis* goes through the list of agents and registers as an information source together with the respective network weight.

5.2.2 The agents

The consumer agents are the core elements of the multi-agent simulation. They are responsible by interaction and communication for the results of the simulation runs.

“An agent is a system that tries to fulfil a set of goals in a complex, dynamic environment. An agent is situated in the environment: it can sense the environment through its sensors and act upon the environment using its actuators.” (MAES 1994, 2). This statement also comprises, on an abstract level, the consumer agents in this multi-agent simulation which are interconnected in networks of other agents and media agents.

Starting point is an agent who maximizes his expected utility. BOECKER AND HANF (2000) have investigated consumer response to food scares. They have proposed a model of individual information processing which is based on a two step risk perception process. They capture differences in the reliability between single types of suppliers by subjective failure probabilities. And then trust in an individual supplier J is defined as the subjective probability that he is the reliable one (P_J).

- Supplier J of Type A who is supposed to be reliable: P_J
- Supplier J of Type B who is supposed to be unreliable: $1-P_J$

The aim was to analyse the effects of incorporating trust in a consumer's risk perception on food purchase decisions. BOECKER AND HANF use a Bayes' rule for this purpose where the Bayesian updating is carried out by revising trust in a supplier of a potentially unsafe food based on new food safety information. It is assumed that consumers apply decision rules which are based on experience as well as on personal and mass media communication (in this paper work modelled by the different types of networks in which the consumer agents are situated). These aspects are supported by satisfactory results until the agents receive a signal which is strong enough to make them revise their prior beliefs or established decision rules.

It is assumed that the purchase decision of the consumer agents depends on four parameters: the utility from a safe unit of a certain product (U_X^+), the subjective probability to purchase a hazardous unit of that product (P_G), the subjectively presumed disutility from consuming a hazardous unit of that product (U_X^-), and the expected utility from consuming a substitute which is perceived to be safe (U_Y) with ($U_Y < U_X^+$).

$$P_G = P_J P(G|A) + (1 - P_J) P(G|B)^9 \quad (7)$$

He only buys and consumes the product if his expected utility is higher than the expected utility of the substitute, under consideration of the possible disutility of a harmed product X .

⁹ With $P(G|A) < P(G|B)$ and $P(G|A) + P(G|B) < 1$.

$$(1 - P_G)U_X^+ + U_X^-P_G > U_Y \quad (8)$$

Further, the artificial consumer agent responds to information about risk and safety of the product. Positive or negative information regarding food safety changes the subjective probability that he relates to purchasing a hazardous unit of this product. For this updating of the prior subjective probability, the Bayesian updating is employed. BOECKER AND HANF have implemented a two step risk perception process. The scenario can be described in the following way: “one or more units of *X* sold by *J* have caused health problems or *J* has violated health regulation and the consumer *K* learns about that either through personal experience, personal communication or media reports” (which will actively be done in the multi-agent simulation model). “He now revises his prior belief about the reliability of *J* according to Bayes’ rule to the posterior probability P_{PJ} . This is the conditional probability of the state ‘*J* is of type *A*’ after having observed the event ‘*X* is unsafe’” (BOECKER AND HANF 2000, 476). In this case the Bayes’ rule for negative information was implemented. And the second step is that “now *K* observes the event ‘*X* is safe’ – once again either through personal experience, personal communication or media reports. He revises his confidence in supplier *J*, with the posterior probability P_{PJ} entering the Bayesian revision process as the new a priori probability. The result is the posterior probability P_{PPJ} , which can also be interpreted as the conditional probability of the state ‘*J* is of type *A*’, after having observed the two consecutive events ‘*X* is unsafe’ and ‘*X* is safe.’” (BOECKER AND HANF 2000, 478). In this case the Bayes’ rule for positive information was implemented.

Updating (trust) mechanisms (*revised trust in supplier J*):

- Negative Information:

$$P_{PJ} = \frac{P_J P(G | A)}{P_J P(G | A) + (1 - P_J) P(G | B)} \quad (9)$$

- Positive Information:

$$P_{PPJ} = \frac{P_{PJ} (1 - P(G | A))}{P_{PJ} (1 - P(G | A)) + (1 - P_{PJ}) (1 - P(G | B))} \quad (10)$$

“Confidence is always – at least partially – regained: $P_{PPJ} > P_{PJ}$ always holds, however, trust is not fully restored.” (BOECKER AND HANF 2000, 478).

Different from the BOECKER AND HANF model, the multi-agent simulation uses the Bayes’ rule as an reinforcement learning instrument for the agents which is similar used in ANN (see 4.1.2). This updating rule leads the consumer agents to revise their trust based on new infor-

mation which comes in each iteration of the simulation as an input from the information sources of the agents. The trust P_J will always be assigned the new P_{PJ} value after each revision so that there is no more a two step risk perception process but a permanent updating until the end of the simulation, i.e. each the trust will be revised according to the news which are around in both network types – the exogenous and the endogenous. Hence if the aggregated information value is positive then the positive updating will be selected which now looks like (11).

$$P_{PJ} = \frac{P_J(1 - P(G|A))}{P_J(1 - P(G|A)) + (1 - P_J)(1 - P(G|B))} \quad (11)$$

After each updating P_J will be assigned the value of P_{PJ} so that P_J can enter into the next revision process $P_J \leftarrow P_{PJ}$. This allows for a permanent updating based on daily news releases of media agents. Hence the dynamics of information release distributions or strategies can be investigated based on these mechanisms. A further extension of the BOECKER AND HANF model is the possibility to work with heterogeneous agents in the sense of different risk attitudes and different trust levels. Furthermore each agent is part in at least one network, the demographic network, but can also be part in other networks. So that, on the one hand, network effects can also be analysed and, on the other hand, the agents act under bounded rationality conditions, since they have different status of information. Each consumer agent is registered in the networks where he belongs to. He can go through the networks and ask for information. Additional to the basic model there is the possibility to ‘see’ how other agents behave in risky situations in the sense of registering the changes in the information states of the related agents which serve as the basis for the direction of the trust updating.

5.2.3 Updating algorithms and micro data of the simulation model

The updating of the information value which is the basis for the trust revision is guided by a number of updating algorithms. The updating algorithms allow for the differentiation between different information sources, i.e. the differentiation between the type of the network, the media source (credibility and influence) and the intensity of the information release and the range of the information release. Information sources in centralised networks like media have far more influence regarding the aggregate outcomes than a single information source in a single social network but on a micro level the single connections are also relevant.

The micro data of the multi-agent simulation model come from an EU-survey which was accomplished in the TRUST-Project¹⁰. The SPARTA model developed by MAZZOCCHI ET AL. (2004b) is derived from the TPB. This model is based on socio-economic differences across the population dependent on classification of trust in information. LOBB ET AL. (2005) have

¹⁰ ‘Food Risk Communication and Consumers’ Trust in the Food Supply Chain’. TRUST - QLK1-CT-2002-02343. <http://www.trust.unifi.it/>

produced five information categories based on a principal component analysis which are (1) trust in media information; (2) trust in food chain actors; (3) trust in public authorities; (4) trust in independent organisations and (5) trust in alternative sources. These trust values serve as the weights for the information sources regarding the information weighting. Furthermore they have performed a segmentation analysis based on the Trust survey data. It categorises consumers into three distinct ‘trust groups’ (1) Non-trusters; (2) Mixed trusters (those that are neither particularly trustful nor distrustful); and (3) Trusters. These segments are implemented in the multi-agent simulation and can be addressed by the segment specific information sources. The model offers the possibility to assign different trust values to the three identified consumer segments. Together with the standard deviations of the segmented trust values the system assigns normal distributed trust values around the mean value of the respective segment to each single agent.

Intensity of information releases

The multi-agent simulation works with numerical information values hence the information regarding the safety of food has to be a numerical value. The reason for this technical issue is that the consumer agent needs to know which updating shall be performed, the negative trust revision or the positive trust revision. This means the choice which of the two equations for the Bayesian updating (9) and (11) has to be chosen is based on the updated and aggregated information value.

The range for the information values released by the centralised media agents on the one hand side (exogenously) and the agents in the networks on the other hand side (endogenously) is between -1 for negative information and 1 for positive information. These are the highest values for both directions. The lesser the values for either directions or say the absolute value, the lesser is the intensity of the information release. Besides the weighting of the information sources this is a second kind of weighting the information.

The intensity of the information can be influenced differently (see 5.2.1.3). If a centralised information source like a local newspaper for example should release information then the intensity of the information is probably less than the intensity of the information release from the television, e.g. for positive information – local newspaper 0.5 and television 0.8. Another example within the same centralised information source can be 0.6 for the news reportage at the prime time and 0.3 for the news reportage in the afternoon for the television information source.

With this variety of information release possibilities and the possibilities for the shaping of different information distribution scenarios, there can be predefined empirical information distributions and there can also be produced information strategies which can be tested with respect to the aggregate outcomes.

Information updating and trust revision

The weight of one network can be interpreted as a placeholder for the importance of this information source for the agents. The higher the weight for this information source, the higher is the influence of this information source regarding the trust building of the agent. The empirical data from the Trust-survey regarding trust in different information sources will be implied in the multi-agent simulation¹¹. They are the weights for the different centralised information sources.

The updating of the information value for each consumer agent follows an algorithm: each agent $i \in \{1,2,3,\dots,n\}$ collects the information values of its neighbours $C(i)$ in his networks and also the information values of the centralised information sources. Then he computes the mean information value v . This will be done for each network, i.e. asking the family, asking the friends from the social networks and asking the information values from the centralised media agents. Each aggregated information value from each network in which the agent is present will be weighted with its corresponding weight, then the mean of these weighted information values will be assigned to the updated information value of this agent. This will be done for every agent.

In each step t of the simulation run the basic agents' internal step method will be invoked.

$$\forall t \forall n \rightarrow \text{step}_i() \quad (12)$$

The population object of the multi-agent simulation invokes the list of agents and calls for each agent the internal step method:

```
for (int j = 0; j < agentsList.size(); j++) {
    ((Agent)agentsList.get(j)).step();
}
```

The internal step method of the agents then collects the information values of the networks and aggregates these together with the respective network weight:

```
step() {
    //getting information and compute new information status
    Vector infoList = myInformation.getInfoList(this);
    updateInfo(infoList);
    //computing new pj value
    newPj=computePj();
}
```

This method goes through the list of related agents, asks for the information value (the information status), evaluates it and it also goes through the list of information sources in order to get information and to update its own information state and to compute the new trust value P_j (see figure 28).

¹¹ See Annex A1.

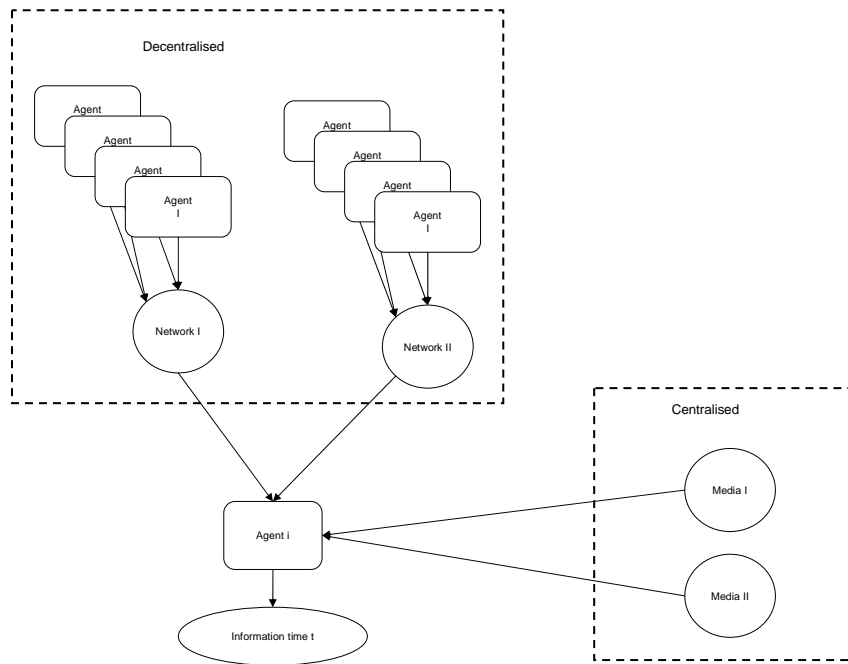


Figure 28: Information collection

One Iteration/Day:

Step 1 - Information Collection and Processing:

In each time step the agents collect information from their neighbours, i.e. from the decentralized information sources and also the agents collect information from the centralised information sources (media, government ...).

Step 2 - Bayesian Updating:

After the information collection the agents update their P_j according to Bayesian updating (see above). The old P_j enters into the equation and revises P_j which then again is the next P_j value which enters in the following updating and so on.

The aggregation rule for the information aggregation is closely related to the aggregation of weights of the information sources. Each agent permanently updates his information status in the time horizon of the simulation run. The updating of the information status results in the aggregation of only one information value (*newInfoValue*). This is necessary because this is the decision parameter for the trust revision. Based on this information value, i.e. positive or negative information value, the trust value P_j will be updated according to Bayes' rule – more trust or less trust compared to the previous trust value. For this reason the agent has to aggregate and weight the information values of the information sources, i.e. he forms a new opinion based on the information collection regarding the safety of the food item and the trust in the supplier: Each information source $h \in \{1, 2, \dots, k\}$ (family, friends, media etc.) has its own information status and a network weight and is registered in the connection list of the respective agent. Both values will be asked by the updating agent. The information values and the net-

work weights will then be multiplied and summarized ($\sum_k (infoValues_h * weight_h)$). Additionally the network weights will be summarized ($\sum_k (weight_h)$). Finally the new information value of agent i ($newInfoValue_i$) will be computed:

$$newInfoValue_i = \frac{\sum_k (infoValues_h * weight_h)}{\sum_k (weight_h)} \quad (13)$$

The trust value will then be revised based on $newInfoValue$, i.e. if $newInfoValue < 0$ then the trust value will be decreased and vice versa. Since the agents permanently update the information status and subsequently the trust value there is a slight adaptation of the trust value following the information environment of the single consumer agent. This agent specific information environment results from the endogenous network connections of this agent and also from the news which comes from his connected media agents. Hence the information environment of each agent differs to a certain extent. However the agents are communicating and consequently they converge after a certain time.

The aggregation rule for the aggregation of the weights respectively the information values is similar to the propagation function in ANN. In ANN the neuron receives input values by a number of different presynaptic cells. The propagation function has to fulfil the task to densify these values into a univalent input signal. This function is usually a summation function. In this multi-agent simulation it is a weighted summation function. The reason is that the information values need to be weighted by the network weights in order to imply the relative importance of the single network respectively information source.

5.3 Information strategies (information policies)

Consumer behaviour in risky markets is, among others, governed by information. A purposeful influence on the behaviour of the consumers using information and communication means can be denoted as an information strategy. A strategy is a long term goal oriented plan. This implies that the goal is known. In case of a risk communication strategy the goal is the prevention of a crisis and the risk minimisation. Both aspects aim at public enlightenment about the potential risks and the means which were grasped to reduce the risk. In the BSE-crisis for example the subjective risk to be harmed by BSE respectively vCJD was n-times higher than the objective risk to be harmed by this disease. This led partially to panic within the population supported by negative media news reportage concerning that topic. And these factors were responsible for the great dimension of the crisis. Effective risk communication respectively and an effective risk communication strategy could have avoided this degree of the crisis.

Trust is one key factor in risk communication. The public trust in politicians and authorities decreased Europe-wide based on food scares in the 1980's and the 1990's. The trust could partially be regained by the implementation of authorities for food safety. Transparency is one important instrument in risk communication. The transparency must be combined with proactive communication which considers the different factors in the risk evaluation and in the risk management including the uncertainties and how these are handled. In order that transparency should be an effective instrument of risk communication, it is not enough for authorities to be open and above board but they have to secure that the public and the interest groups can participate in the communication process.

The information strategy which is the basis for the risk communication strategy influences the trust of the population. This multi-agent simulation provides a mean to investigate different information strategies based on the trust building of the artificial consumer society. The measure for the information strategy is the recovery rate R . The aggregated trust is denoted by \hat{P}_J .

$$\hat{P}_J = \frac{\sum_{i=1}^n P_{Ji}}{n}, \text{ with } P_{Ji} \text{ as the trust value of agent } i. \quad (14)$$

The starting value is the aggregated trust value of the consumer population in the beginning \hat{P}_J^s . This is the reference value. The aggregated trust value in the end of one simulation run \hat{P}_J^e is the outcome of one simulation run. Both values will be set in relation this marks the recovery rate R .

$$R = \frac{\hat{P}_J^e}{\hat{P}_J^s} \quad (15)$$

R indicates the effectiveness parameter of the selected information strategy, this means that R depends on the shape of the information strategy (IS), the communication and updating processes of the population and the media (CUP) and the network structure (NWS):

$$R = f(IS, CUP, NWS) \quad (16)$$

The question now is 'which impact do different information strategies have on the aggregated trust respectively demand if trust is a proxy for demand?', i.e. is it possible to evaluate risk communication strategies?

Equation (16) implies that if R is a measure for the effectiveness of an information strategy then either CUP and NWS have to be fixed in order to evaluate different information strategies or IS has to be fixed in order to investigate different environment conditions for one information strategy (stochastic elements). A way to include both influences is to run different simulations and to compares these simulation runs, so that a tendency can be identified.

An example for one IS with $R = f(IS, \overline{CUP}, \overline{NWS})$ is described in the following:

Since food scares and the corresponding changes in the demand are investigated, the focus lies on information strategies which start with negative information releases regarding the food item under investigation followed by positive information releases driven by stakeholders who use the media to spread positive information and to counter the negative scenario in the beginning.

The distribution of the information releases by the centralised media can be chosen by the user of the simulation. Here the centralised media agents spread negative information over the network respectively the population in the sense of observing a product failure regarding the food item under investigation, so that each agent receives this negative information signal. In continuing time, here the iterations/days of the communications steps, the intensity of the information release decreases. It follows an exponential distribution. In a certain point in time, it is called the inversion point, the information release changes from negative to positive information, e.g. it was discovered that the food is safe or certain safety rules were implied by authorities (fast tests for BSE cognition, banning of risk material, prohibition of feeding animal meal). It also follows an exponential distribution, beginning with a high intensity and decreasing intensity in continuing time. The information release strategy can be selected and parameterised by the user and can be visualised by the simulation in an output graph (see figure 29).

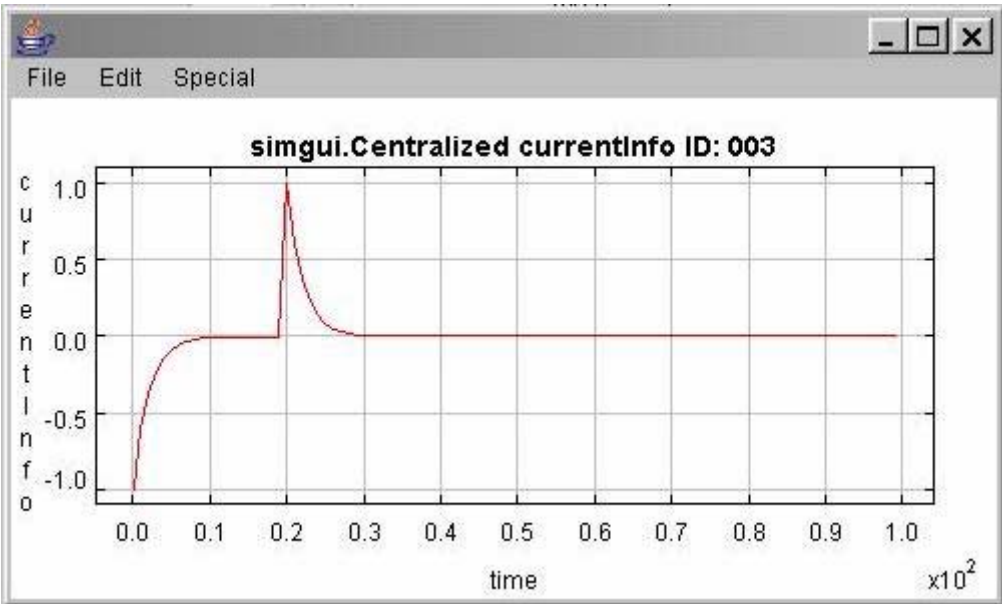


Figure 29: Information release strategy by media agent 3.

In this specific simulation run three global centralised media agents were activated. Each of them has implemented a double exponential information distribution. Figure 26 displays the shape of the information distribution of media agent with the identification number 3. This information release distribution starts with an intensity of -1, i.e. a very strong negative news

reportage regarding a food scare. The time scale is displayed on the x-axis. The x-values have to be multiplied by 10^2 to get the correct scale, e.g. $0.1 \cdot 10^2 = 10$ which means at 0.1 on the x-axis the information value (intensity) at day 10 can be derived from the y-axis. In this example at day 10 this information source respectively the centralized media agent does not longer report about this food safety issue whether negative nor positive. At day 20 (set by the user in the inversion text field) this media agent reports that the food under investigation is safe. There is a positive information release which has the same information intensity as a starting value like the negative news reportage (may it be in the television at prime time). The agents update their own information state and hence their trust value partially based on this new information but also they look around in their networks and also they receive information from the other media agents which are connected to this agent. The consumer agents are equipped with heterogeneous starting parameters. On the aggregated level the development of the average trust value of the population emerge by taking the new information releases into account on the micro level and communicating and updating accordingly. The resulting outcome of this information strategy is displayed in figure 30.

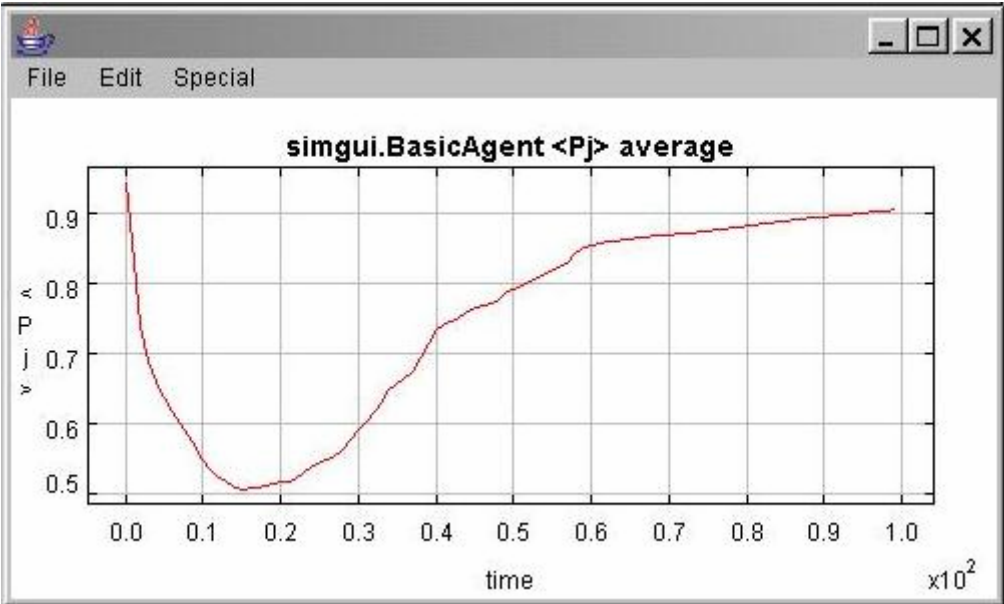


Figure 30: Development of the aggregated trust value of the consumer population after 100 days

The development of the aggregated trust value of the consumer population \hat{P}_j shows the shape of the pattern which emerges during the communication time after 100 days. It describes a sharp and immediate drop in aggregate trust and then despite positive counter information follows a slow and in this case incomplete recovery toward previous trust levels again. This pattern is also described by LIU ET AL. (1998) but for the demand in contaminated food. Trust

may serve as a proxy for demand in this case (without specifying the link between trust and demand¹²).

This double exponential distribution of information releases is only one possibility; there can be a lot of other examples. In the chapter 6 there will be described and tested some specific scenarios. The user of the multi-agent simulation can implement self created information distributions and strategies and can also test segment specific information strategies by directing specific consumer segments with information policies. Varying the inversion day, the intensity, the shape and other parameters leads to different information strategies. These information strategies have different implications for the aggregate demand. An evaluation of information strategies efforts several simulation runs under controlled conditions.

5.4 Model calibration

The model calibration is based on the results of the cooperation with partners in the Trust-Project. Assumptions and implementations were considered if they are plausible and in accordance with empirical data and observed behaviour. The requirements analysis was performed in multiple iterations and has shown that quantitative aspects and qualitative aspects of the artificial consumer agents are consistent with respect to observed real consumer behaviour. The quantitative part was done by partner 4 (University of Reading and University of Florence) in working package 4 (WP4). The psychological aspects were analysed by partner 2 (University of Trento) in working package 2 and the sociological analysis of the focus groups were performed by partner 3 (University of Gorizia and University of Wageningen) in working package 3. The results of these partners partially entered into the development and the calibration of the multi-agent simulation.

5.4.1 Qualitative aspects of focus group analysis and behaviour of consumers

The qualitative analysis of the Trust-project was based on two subsequent focus group rounds and on psychological experiments. These focus group rounds took place in the five participating EU-countries whereas the psychological experiments took place in Trento (Italy). Both the focus group analysis and the psychological experiments supported on a qualitative basis the understanding of trust and the judgment strategies of the consumers in food risk information.

Some of the major results of these investigations are presented in this sub-section. The focus group analysis showed in general the attitude of the respondents based on questions regarding food scares: “...*food consumption scares are not a major issue in consumers’ every-day life, but when a risk is introduced in the system, people react differently according to their past*

¹² See a theoretical approach by extending the ‘Theory of Planned Behaviour’, e.g. 4.5.

experience, sense of agency, information, personal situation, attitude towards economics, cultural and political environment, age."¹³ According to the results of the psychological experiments attitude is a stronger influencing parameter in decision making than trust, but taking the 'Theory of Planned Behaviour' into account trust influences the attitude so that trust seems to be crucial when focusing on demand. The information sources and the information processing play also a crucial role concerning the aggregate demand after a food scare: "...Any information campaign should be addressed to different targets, i.e. not only the mass-media should be considered, but also different channels and means of information, such as shop-keepers, butchers, etc."¹⁴ This statement supports the idea to address exclusive information policies to specific consumer segments.

Another important issue is the forgetfulness, i.e. when time continues it goes hand in hand with a gradual 'fading away' of personal concern. This is usually parallel to a decline in media coverage. The Bayesian updating itself contains an implicit forgetting. Together with the declining intensity of the media news reportage also the implicit forgetting increases. The reason is that the trust will be updated permanently based on the information and since the information in the environment of the general discussion approximates after a certain time the zero line also the trust recovers.

The feeling of 'enough is enough' is usually connected with an overload of information from unremitting a pervasive media coverage. There are empirical findings that with continuing time the consumers follow a blunting effect. In the beginning of the 1990s when the first articles about BSE were published it needed fewer articles to evoke the same anxiety for the people than ten or fifteen years later (HAGENHOFF 2003, 86).

5.4.2 Quantitative aspects of the EU-survey and the trust analysis

The EU-survey on consumer behaviour and the food supply chain was driven by partner 4 (University of Reading). It was a European wide investigation of the issues surrounding the food supply chain, especially focusing on chicken consumption. It took place in five EU-member-countries: Italy, England, The Netherlands, France and Germany. WP4 has developed a questionnaire following the 'Theory of Planned Behaviour' framework in order to analyse EU consumer's behaviour in relation to purchasing chicken. For analysing the effects of trust and risk perception the SPARTA model was developed which is an extension of the TPB. A nationally representative survey was conducted in the above mentioned countries in May 2004 on 2725 respondents as face-to-face, in-home interviews. The household was the sampling unit, and the respondent was the person responsible for the actual purchase of food.

¹³ PELLIZZONI AND GRECO presentation, Kiel 2nd interim meeting 29.11.2004.

¹⁴ *ibidem*.

Subsequently to the survey a segmentation analysis and a causal model analysis were conducted (LOBB ET AL. 2005).

The segmentation analysis of the survey data was performed in several ways: according to life-styles, demographic characteristics, and trust in sources of information. Taking into account only demographic or lifestyle variables did not lead to informative classification, moreover the interaction between these variable was limited. The most significant segmentation was related to trust in sources of information. WP4 have identified three different trust segments: ‘Non-truster’, ‘Mixed trusters’ and ‘Trusters’.

Non-trusters are characterised by the low level of trust in all sources and especially in independent ones. Mixed trusters mainly distrust food chain actors and trust independent sources while trusters trust all the sources of information, even if with different intensity, and particularly the food chain actors, while they trust less media sources (CAVICCHI ET AL. 2005, 2). Partners 4 and 6 have performed the cluster analysis with K-means method. Table 4 reports the results of the convergence’s achievement after 25 iterations.

Table 4: Segmentation on Trust variables

Segmentation on Trust variables	Cluster		
	1 Non-trusters	2 Mixed trusters	3 Trusters
Trust in media	-.38536	.23765	.06646
Trust in food chain actors	-.08513	-.94193	.67307
Trust in independent	-1.24728	.55694	.35563
Trust in alternative sources	-.16913	-.17910	.21680
Trust in vested interest	-.10538	-.32443	.27600

Source: CAVICCHI ET AL. (2005).

“Looking at table 4 it is possible to give a name to these groups. The first seems to be composed of people who distrust all the sources (all negative signs) and especially the independent ones: university scientists, national and European food authority, governments and doctors. Thus we can qualify this segment as “Non-trusters”. This cluster is composed of 507 respondents (25.9% of the valid cases). 28.6% of this group consist of people from Italy while the Netherlands are a little part of this (only 11,6%). The second segment, “Mixed trust”, is characterized by the distrust in food chain actors and trust both in independent sources and (even if slightly) in media. Mainly characterized by the presence of people from Germany and Netherlands (27.2% and 26%) this group includes the 29.5% of the population. Finally the last segment seems to be characterized by a general trust in all food sources of information and especially in food chain actors: people belonging to this segment can be qualified as “Trusters”. The group of “Trusters” is well balanced: every country influences for around

20% and overall considered it is the most numerous segment (873 cases, 44.6% of the valid cases).” (CAVICCHI ET AL. 2005, 14).

The segmentation analysis was performed for different countries so that a cross-country comparison was possible. The distribution of the segments within the countries displays table 5.

Table 5: Segment’s composition by country

Segment’s composition by country		Cluster (Trust variables EU)			Total
		1 Non-trusters	2 Mixed-trusters	3 Trusters	
UK	Count	111	66	168	345
	% within Country	32.2%	19.1%	48.7%	100.0%
	% within Cluster (Trust variables EU)	21.9%	11.4%	19.2%	17.6%
	% of Total	5.7%	3.4%	8.6%	17.6%
Italy	Count	145	132	191	468
	% within Country	31.0%	28.2%	40.8%	100.0%
	% within Cluster (Trust variables EU)	28.6%	22.8%	21.9%	23.9%
	% of Total	7.4%	6.7%	9.8%	23.9%
Germany	Count	94	157	180	431
	% within Country	21.8%	36.4%	41.8%	100.0%
	% within Cluster (Trust variables EU)	18.5%	27.2%	20.6%	22.0%
	% of Total	4.8%	8.0%	9.2%	22.0%
Netherlands	Count	59	150	163	372
	% within Country	15.9%	40.3%	43.8%	100.0%
	% within Cluster (Trust variables EU)	11.6%	26.0%	18.7%	19.0%
	% of Total	3.0%	7.7%	8.3%	19.0%
France	Count	98	73	171	342
	% within Country	28.7%	21.3%	50.0%	100.0%
	% within Cluster (Trust variables EU)	19.3%	12.6%	19.6%	17.5%
	% of Total	5.0%	3.7%	8.7%	17.5%
Total	Count	507	578	873	1958
	% within Country	25.9%	29.5%	44.6%	100.0%
	% within Cluster (Trust variables EU)	100.0%	100.0%	100.0%	100.0%
	% of Total	25.9%	29.5%	44.6%	100.0%

Source: CAVICCHI ET AL. (2005).

The multi-agent simulation has implemented these distributions. This offers the possibility to imply segment specific information policies in different countries which provides a tool to in-

investigate different information strategies within different countries and to perform a cross-country comparison. Besides this segmentation analysis also the trust in different kinds of information sources was conducted by WP4. These values are the basis for the network weights which are implemented in the multi-agent simulation. The distribution of the weights for the different information sources by the different consumer segments are displayed in annex A1 in figure A1 and A2.

5.5 Model validation

The validation of a model implies that the behaviour of the model must be conforming to the behaviour of the target. If a pattern is observed in reality then the simulation must reproduce this pattern (see 3.4). The model validation of this multi-agent simulation will be performed based on two real world examples of food scares where data are available. One is the BSE-crisis in Germany and the other food safety incident is the Heptachlor-crisis in Hawaii.

5.5.1 BSE-crisis

One of the most influencing cases of a food scare with respect to demand was the BSE-crisis. The idea behind the validation of this kind of multi-agent simulation is that there must have been a food scare, the media must have reported about this food safety incident (information distributions and diffusions) and the demand must have changed significantly, i.e. the consumers have realised this crisis. HAGENHOFF (2003, 269) has analysed how the impact of the media news reportage concerning BSE in the print media has influenced the opinion of the population in Germany. She counted the number of articles regarding BSE for a representative number of German newspapers for the time of 1990 until 2001. With these numbers it is possible to display the distribution of articles (information releases) over this period. This distribution will be used to test this real information release distribution by the centralised media agents and to see how the artificial consumer population reacts in their trust behaviour. In this case trust serves as a proxy for demand.

The output of the multi-agent simulation must be tested in order to validate the simulation. This means that the simulation model must reproduce the pattern which was observed in reality. The development of demand of beef in Germany for the same period serves as the pattern which should be reproduced by the multi-agent simulation (see 4.6.4 for the distribution of articles, the information release distribution and also the development of the demand of beef).

In November 2000 the first case of a mad cow disease was discovered in Germany. The media reportage in the print media as well as in all the other media was immense. The shock for the population to face such a disease with its unknown incubation time and the result for the human being was sustainable. The minister of agriculture had to give up his position and also

the ministry was changed dramatically from the agricultural focus to the consumer and the safety of food focus.

The demand of beef in Germany over the time from 1990 until 2002 was decreasing. The trend to consume less beef can be explained by the demographic change. There are an increasing number of single households who are consuming more convenience food which does not contain beef. But there is one extraordinary peak down in the year 2000 which left the trend and comes back in the end of 2001. Right in that time the first mad cow was discovered in Germany. Based on the information released by the centralised media the demand in beef decreased rapidly after the food scare and recovered more slowly into the direction of the former level when time continued. This pattern in the consumption must be reproduced by the simulation given the information release distribution by the print media in Germany. The information release starts with negative information at the time of November 2000. In the following months the information about the mad cow disease increased rapidly until a peak was reached and subsequently decreased again in time.

Since there was no positive information during the first two months after the first discovered BSE-case in Germany but only a decline in the number of articles as time continued it is reasonable to choose an exponential distribution with only negative information values decreasing in time (see figure 31).

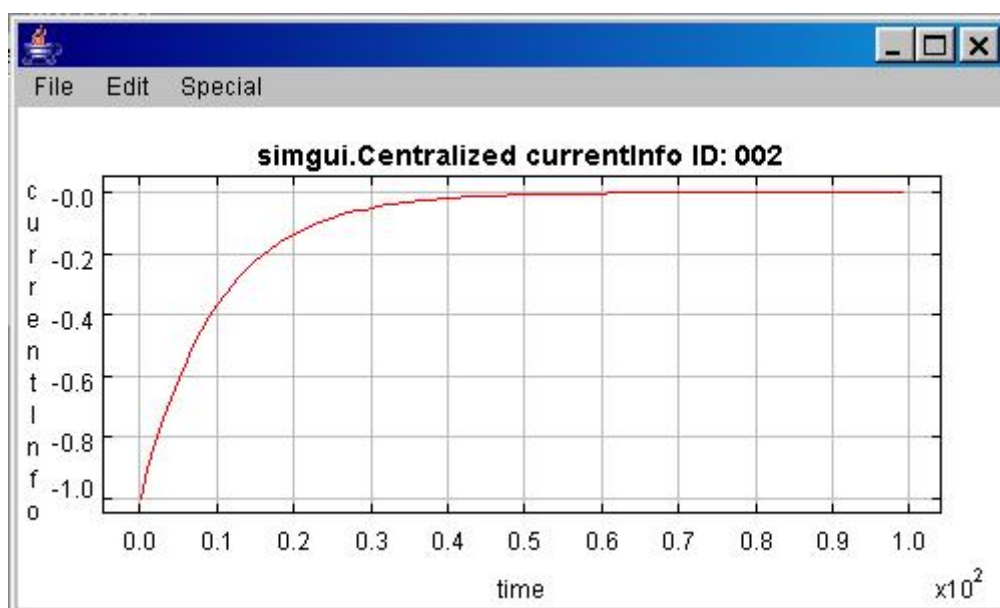


Figure 31: Negative news release simulation for BSE reportage (time: 100 days)

Figure 31 displays such a news release scenario: there are negative information releases each day. When time continues the intensity of the information decreases (reasons may be less interest or other more interesting news or information overload by the recipient of the information).

The output, i.e. the aggregated P_j trust value, under this information scenario is displayed in figure 32.

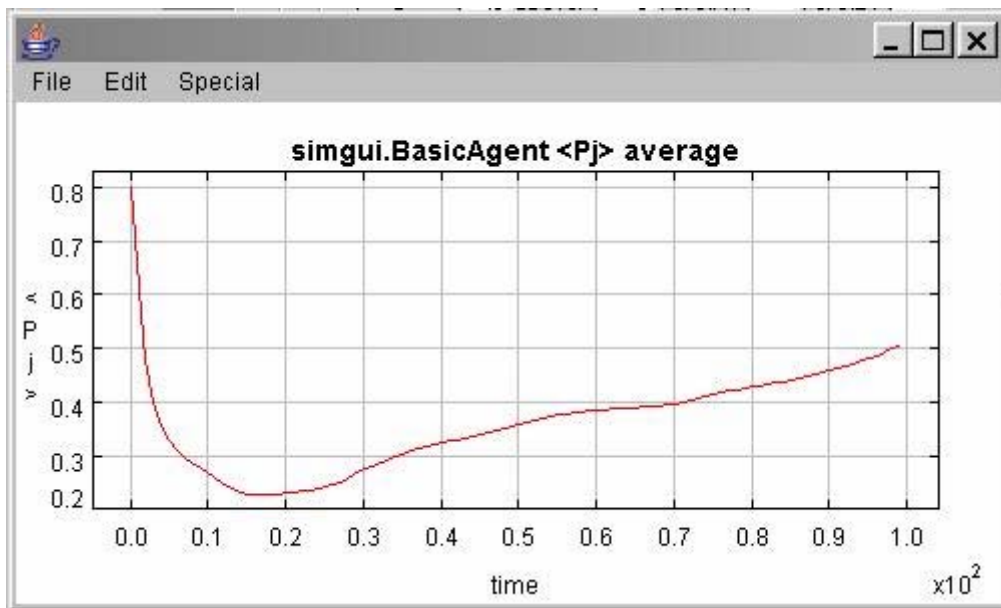


Figure 32: Average trust value – rapid decline in trust and slower recovery

In this case trust is assumed as a proxy for the demand thus the pattern looks like the pattern of demand of beef in Germany in that time and under this information environment. The recovery of the trust respectively the demand seems to be consistent with the real data identified by BRUHN (2001) who stated that after 7 month the discovery of the first mad cow in Germany the trust was nearly at the level from before this event. 7 month are approximately 210 days – figure 29 shows ~50 % after 100 days are recovered, if this development will be interpolated then the starting value will nearly be reached after 7 month.

The pattern in figure 29 is only one example of one simulation run but the pattern was always reproduced in the sensitivity analysis in a number of simulation runs (see annex A4).

The development of the trust value for each agent depends on the one hand side on the updating algorithm (the Bayesian updating) but on the other hand on various other factors. The agents are heterogeneous in their parameter equipment and in their network relations. They update randomly and not every day and this is one reason why the development of the individual trust values is different. No agent is fully informed, i.e. each agent is rationally bounded regarding the updating of trust and the decision making. This issue is the interesting point in this methodology of using a multi agent simulation. Individually the behaviour of the agents is not always conforming but on the aggregate level, i.e. the macro level, the pattern which evolves seems reasonable.

Some reasons for the different behaviours of the agents are discovered in the focus group analysis. DE MARCHI ET AL. (2005), 22 and 23:

“The effects of food scares on the participants’ behaviour can be summarised as follows:

- *Temporary change of behaviour: This is the prevailing and most immediate reaction and it ranges from temporary interruption to reduction of consumption of ‘hazardous’ foods. This entails shift to different types of food, brands, etc.*
- *Durable change of behaviour: This is a rather frequent response. It may be the consolidation of an already present consumption orientation (e.g. a low use of meat) or a change in shopping preferences (e.g. turning from supermarkets to small shops). Sometimes changes in the family composition, such as the birth of a child, plays a role in fostering a behavioural change, more and beyond food scares. Once taken up, new habits are considered generally healthier than the previous ones, beyond the specific protective function they had been originally adopted for.*
- *No change of behaviour: This reaction characterises a minority of participants, who judge their usual behaviours sufficiently self-protective already or resolve that it is pointless to change habits. The latter are convinced that once the warning is issued, it is already too late to adopt effective ‘preventive’ measures. They also refer to the pervasiveness of food safety problems, while a few declare their ‘antagonism’ towards official warnings and hammering media coverage. This results in doing the opposite of what seems advisable (e.g. consuming more meat during the BSE scare).*

Reasons for resuming original behaviours are:

- *Tedium with the issue, feeling that ‘enough is enough’. This is usually connected with an overload of information from unremitting a pervasive media coverage.*
- *Forgetfulness, gradual ‘fading away’ of personal concern. This is usually parallel to a decline in media coverage.*
- *Practicality, i.e. difficulties in persisting with restrictions in diet.*
- *Reassurance from the media, friends, shopkeepers. Few participants mention this motive, or judge it as the least relevant.”*

These qualitative issues discovered by the focus group analysis may provide reasons for the emergence of the demand pattern which was discovered in the demand after a food scare like the BSE-crisis. It also may explain the implicit forces which leads to these outcomes produced by the simulation although partially not explicitly modelled.

5.5.2 Heptachlor crisis in Hawaii

Another example of food scares connected with negative media reportage and changes in the (buying) behaviour of the consumers is the heptachlor crisis in Hawaii in the beginning of the 1980s. Heptachlor was used by pineapple producers on the island of Oahu. This pesticide is highly toxic carcinogen. The pineapple producers have applied heptachlor to kill ants upon which the mealybug depends. The mealybug exudes a granular white secretion which has a

mealy appearance. It is considered pest as it feeds on plant juices of greenhouse plants, house plants and subtropical trees. In the case of the pineapples the mealybug is responsible for the damage of the plants by secreting a substance that withers roots. The dairy cows in Oahu were fed with pineapple leaves and stems. This fodder was a cheap substitute for cattle feed which was imported from the mainland. But there were residues of heptachlor in the leaves and stems of the pineapples and consequently the pesticide was transferred to humans who have consumed the local dairy products.

Hawaii's State Health department has announced in March 1982 that local dairy products contained 15 times the official acceptable adult level of heptachlor pesticide (LIU ET AL. 1998, 693). The problem also was that no fluid milk was imported until that time so that the entire population of Oahu was exposed to the heptachlor-contaminated milk (FOSTER AND JUST 1984, 24). Especially children have faced a higher risk since they have consumed more milk particularly in schools and even mother's milk was partially contaminated by heptachlor.

The first news regarding the contamination crisis were published on March 18 in 1982 when the state's Health Department declare that they want to decrease the pesticide levels in milk. From that moment on the media especially the press was increasingly engaged in this topic. Due to the fact that the entire population of Oahu was affected by the contaminated milk the media exploited this food scare by releasing a number of articles around this food safety incident. And the consumers by nature were interested in getting new information. The news reportage went on for several months after this contamination became public. In doing so, the press has offered the consumers' sometimes bewildering information on the safety of available milk supplies especially in March and April (FOSTER AND JUST 1984, 25). The daily milk consumption dropped from 32,259 gallons for February to 5,405 gallons for April (see table 6).

Table 6: Fluid consumption of fresh milk in Hawaii (January 1981 – August 1983)

Month	1981	1982	1983
	gallons per day		
January	34,556	31,821	28,668
February	34,947	32,259	28,905
March	32,127	16,402	31,681
April	35,520	5,405	31,299
May	34,858	15,221	31,571
June	30,590	20,611	26,972
July	31,304	22,215	27,267
August	30,943	22,873	28,345
September	34,434	24,843	-
October	33,527	23,131	-
November	31,729	23,296	-
December	31,002	23,852	-

Source: FOSTER AND JUST (1984), 28.

The pattern of the demand during the phase of this food safety incident looks similar like the pattern of demand during the BSE-crisis (see figure 33).

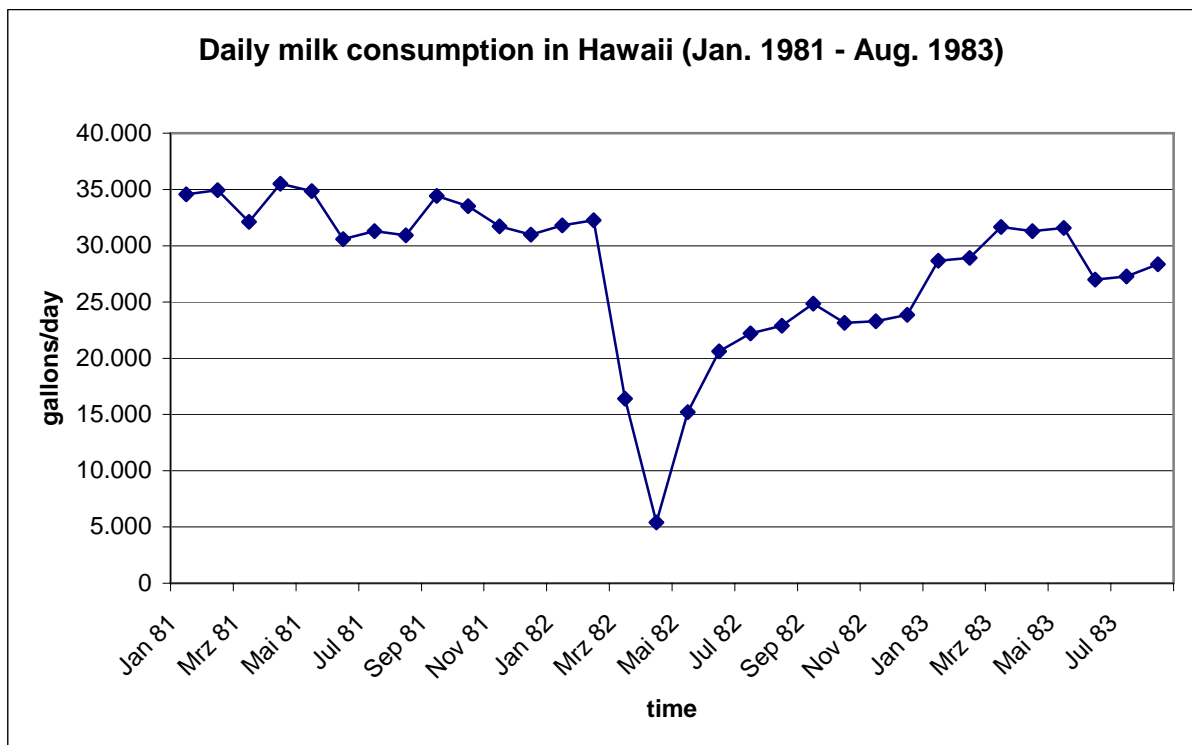


Figure 33: Daily milk consumption in Hawaii (Data from FOSTER AND JUST 1984, 28).

Again this pattern is characterised by a sharp and immediate drop in aggregate demand followed by a slow recovery toward the previous consumption level again. The media news reportage has obviously a significant impact on this development. FOSTER AND JUST (1984) have reported that the number of headlines concerning the milk contamination in Honolulu's two major newspapers have declined from approximately 20 per week to approximately 4 per week by the beginning of May. After the negative peak in May 1982 there was little or no information found in newspapers concerning heptachlor contaminated milk in Hawaii. Instead they were reporting that quality restrictions were tightened and that the milk is safe. This is similar to the news reportage in Germany where after the disclosure of the BSE-infected cows the responsible policy makers have implemented quality assuring arrangements and where these efforts were reported by the media. However the consumers in Hawaii also like the consumers in Germany after the BSE-crisis remained wary. In June and July the consumption slowly returned to the beginning level. The uncertainty of the consumers led to the import of fluid milk of California as a substitute for the homelike milk. The duration of the recovery is round about 100 days (no full recovery). Even positive information does not seem to have a multiplier effect towards a faster recovery. The simulation also replicates this pattern of demand under the condition that trust serves as proxy for the demand (see figures 25 and 26). One important aspect which was already highlighted by FOSTER AND JUST (1984) was information policy of the state authorities. During the heptachlor crisis in Hawaii there was an obvious hesitance of the state authorities to disclose information before the public became aware of the possibility of contamination. In this case the Department of Health was criticised by the state's Senate Committee for the delaying the release of information to the consumers. Hence the information strategy seems to be important to regain consumers' trust.

6. Information scenarios and risk communication strategies

In this chapter different information and risk communication scenarios will be tested in order to evaluate and identify differences between risk communication scenarios and to evaluate them. Here the effects of specific information and monitoring approaches directed at creating trust in the food chain are investigated. In order to avoid an overly detailed set of simulations the focus lies on the most relevant elements of such approaches.

The multi-agent simulation consists of n consumer agents, m media agents and a number of auxiliary objects. The parameter space of the multi-agent simulation consists of x initial parameters and y structural parameters. The parameter exploration is directed to

1. Initial parameters
 - i. parameter distributions
 - ii. parameter distribution moments
2. Structural parameters

- i. social networks
 - a) link distribution
 - b) link distribution moments
- ii. network weights

The analysis of the experiments:

- for every scenario running multiple simulations with different random number generator seed
- for every scenario computing means and recovery rates.
- scenarios comparison: time series plots, distributions and others: comparing the effects of the parameter changes¹⁵.

The parameter space in its full size is not testable due to combinatorial reasons: more than 150 different parameters. For this reason only explicit scenarios can be tested by applying multiple simulation runs.

6.1 General sensitivity analysis

The general sensitivity analysis is directed to test in advance if it makes sense at all to imply countermeasures, i.e. spreading positive information, by public authorities and under the conditions of this multi-agent simulation compared to the situation of the natural fading away of such crisis.

Risk communication strategies will be formulated in information distribution scenarios which are to be tested. Depending on the form of the risk communication strategy, i.e. the duration and the shape of strategies, the recovery of the trust, respectively the demand can be the measure for the effectiveness of the risk communication strategy.

In the general sensitivity analysis two information distribution scenarios are tested: natural fading away where no risk communication is implemented and positive counter information where a risk communication strategy is implemented. The consumer population can be divided into three segments: ‘Trusters’, ‘Mixed-trusters’ and ‘Non-trusters’. These segments vary from country to country and the empirical data are implemented in the multi-agent simulation. But for the first instance in the general sensitivity analysis there is no country scenario selected instead the information scenarios are tested according to different durations of the simulations runs (10, 20, 30, 50 and 100 days).

The sensitivity analysis starts from a general point of view so that the results can be seen as reliable afterwards some special scenarios will be tested. The impact of positive and negative information should be analysed first, i.e. what does the simulation produce when only negative information is available (but whose intensity decreases in time) and second what impact has positive information on the trust building in the time after negative information was re-

¹⁵ This can just be done for a small number of scenarios.

leased by the media. The comparison of these aspects gives insights into the impact of the general mechanisms which influence the trust building. A general sensitivity analysis can identify the boundaries and the threshold parameter values which are important to improve risk communication strategies.

6.1.1 Natural fading away – no risk communication strategy

In this sub-section there will analysed the case when only negative information are released by the media. It is to mention that the intensity of the negative information decreases over time. A practical and empirical reason for this distribution is the fact that a theme loses its interest for the media and for the population when time continues. Another reason is that other topics become more interesting for the public and for the media, e.g. a shock like the 9/11-incident. Hence the shape of the distribution is roughly an exponential distribution beginning with very intense negative information. The initial parameters of this simulation scenario are displayed in the following table 7:

Table 7: Parameter settings of the natural fading away scenario.

<i>Parameters</i>	<i>Initial parameters</i>	<i>Structural parameters</i>
<i>Iteration/Duration</i>	100 days	-
$P(G A)$	Segment specific	-
$P(G B)$	Segment specific	-
P_j	100 % trust	-
<i>Rnd P (G A)</i>	-	-
<i>Rnd P_j</i>	-	-
<i>Decision fct.</i>	-	Bayes selected
$P_j \text{ Segm } i (i=1, \dots, n)$	100 %	-
$SDev(P_j S_i) (i=1, \dots, n)$	0	-
<i>Supplier types (j=1, ..., 6)</i>	-	-
<i>Forgetting parameter</i>	0 no explicit forgetting	-
<i>Info diff</i>	-	selected
<i>Mean</i>	-	3 links to other agents than the family
<i>Variance</i>	-	1
<i>Distrib</i>	-	LogNormal
<i>Pop. Size</i>	100 consumer agents	-
<i>Off. gen1</i>	-	3
<i>Off. gen2</i>	-	3
<i>Netw. weight Media 3,4,5</i>	0.5	-
<i>Sdev.netw.weight Media 3,4,5</i>	0.1	-
<i>Negative Info Media 3,4,5</i>	-1	-
<i>Positive Info Media 3,4,5</i>	1	-
<i>Distrib_k (k=1, ..., l) Media 3,4,5</i>	-	Exponential
<i>Inversion Media 3,4,5</i>	Day 30	-
<i>Negative slope Media 3,4,5</i>	-0.5	-
<i>Positive slope Media 3,4,5</i>	1	-
<i>Segm1</i>	35 %, 3-segment case	-
<i>Segm2</i>	35 %, 3-segment case	-
<i>Segm3</i>	30 %, 3-segment case	-

This simulation scenario was performed for different durations: from 10 to 100 days. The reason is that the dynamics, respectively the development of the aggregated trust values of the artificial consumer population should be displayed and reconstructed. Each of these simulation runs was run 50 times so that there is some reliability that the multi-agent simulation produces comparable and repeatable results. The mean recovery rate of these 50 simulation runs for each duration time is displayed in the table 8:

Table 8: Recovery rates of the natural fading away scenario.

Duration		Starting P_J (all)	End P_J (all)	End P_J Segm3	End P_J Segm2	End P_J Segm1
10	Recovery rate:	0.99	0.32	0.77	0.15	0.01
20	Recovery rate:	0.99	0.37	0.80	0.23	0.03
30	Recovery rate:	0.99	0.39	0.78	0.30	0.05
50	Recovery rate:	0.99	0.48	0.80	0.47	0.12
100	Recovery rate:	0.99	0.57	0.86	0.63	0.18

Each consumer agent of the artificial consumer population starts with a P_J -value of 0.99, i.e. nearly full trust¹⁶. After 10 days the overall trust went down to 0.33, the mean P_J -value for segment 3 ‘Trusters’ is 0.78, for the ‘Mixed-trusters’ segment 0.15 and for the ‘Non-trusters’ segment 0.01. The picture looks different after 100 days: the overall trust recovered to 0.58, the mean P_J -value for the Trusters is 0.87, for the Mixed-trusters 0.64 and for the non-trusters 0.18, i.e. even this segment recovers a little bit. The overall trust development between day 10 and day 100 follows a slow and steady recovery. There is a conspicuous effect in the development of the trust values of the different segments. The ‘Trusters’ segment does not lose too much trust but also does not recover that fast like the other segments, i.e. they remain on a high trust level. In comparison the ‘Mixed-trusters’ lose significantly trust in the suppliers but recover also very fast towards a moderate level within 100 days. The ‘Non-trusters’ lose as expected nearly all the trust in the beginning of the news reportage on the food safety incident. But even this segment starts to recover the trust in the suppliers. Technically this depends on the connection to more trusting agents which influence the opinion formation even of these ‘Non-trusters’.

The heterogeneity of the agents and the network structure leads in each simulation run to slight changes in the results but the standard deviation seems to be in an acceptable range, so that the mean result is reliable (see appendix A.4).

6.1.2 Positive counter information – with risk communication strategy

The previous information distribution only considered negative information releases. But even if only negative information will be released the overall trust recovered after the negative peak approximately to the starting conditions. This result however can only be obtained if the negative information release distribution follows an exponential distribution with very in-

¹⁶ 0.99 has to be chosen since the Bayes’ rule won’t work with 1, the result would always be 1.

tense negative information in the beginning. Tests with permanently negative information have led the agents to lose the trust in the suppliers completely; they have produced a P_J – value of 0.

In this section there will be analysed how and if positive information releases influence the recovery of the trust, since this is the most interesting point for implementing effective risk communication strategies especially with respect to a cost-benefit-ratio. Positive information can be for example the introduction of a quick test to check whether cows are infected by BSE or news like ‘it is forbidden to process risky parts of the cow’ or ‘the prohibition of feeding meat and bone meal’ and especially advertisement campaigns concerning the reliability and the quality of this food item under investigation.

The shape of the information release distribution is similar to a double exponential distribution where the first part is a negative exponential distribution with very intense negative information in the beginning which approximates the zero line and changes its sign after a certain inversion day in this case after 30 days. Then positive information will be released which also follows an exponential distribution starting with intense positive information. Each testing scenario is also performed a 50 times. The initial parameters of this simulation are displayed in the following table 9:

Table 9: Parameter settings of the positive counter information scenario.

<i>Parameters</i>	<i>Initial parameters</i>	<i>Structural parameters</i>
<i>Iteration/Duration</i>	100 days	-
$P(G A)$	Segment specific	-
$P(G B)$	Segment specific	-
P_j	100 % trust	-
$Rnd P(G A)$	-	-
$Rnd P_j$	-	-
<i>Decision fct.</i>	-	Bayes selected
$P_j \text{ Segm } i (i=1, \dots, n)$	100 %	-
$SDev(P_j S_i) (i=1, \dots, n)$	0	-
<i>Supplier types (j=1, ..., 6)</i>	-	-
<i>Forgetting parameter</i>	0 no explicit forgetting	-
<i>Info diff</i>	-	selected
<i>Mean</i>	-	3 links to other agents than the family
<i>Variance</i>	-	1
<i>Distrib</i>	-	LogNormal
<i>Pop. Size</i>	100 consumer agents	-
<i>Off. gen1</i>	-	3
<i>Off. gen2</i>	-	3
Netw. weight Media 3,4,5	0.5	-
Sdev.netw.weight Media 3,4,5	0.1	-
Negative Info Media 3,4,5	-1	-
Positive Info Media 3,4,5	1	-
Distrib_k (k=1, ..., l) Media 3,4,5	-	Double exp.
Inversion Media 3,4,5	Day 30	-
Negative slope Media 3,4,5	-5	-
Positive slope Media 3,4,5	1	-
<i>Segm1</i>	35 %, 3-segment case	-
<i>Segm2</i>	35 %, 3-segment case	-
<i>Segm3</i>	30 %, 3-segment case	-

This simulation scenario was also performed for different durations: from 10 to 100 days. Each of these simulation runs was also run 50 times so that a comparison between the two information scenarios can be made. The mean recovery rate of these 50 simulation runs for each duration time is displayed in table 10:

Table 10: Recovery rates of the positive counter information scenario.

Duration		Starting P_J (all)	End P_J (all)	End P_J Segm3	End P_J Segm2	End P_J Segm1
10	Recovery rate:	0.99	0.33	0.78	0.15	0.01
20	Recovery rate:	0.99	0.35	0.78	0.21	0.03
30	Recovery rate:	0.99	0.40	0.79	0.30	0.06
50	Recovery rate:	0.99	0.49	0.82	0.47	0.12
100	Recovery rate:	0.99	0.63	1	0.66	0.17

Also here each agent of the artificial consumer population is equipped with a P_J -value of 0.99. After 10 days the overall trust decreased to 0.33, the mean P_J -value for the ‘Trusters’ segment is 0.79, for the ‘Mixed-trusters’ segment 0.16 and for the ‘Non-trusters’ 0.01 which looks quite similar to the natural fading away scenario after this duration. This is reasonable since there is no positive counter information at this time. The counter information respectively the inversion starts at day 30, from this day on the artificial consumer population receives positive information from the centralised media agents and they communicate this information with their friends and relatives. Hence there should be a positive influence on the aggregate trust building of the entire artificial population.

After 100 days the overall trust recovered to 0.64, the mean P_J -value for the ‘Trusters’ is 1, i.e. the trust in this segment is fully recovered. The ‘Mixed-trusters’ reach 0.67 and the ‘Non-trusters’ 0.18. Compared to the natural fading away scenario the positive counter information scenario leads to a higher overall trust value. In the aggregated level the trust respectively the P_J -value as a measure of the effectiveness of an information strategy indicates that positive counter information has a positive influence on the development of the aggregated trust of the population. Especially the ‘Trusters’ segment seems to be influenced positively by the positive counter information. In reality this might be explained by the general attitude towards trust in information sources, i.e. the ‘Trusters’ are easier to influence.

Positive information seems to support the recovery in time, i.e. it leads to a faster recovery than without positive information, but the differences are not too high. Furthermore there is little said about different random conditions regarding the network and the parameter constellations on the single consumer agents. The following sub-section addresses different information scenarios and tests in a deeper way the parameter space.

6.2 Scenario testing

The testing of different information strategies and their impact on the development of trust, respectively demand is in the focus of this section. Referring to the size of the parameter space and the discussion about deterministic and stochastic networks and their effects on the outcomes, however, the testing will be limited to three different approaches which will be discussed in the following three sub-sections. Different hypothesis will be investigated and compared with the results of the multi-agent simulation. The hypotheses are listed in the following and the comparison with the simulation results will be done within the following sub-sections:

- H1: Forgetting processes or overlaying processes of other news topics lead to a recovery of the trust toward the level before the disclosure of the food scare (HINRICHS 2004, 88; ENGEL ET AL. 1995, 435).
- H2: Positive counter information has a positive influence on the recovery of the aggregate trust (ROMANO ET AL. 2005).
- H3: The type of media has an influence on the development of the aggregate trust (HAGENHOFF 2003, 225).
- H4: The country has an impact on the risk perception of the people, at least in case of beef (PENNINGS ET AL. 2002).
- H5: The introduction of quality assurance systems and the communication of establishing and controlling these systems can increase the aggregate trust (implemented by permanent positive counter information) (EN ISO 9000:2000, 3.2.11¹⁷).
- H6: Opinion leaders have an influence on the public opinion formation (LAZARSELD ET AL. 1948; BONFADELLI 1999, 136).
- H7: The structure of the network influences the diffusion and the effects of information (JANSSEN AND JAGER 2003).

In 6.2.1 the first approach is directed to a *ceteris paribus* comparison of different information strategies where the networks are set up randomly but once they are set up several simulation runs with different information strategies under the same starting conditions are performed. This gives insights about the differences of the different information strategies with respect to the aggregated outcome. In 6.2.2 the second approach is directed to investigate different random conditions regarding the network set up and the testing of only one information scenario. This approach is directed to explore the differences of different network compositions with respect to the aggregated outcome. Both approaches have one *ceteris paribus* component, otherwise the effects are not decomposable since they influence each other due to the interaction and random components on both sides. In 6.2.3 the third approach is directed to test network effects especially the role of opinion leaders.

¹⁷ According to EN ISO 9000:2000, 3.2.11 quality assurance is defined as the part of quality management which is directed to fulfil the requirements of quality by creating trust.

6.2.1 Scenario 1: Fixed random conditions and different information scenarios

In this sub-section six different information scenarios will be tested regarding the development of the aggregated trust value; H1-H5 will be compared with the results of the multi-agent simulation.

The network set up follows fixed random conditions, i.e. randomly the initial parameters will be chosen and the networks will be set on the basis of these random values. Then the different information scenarios will be tested. Each scenario will be tested 50 times and afterwards the mean of these simulation runs will be computed. This mean recovery rate will subsequently be compared with the mean recovery rates of the other information scenarios.

The information scenarios have some common core components respectively starting conditions:

- Duration period: 50 days,
- Population size: 100 consumer agents,
- Offspring of the first and second generation: 3 and 3.
- Three global centralised information sources: A. Television News, B. Newspapers, C. Internet.
- Country: United Kingdom.

A comparison between the different information scenarios will be performed. The differences between these information scenarios and their respective outcomes are based on the network weights, i.e. the different trust values for the different information sources (see figure A1 in the annex), and the equipment of the different consumer segments (see table 5).

1. Natural fading away scenario (H1)

The natural fading away scenario is similar to the above described natural fading away scenario but in this case it is implemented for UK. In this information scenario no risk communication is implemented. The media only reports negatively for a while about the safety of the food item under observation. Forgetting processes or overlaying processes will be investigated.

The three different global centralised information sources implement each an exponential distribution with the respective weight of these information sources coming from the EU-survey analysis. In this information scenario there is not positive counter information for the consumer agents of the artificial consumer society available. The next three scenarios implement such positive counter information distributions: one for TV, one for newspaper and one for the Internet. Again in these information scenarios there are the three above mentioned global centralised information sources. In each of the three following information scenarios, two of these global centralised information sources implement an exponential distribution like a fading away scenario while one information source will be used to implement a positive counter

balancing information distribution. This last named distribution is in principle a double exponential distribution which will be applied for three different media types in order to perform a comparison.

2. Single source counter balancing information (H2 and H3): TV news, Newspaper, Internet

The duration for these information scenarios remains 50 days and the inversion day for the positive counter balancing distribution is after 30 days. In these information scenarios the impact of positive counter information will be tested (H2). They follow a double exponential distribution. This information distribution will be implemented for the three above mentioned media types in order to investigate the effects on the development of the aggregate trust (H3).

3. Budget allocation scenarios (H3 and H5): TV ads, Newspaper

In these two information scenarios advertisement campaigns will be analysed regarding their impact on the aggregated trust of the artificial consumer population. One advertisement campaign will be implemented for TV ads and the other one for Newspapers. The advertisement campaign is defined as communication about the implementation of quality assurance systems to the public.

The duration of these two information scenarios is also 50 days and again two global centralised information sources will implement an exponential distribution while the remaining third global centralised information source will apply a user defined distribution of permanent constant positive information values. The shape of the distribution of positive information values is a linear straight line which starts one day after the disclosure of the food safety incident.

The TV ad campaign is an advertisement passage which is repeated until the duration of the simulation ends. The intensity of the TV ad campaign is set to 1 (this is an intense positive information value). Contrary to the previous testing which referred to TV news coefficients for the weight of that media type here the media coefficients refer to TV advertisement.

The intensity of the newspaper advertisement campaign is proportionally reduced with respect to the TV advertisement campaign to account for the different number of people reached through this media.

Table 11 displays the outcomes of the simulation runs for the different information scenarios for UK (H4).

Table 11: Recovery rates of the different information scenario for UK.

Duration		Starting P_j (all)	End P_j (all)	End P_j Segm3	End P_j Segm2	End P_j Segm1
United Kingdom:						
50 (natural fading away)	Recovery rate:	0.99	0.47	0.74	0.39	0.12
50 (single source counter balancing information: TV news)	Recovery rate:	0.99	0.49	0.74	0.43	0.14
50 (single source counter balancing information: Newspaper)	Recovery rate:	0.99	0.48	0.73	0.42	0.13
50 (single source counter balancing information: Internet)	Recovery rate:	0.99	0.48	0.73	0.43	0.13
50 (budget allocation scenario: TV ads)	Recovery rate:	0.99	0.65	1	0.62	0.23
50 (budget allocation scenario: Newspaper)	Recovery rate:	0.99	0.65	1	0.62	0.22

These six information scenarios were performed in a comparable simulation environment. This environment was set up once randomly and these conditions were maintained for the comparison of these information scenarios. The first important aspect to mention is that even when the environment is fixed, the outcomes of the single simulation runs vary noticeable. The reasons for these variations are some random conditions with respect to the heterogeneity of the agents and the network conditions. Nevertheless there can be drawn some implications of the simulation runs concerning the different information scenarios and their impact on the development of the aggregated trust and also a comparison to hypotheses H1-H5 can be made:

H1 can be confirmed according to the results of the multi-agent simulation:

The natural fading away scenario does not take care of positive information. In this scenario there is only negative information regarding the safety of the food item respectively the supplier of this item reported. But the intensity of the negative information releases decrease in continuing time so that the trust even recovers when no positive information is released. This means that forgetting processes or overlaying of other news are influencing the recovery of the aggregate trust of the artificial consumer population.

The picture is different if permanently negative information with constant intensity is released. In this case the aggregated trust value decreased to zero and never recovers.

H2 can also be confirmed by the results of the multi-agent simulation but with little effects and H3 can not be confirmed by the results of the multi-agent simulation:

The influence of positive counter information which implicitly can serve as a proxy for a risk communication strategy is case dependent. The three scenarios of single source counter balancing information have little impact on the recovery of the aggregated trust of the artificial consumer population – none of the three different media types, i.e. the type of media has no influence on the development of the aggregate trust according to the results of the multi-agent simulation and also with respect to the EU-survey analysis where the respondents were asked for the trust in different media sources (see figure A1 in the Annex). One likely reason for the little impact of positive information is based on the shape of the distribution (H2). As already mentioned this distribution follows a double exponential distribution. The negative part has more influence than the positive part; this is in accordance with the literature (e.g. KAHNEMAN AND TVERSKY 1979). And this might be the reason why the positive information released by this media agent is not sufficient enough to generate a higher recovery rate of the aggregated trust – independent on the type of media source. This looks different for permanent positive counter information (H5).

H5 can be confirmed by the results of the multi-agent simulation:

In contrast to the single source counter balancing information releases the budget allocation scenarios seem to have an influence on an increased recovery of the aggregated trust value. In both cases, the TV ads and the newspaper ads, there is a significant higher mean recovery rate compared to the other scenarios. The effect is likely to trace back the shape of the information release distribution and hence to the information strategy. This one global centralised information source is one day after the disclosure of the food safety incident permanently counter-acting to negative information releases of the other two global centralised information sources. The intensity of the information releases is relatively high so that it has a high impact in the information processing of the single agents and the networks as a whole which leads to a faster recovery of the aggregate trust than only little or no counter arrangements¹⁸.

H4 is directed to risk perception; however the multi-agent is directed to investigate trust. It is likely that there is a relation between risk perception and trust but there can not be made conclusions with respect to H4. The results of the multi-agent simulation show that there is nearly no country difference in the trust recovery:

This scenario testing was also made for Italy. It was performed to enable a cross-country comparison under the same initial conditions and the same environment. In doing so it disclosed a system immanent bias: the different trust segments influence each other, i.e. the

¹⁸ The evaluation of the costs and benefits of such a campaign in realistic terms is difficult to accomplish. An approach to capture this aspect was done by STEFANI ET AL. (2005).

‘Trusters’ in the UK which were in a greater segment than the ‘Trusters’ in Italy decreased relatively to the Italian ‘Trusters’ segment, the same happened to both ‘Non-trusters’ segments but in the other direction. This can clearly be seen in the following table 12 (H4).

Table 12: Recovery rates of the different information scenario for Italy.

Duration		Starting P_J (all)	End P_J (all)	End P_J Segm3	End P_J Segm2	End P_J Segm1
Italy:						
50 (natural fading away)	Recovery rate:	0.99	0.48	0.79	0.41	0.13
50 (single source counter balancing information: TV news)	Recovery rate:	0.99	0.50	0.81	0.43	0.14
50 (single source counter balancing information: Newspaper)	Recovery rate:	0.99	0.49	0.80	0.43	0.14
50 (single source counter balancing information: Internet)	Recovery rate:	0.99	0.49	0.81	0.42	0.13
50 (budget allocation scenario: TV ads)	Recovery rate:	0.99	0.68	1	0.65	0.23
50 (budget allocation scenario: Newspaper)	Recovery rate:	0.99	0.68	1	0.66	0.22

Although a segmentation into different trust segments in this way is due to the communication and influencing structure in the networks not very useful, it is possible to evaluate different information scenarios. This can also be seen in table 12, there are the same implications for the different information scenarios like in the case of UK.

Furthermore the country differences seem to play no crucial role. This supports the findings of LOBB ET AL. (2005) who stated that the „*socio-demographics and country differences are of minor relevance for the case of chicken purchase*”.

The most influencing aspect with respect to the outcomes, i.e. the different aggregated trust values and their recovery, is likely to be the network structure (H6 and H7). The next subsection refers to that issue. The changing of the random conditions concerning the network set-up changes the dynamics and the development of the aggregated trust value significantly. This is an evidence for the importance of the network structure and the role of certain players within this network (for example opinion makers with have more contacts to other agents than the average agents).

6.2.2 Scenario 2: Changing random conditions and one information scenario

The random conditions are of high importance regarding the outcomes of the simulation runs. The impact of the network effects can be highlighted by changing randomly parameters of the environment and the equipment of the agents. In this case there will be investigated only one information scenario which serves as a comparison measure for the different settlements due to the randomly changing environment.

The information scenario is the single source counter balancing scenario from the previous section, particularly the Internet as the media will be investigated. Table 13 gives an overview about the different constellations and the respective outcomes of the performed simulation runs.

Table 13: Recovery rates of the different random conditions - single source counter balancing (Internet).

Duration/ No. of random scenario	Population size/1.offspring/ 2.offspring	Starting P_J (all)	End P_J (all)	End P_J Segm3	End P_J Segm2	End P_J Segm1
UK/Italy:						
50/1	500/2/2	0.99	0.55/0.55	0.83/0.86	0.58/0.59	0.12/0.11
50/2 (only UK)	300/2/2	0.99	0.56	0.84	0.60	0.12
50/3	100/3/3	0.99	0.49/0.49	0.76/0.80	0.44/0.45	0.12/0.12
50/4	100/3/3	0.99	0.47/0.48	0.74/0.79	0.43/0.46	0.10/0.10
50/5	100/3/3	0.99	0.48/0.50	0.75/0.82	0.43/0.47	0.11/0.11
50/6	100/3/3	0.99	0.48/0.49	0.75/0.80	0.44/0.46	0.10/0.10
50/7	100/3/3	0.99	0.47/0.47	0.73/0.78	0.42/0.40	0.11/0.12

The data show two points, one is that even if the random conditions with respect to the heterogeneity of the agents change, like in the scenarios 50/3 to 50/7 which have the same network structure, there were produced similar results. The other is the network effect.

H7 can be confirmed by the results of the multi-agent simulation:

This means that a change in the size of the population and the numbers of the offspring generations lead to different networks and the outcomes are different from the results of the other network structure (see the difference of the P_J -values from 50/1 and 50/2 compared with the P_J -values of the 50/3 to 50/7). This finding is in accordance with the relevant network aspects described in 3.4.3 where the topology of the network, the importance of specific actors (hubs) and other technical factors of networks were highlighted as important for many real world examples and especially the connected results they produce. An evaluation of information strategies must include analysis of network properties so that the relevant opinion leaders (hubs) are identified and can be addressed with certain information.

6.2.3 Testing network effects

The previous two sub-sections have already indicated that the structure of the networks have a strong influence on the aggregated outcomes. The insights of JANSSEN AND JAGER (2003) are another evidence for the importance of networks and their implications for influencing intentions. In 4.6.3 the results of their model was presented which have indicated that large scale-free networks are numerous in consumption networks to find. In these networks opinion leaders in the form of hubs have a higher number of connections to other agents than the average agent has. This implies that these central figures in the network have a far reaching influence regarding the outcomes of the information communication and the connected behaviour of the agents.

Some network effects have been tested with the multi-agent simulation. Three different scenarios have been developed in which the environment was always the same: the three global centralised information sources have implemented an exponential distribution (one for TV news, one for Newspapers and one for the Internet), i.e. the natural fading away scenario, the duration was 50 days and the country was UK. Then there was introduced an opinion leader who was once connected to the ‘Trusters’ segment, once to the ‘Mixed-trusters’ and finally to the ‘Non-trusters’. In this way the opinion leader can address certain parts of the whole networks. This opinion leader has implemented in each scenario an information distribution which was similar to the TV ad campaign. This means one day after the food safety incident happened he spreads positive counter information to his related agents. The intensity was 1 and the duration lasted until the end of the 50 days of the observation period. Table 14 displays the results.

Table 14: Recovery rates of the different opinion leader connections.

Duration/ scenario	Popula- tion size/1.off spring/2.of spring	Starting P_J (all)	End P_J (all)	End P_J Segm3 (Trusters)	End P_J Segm2 (Mixed- trusters)	End P_J Segm1 (Non- trusters)
UK (Trusters: 49%, Mixed-trusters: 19%, Non-trusters 32%):						
50/Trusters	100/3/3	0.99	0.68	1	0.64	0.21
50/Mixed-trusters	100/3/3	0.99	0.62	0.89	0.65	0.18
50/Non-trusters	100/3/3	0.99	0.64	0.92	0.62	0.23

The segmentation for the UK by the EU-survey analysis led to the following results: ‘Trusters’ segment 49 %, ‘Mixed-trusters’ segment 19 % and ‘Non-trusters’ 32%.

H6 can be confirmed by the results of the multi-agent simulation and also H7 was confirmed again:

The first observation is that if the opinion leader is positively influencing the communication within the network the aggregated trust value increases significantly. This is an evidence for the relevance of network effects with respect to the aggregated outcomes and this supports the findings of JANSSEN AND JAGER (2003). The second observation is that the opinion leader has more influence to his direct relations and only implicit effects to the general network. The grey cells in table 14 are the respective addressed segments of the opinion leader. Compared to the other generated aggregated trust values of the segments in the vertical levels these values are the highest generated trust values. This is in accordance with the direct influence which the opinion leader has to his followers. But even the implicit effects (by word-of-mouth and the communication of his information) have a positive influence of the aggregated trust recovery.

Finally after performing the scenario testing and the simulation runs there should be mentioned that there are problems with predictions. GILBERT AND TROITZSCH (1999, 7) have some ideas about that: *“Skepticism about the possibility of making social predictions, based on both the inherent difficulty of doing so and also the possibility, peculiar to social and economic forecasting (in natural sciences it is different, e.g. weather), that forecast itself will affect the outcome (self-fulfilling prophecy). For this reason social scientists tend to be more concerned with understanding and explanation”*. Each form of simulation has its boundaries which have to be considered. The first boundary is the limit of the means, i.e. the finiteness of energy (for example also computing power), time and money. Hence a simulation has to be economically reasonable. The restrictions imply that a model has to be simple. This again implies that also the results of a simulation are just simplifications of the reality. This leads to the second boundary: a model just produces results for a specific context. In other parameter areas the results might be wrong. For this reason the verification of models has to be done on the respective application area. Other possible boundaries may be set by impreciseness of the original data (e.g. error of measurement) and subjective obstacles (e.g. lack of information flow concerning production failures). But to give some reasons for using simulations, the results of simulation must be checked if they are plausible, if this condition is fulfilled then the usage of simulations is an acceptable mean to investigate social phenomena.

The output of one simulation run is one possible result. If it is repeated many times with ‘random’ parameter constellations the result may be different for each run, but the average result over a large number of runs will be useful. Thus it can be seen that simulation allows the researcher to conduct experiments in a way that is normally impossible in social science. In this light the results of this multi-agent simulation can serve to give some insights for consumer behaviour in risky markets and here with special emphasis on potentially contaminated food.

6.3 Implications for risk communication strategies

The previous remarks concerning the testing of the whole parameter space won't be neglected when focusing on possible conclusions which can be drawn by the simulation results. Nevertheless some plausible insights which were in accordance with observed phenomena and already existing theories can be used to draw some implications for risk communication strategies.

The addressed coherence of risk perception, trust and risk communication in 4.6.4 together with the results of the previous sections of chapter 6 serve as the basic references for the derivation of implications for risk communication strategies.

Basically every risk topic follows the same pattern with respect to public attention (see figure 19). The history of a risk topic starts with a latency phase in proceeding time the risk topic emerges into the attention of the public supported by the media until it comes to a crisis. After the peak of the crisis the public attention decreases; this is the regulation phase. This pattern offers possibilities for a timely and cost adequate reaction regarding the developments which could lead to a threat. The design of risk communication strategies should take care for this pattern and its implications in order to grasp adequate arrangements to avoid a threat.

In 6.2.1 the impact of different information distributions by centralised media agents were tested. Although the scenario testing was done under fixed random conditions the results of different random conditions in 6.2.2 have supported the findings in 6.2.1. These findings were first, that the natural fading away scenario also leads to recovery of the aggregated trust, in reality this behaviour can also be observed and is reasoned by forgetting effects and overlaying effects of other topics. Second, the double exponential distributions with positive counter information which exponentially decrease are of little influence regarding the speed of the recovery of trust; there were only little positive effects on the trust recovery. Third, a permanent positive counter information strategy had an effect on the recovery of the aggregated trust value. This information strategy was accompanied with high investments due to the high intensity of the positive counter information values. The question of the cost-benefit-ratio for this information strategy is left open. But in the light of the history of a risk topic it does not seem to be advisable to implement such high costly counter arrangement since the risk topic disappears anyway. Instead, it seems to be more appropriate to invest in credible physical counter arrangements (e.g. fast tests for BSE cognition, banning of risk material, prohibition of feeding animal meal combined with a credible control) and to communicate these adequately and as early as possible. Another aspect is the public communication of these potential risks. The heptachlor crisis in Hawaii and also the BSE-crisis in Germany give evidence that a clear and true public communication of the facts around a crisis is best suited to shorten the history of a risk topic (since the media is not more interested in such 'unspectacular' news) and to keep welfare losses small. This kind of taking responsibility is likely to be most

accepted by the public and the consumers. FOSTER AND JUST (1984) came to the same conclusions. Their investigation was concerned with consumer valuation of health risks based on the case of heptachlor contamination of milk in Hawaii. They stated that contamination prior to public awareness causes welfare losses for consumers. They have measured these welfare losses with the help of revealed preferences. Their results showed “*that consumer losses from contamination when information is withheld can be greater than after information is released. In particular, estimates for the Hawaiian heptachlor crisis show that consumer losses prior to consumer awareness in March, 1982, may have exceeded the losses incurred since and that over 10 percent of the losses incurred before consumer awareness may be due to withholding of information by public officials*” (FOSTER AND JUST 1984, 40 and 41). Withholding of information potentially enforces the effect of negative information and leads thereby to a breach of trust.

Risk communication is part of risk management. It is not the end in itself. Enterprises who work with products which are fraught with risk and governments who conduct prevention and risk minimisation have a high interest in performing risk communication. Another thing is changing behaviour through policy making. According to HM Government (2005) sustainable development will largely depend on long-term changes in behaviours of individuals, communities, firms and the public sector. In Germany the BSE-crisis has caused such a change, it led to a more careful production and trade of beef but it only short-time changed the consumer behaviour – the consumers came after a phase of uncertainty back to the most determining aspect of general demand: the price, i.e. they return back to buy most of the time at discounters. Attitude and behaviour change is a complex subject. Information alone does not lead to behaviour change or close the so-called ‘attitude-behaviour gap’. This means that “*information does not necessarily lead to increased awareness, and increased awareness does not necessarily lead to action. Information provision, whether through advertisements, leaflets or labelling, must be backed up by other approaches*” (Demos and Green Alliance, 2003). The behaviour of the individuals is determined by many factors. It is embedded in social norms, institutional contexts and cultural norms. Often the consumers find themselves ‘locked-in’ like a path dependency to unsustainable behaviours by combination of habit, disincentives, social norms and cultural expectations. The multi-agent simulation presented here can only cover parts of these complex coherences but it is also only directed to explain parts of it. It was designed to analyse consumer behaviour, respectively trust development in risky situations, particularly food safety incidents, combined with different information strategies. These information strategies have been investigated regarding their different influences on the aggregated trust development of the artificial consumer population. The impact of these information strategies with respect to the trust recovery was different. The evaluation of these information or say risk communication strategies is difficult to perform since the costs and benefits are hard to estimate. But the following statement might give some hints in which direction the in-

vestment in risk communication strategies should go: *“In the past we have seen significant benefits to society brought about by change in behaviour following regulation and economic incentives (taxes and grants). But those have been more effective with business than with individuals where we have tended to rely on big publicity campaigns to give information – but that has rarely led to lasting changes in action. One of the key problems is that governments too often say one thing and do another themselves – which at best means we are less effective in achieving our goals and at worst creates cynicism and makes people reject the message”* (HM Government, 2005). This statement also indicates that risk communication alone is not enough to change behaviour. If only risk communication within risk management shall be performed then there are two basic tasks of risk communication: to tranquilise in case of little risks and to warn in case of substantial risks. A change of behaviour like aspired by the German government during and after the BSE-crisis by changing the whole agricultural and nutritional policy is something different than performing an effective risk communication strategy, especially with a view to the trust recovery which is self-adjusting.

6.4 Perspectives and outlook

The investigations and the outcomes of this thesis and the TRUST-Project¹⁹ have confirmed some insights and findings of other research and have also led to further insights which are of value for further research. Besides these aspects it came out that little is said about the utility function of the consumers. In the multi-agent simulation it is assumed that the utility function of the single agents is not changing. In the light of food scare, however it seems reasonable that the consumers change their utility function in the sense of changing the consumption and buying behaviour²⁰. In ceteris paribus conditions this leads to a loss in utility of the single consumer and hence on the aggregate level. But what if the consumers realise that the change in their utility function based on the food safety incident leads to a higher utility, e.g. if they realise that they feel better being a vegetarian. These welfare effects were not considered in this approach and further research would be necessary to answer this question.

The multi-agent simulation can not answer this question but it can provide some insights how single consumer agents are developing differently than the majority of the entire artificial consumer population (see figure 34).

¹⁹ See <http://www.trust.unifi.it>

²⁰ Bruce TRAILL mentioned this aspect in the presentation of the TRUST-Project at the 11th International Congress of the EAAE (European Association of Agricultural Economists), ‘The Future of Rural Europe in the Global Agri-Food System’, Copenhagen (DK) August 24-27, 2005.

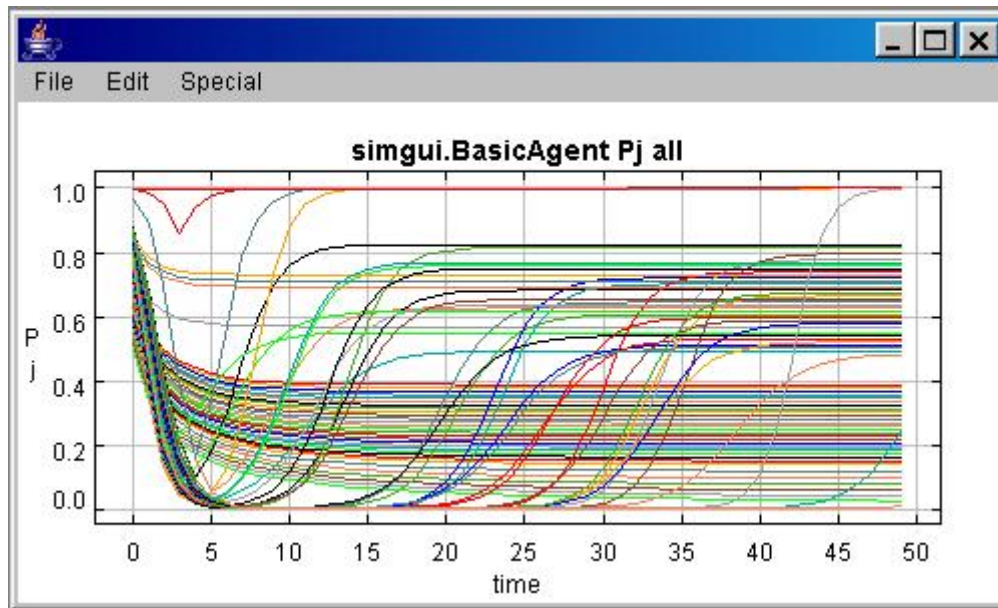


Figure 34: Trust building on the individual level

The different coloured lines in figure 34 display the trust development of the single consumer agents. The agents are updating their trust in the supplier of the suspicious food item by reacting to the information gathered from the media and from the communication within the social networks. Some agents recover quiet early while others recover partially during the duration period of 50 days. But there are also some consumer agents who complete loose trust in the supplier of this potentially contaminated food item. It is likely that these agents won't buy this food item which would implicate that they would substitute it by another safe food item. Under the conditions of the food scare it seems reasonable that especially these consumer agents might have changed their utility function. But again, the question of the welfare effects with respect to a change of the utility function of at least some consumer agents is left open. Also for the real world consumers this question seems to be interesting and further research would be necessary to gain insights regarding these issues which would have in turn further implications for policy making.

7. Summary, conclusions and implications

Consumer behaviour is a research object which is and has been frequently investigated with differing intentions and backgrounds. In most cases however, consumers are in risky markets which are characterised by uncertainty. Incomplete information, bounded rationality, and trust properties of products which can not be observed in advance to the purchase, describe the consumer's decision making environment. This holds true especially for food products. Usually people have to eat every day and thus have to make decisions which food to buy and to consume. Food has to be produced and processed which, in turn, bears potential sources for

failures in the safety of a food item. The case of food scares, as an example for risky markets, is investigated in this thesis. Consumers, who are confronted with potentially contaminated food, face a high degree of uncertainty when consuming this food item. Information about the food scares or the safety of food are published and diffused by the media. They are of special interest to ensure consumers' trust in food production and processing.

The media influence consumers in their opinions, behaviour and decision making. Consumers usually individually form an opinion, but they are part of the entire society, which aggregates these individual opinions into the public opinion which, in turn feeds back to the opinion formation of an individual, forming a reciprocal dynamic system.

The opinion formation happens not only by exogenously released information of the media but also by social contacts and the communication within social networks. The communication process is an important aspect in this endogenous form of information processing. Information is retrieved by communication and decision situations are re-evaluated. In this way, the public opinion will either be confirmed and enforced or revised.

Agent-based modelling is a simulation method which can be used to reproduce and investigate processes which are observed in reality. In this way, social processes can be analysed using a dynamic system of artificial agents which represent real world objects. This dynamic system develops in iteration steps over time, in which the artificial agents communicate with each other within their social networks. In this thesis, a multi-agent simulation for investigating consumer behaviour in risky markets was presented. It was applied for the case of food scares, where artificial agents represent consumers which are interconnected in networks and map an artificial consumer society. The aim of this thesis was to analyse and evaluate the effects of different information strategies released by the media with respect to the development of the aggregate trust. The media is explicitly modelled as media agents who serve as exogenous information sources for the artificial consumer agents and who release information regarding the safety of a potentially contaminated food item. The information strategies were defined as risk communication strategies. These risk communication strategies were then evaluated by the outcomes of the multi-agent simulations. In this way, the effectiveness of different risk communication strategies concerning the recovery of the aggregate trust was measured and evaluated, providing some insights for actual risk communication strategies, however within the restrictions of the implied multi-agent simulation.

This thesis is divided into seven chapters. After the general introduction into the topic, the second chapter made a classification of agent-based modelling within the general scientific context. The third chapter dealt with simulation theory which provides the basic concepts and the modelling approaches for agent-based modelling. The general coherences of information processing of individuals and consumers were considered in chapter 4. In this chapter, special emphasis was directed to the influence of the media on the perception and the cognitive processes of individuals. Risk perception regarding the safety of food products, the development

of trust and risk communication was also investigated in this chapter based on the BSE-crisis in Germany in 2000/2001. The fourth chapter provided the preconditions for the modelling of the multi-agent simulation for investigating consumer behaviour after a food scare. It concludes with the description of the cognitive processes which are implied on the basis of the single agents in the multi-agent simulation. The fifth chapter referred to the concepts of the previous chapters and displayed the modelling of the multi-agent simulation. Consumers' response to food scares was modelled as the updating of their trust in suppliers of the food under suspicion of being unsafe. An artificial consumer population was created. The consumer agents are interconnected in networks and they are also connected to media agents. Hence, the information sources are first, the media agents which release different exogenous information regarding the safety of food items and second, the social networks which provide endogenous information. Each agent processes this information and updates his trust accordingly. The multi-agent simulation was calibrated based on data of an EU-survey and validated based on data of the BSE-crisis in Germany and also on the heptachlor-crisis in Hawaii. In the sixth chapter the multi-agent simulation was used to test different information scenarios and risk communication strategies. The general sensitivity analysis was directed to discover if positive counter information, i.e. implementing risk communication, has an effect on the recovery of the aggregate trust. The simulations have shown that the natural fading away of news regarding the safety of food already leads to a recovery of the aggregate trust. The implemented Bayes' rule as the updating mechanism of the individual trust supports this process. If no negative news will be released by the media agents, then the trust slowly approximates the initial level before the disclosure of the food scare. The simulations also showed that positive counter information have a positive impact on the recovery of the aggregate trust.

The scenario testing in 6.2 was divided into three sub-sections; the reason is that three different approaches were considered. The first sub-section 6.2.1 is directed to a *ceteris paribus* comparison of different information strategies where the networks are set up randomly, but once they are set up, several simulation runs with different information strategies under the same starting conditions were performed, i.e. different information scenarios, respectively risk communication scenarios were tested regarding their effect on the recovery rate of the aggregate trust of the artificial consumer population. Different types of media were tested and a cross-country comparison among the United Kingdom and Italy took place. The second sub-section 6.2.2 was directed to investigate different random conditions regarding the network set up and the testing of only one information scenario. This approach was used to explore the effects of different network compositions on the aggregated outcome. The third sub-section 6.2.3 tested network effects; especially the role of opinion leaders was investigated.

First the results show that also here the natural fading away scenario leads to a recovery of the aggregated trust, i.e. forgetting processes or overlaying processes of other topics seem to play a role. Second, positive counter information which follow a double exponential distribu-

tion, i.e. intense positive information which decreases over time, have little positive impact on the recovery of the aggregate trust. Third, the type of media is of little importance (at least based on the results of the multi-agent simulation which has implemented the data of the EU-survey). Fourth, the country does not play a significant role based on the results of the multi-agent simulation. This supports the findings of LOBB ET AL. (2005) who stated that the „*socio-demographics and country differences are of minor relevance for the case of chicken purchase*” which was one of the results of the analysis of the EU-survey of the TRUST-project. Fifth, a permanent positive counter information strategy had a high positive effect on the recovery time of the aggregated trust of the artificial consumer population. But this risk communication strategy was accompanied with high investments due to the costs of the high intensity positive counter information. In this scenario, this permanent positive counter information strategy was defined as advertising campaigns. The question of the cost-benefit-ratio for this information strategy is left unanswered. But, in the light of the history of a risk topic, it does not seem to be advisable to implement such high costly counter arrangement since the risk topic disappears over time anyway. Instead, it seems to be more appropriate to invest in credible physical counter arrangements, e.g. implementation of quality assurance systems, although there are problems with opportunistic behaviour (HINRICHS 2004), fast tests for BSE cognition, banning of risk material, prohibition of feeding animal meal combined with a credible control, and to communicate these adequately and as early as possible. Sixth, the testing of network effects has shown that agents, who are modelled as opinion leaders, influence the communication within networks and have an influence on the recovery time of the aggregate trust. This is an evidence for the relevance of network effects with respect to the aggregated outcomes and this supports the findings of JANSSEN AND JAGER (2003). At last, opinion leaders were found to have more influence on their direct relations and only implicit effects on the general network. However, even the implicit effects (by word-of-mouth and the communication of their information) have a positive influence of the aggregated trust recovery. The heptachlor-crisis in Hawaii and also the BSE-crisis in Germany give evidence that a clear and true public communication of the facts around a crisis is best suited to shorten the history of a risk topic. On the level of the firms this strategy seems also be appropriate. Firms which have implemented transparent production processes and continuous quality assurance combined with risk communication which addresses the entire processes are strategically well-positioned with regard to trustfulness. This kind of information policy gives incentives for the media not to exploit the topic which in turn leads to a faster recovery of the aggregate trust. On the aggregate level risk communication is appropriate if it calms in the case of low risks and if it warns in the case of substantial risks.

This thesis was directed to investigate consumer behaviour in risky markets. The case of food scares was analysed by using a multi-agent simulation. The main findings were that the multi-agent simulation could show how the observed pattern of a rapid decline in trust after the dis-

closure of a food scare followed by a slow recovery of the aggregate trust could adequately be reproduced based on heterogeneous interacting agents. Furthermore the multi-agent simulation could be used to evaluate risk communication strategies. It came out that the aggregate trust recovered even if there was no risk communication in the sense of positive counter arrangements and information, i.e. forgetting and overlaying processes by other topics seem to be active. On the other hand risk communication with permanent counter arrangements had a significant influence on the recovery time of the aggregate trust. The type of the media and the country were of little importance concerning the recovery of the aggregate trust. Opinion leaders and the structure of the networks were in contrast of high importance. This implies that risk communication strategies should include opinion leaders. Also risk communication should be connected to quality assurance systems since this supports the trust in the suppliers and producers of food and the risk management.

8. Zusammenfassung

Konsumenten befinden sich in Märkten, die durch Unsicherheit gekennzeichnet sind. In den meisten Fällen herrscht keine vollkommene Information und viele Produkte weisen Vertrauenseigenschaften auf, die nicht im Vorwege geprüft werden können. Informationen über Lebensmittelskandale die von den Medien veröffentlicht und verbreitet werden sind von besonderer Bedeutung für das Vertrauen in die Lebensmittelproduktion und in den Lebensmittelhandel.

Die Medien beeinflussen die Konsumenten bei ihrer Meinungsbildung, in ihrem Verhalten und bei ihren Entscheidungen. Die Meinungsbildung entsteht dezentral auf der Ebene des Individuums welches Teil der gesamten Gesellschaft ist. Erst im Aggregat entsteht die öffentliche Meinung, die wiederum auf die individuelle Meinungsbildung zurückwirkt und so ein reziprokes dynamisches System bildet.

Die Meinungsbildung findet aber nicht nur über die exogenen Medien statt, sondern auch über soziale Kontakte und Netzwerke. Der entscheidende Aspekt dieser endogenen Form der Informationsverarbeitung ist die Kommunikation. Durch Kommunikation werden Informationen aufgenommen und Entscheidungssituationen neu bewertet. Dadurch findet eine Beeinflussung der Meinungsbildung statt, entweder wird die vorherrschende Meinung bestätigt und verfestigt oder es kommt zu einer Revidierung der Meinung.

Agentenbasierte Modellierung ist eine Simulationsmethode, um Abläufe, die in der Realität beobachtet werden, nachzubilden und zu untersuchen. Soziale Prozesse können auf diese Weise in einem dynamischen sich über die Zeit entwickelnden System von einzelnen Agenten, die als Platzhalter für reale Objekte angesehen werden und in Netzwerkstrukturen miteinander verbunden sind, analysiert werden.

Die Arbeit gliedert sich in sieben Teile. Nach der allgemeinen Einführung in das Thema wird im zweiten Teil eine Einordnung der agentenbasierten Modellierung in den allgemeinen wissenschaftlichen Kontext vorgenommen. Der dritte Teil widmet sich der Simulationstheorie, die der agentenbasierten Modellierung in dieser Arbeit zugrunde liegt. Im vierten Teil werden die allgemeinen Zusammenhänge der Informationsverarbeitung der Individuen und Konsumenten unter besonderer Betrachtung des Medieneinflusses analysiert. Dieser Teil schafft die Voraussetzungen für die Modellierung einer Multiagentensimulation zur Analyse von Konsumentenverhalten bei Lebensmittelskandalen im fünften Teil. Mit Hilfe dieser Multiagentensimulation werden im sechsten Teil verschiedene Informationsstrategien, die als Risikokommunikationsstrategien definiert sind, auf ihre Effizienz hinsichtlich der Rückgewinnung des Vertrauens in das unter Verdacht geratene Lebensmittel untersucht. Daraus ergeben sich Implikationen für die Ausgestaltung der Risikokommunikation auf Unternehmensebene und gesamtwirtschaftlicher Ebene. Die Arbeit schließt mit einer Zusammenfassung.

Als Ergebnis der Multiagentensimulation zeigt sich, dass das aggregierte Vertrauen der künstlichen Konsumentenpopulation auch bei einer nachlassenden Berichterstattung ohne positive Gegeninformation, d.h. ohne aktive Risikokommunikation, sich über die Zeit wieder erholt. Positive Gegeninformationen in der Form, dass das Produkt sicher ist, bewirken nur geringe Effekte auf die Erholung des aggregierten Vertrauens. Starke positive Gegeninformationen in Form von permanenten Werbekampagnen haben jedoch einen größeren Effekt auf die Erholungsrate des Vertrauens. Unter Kosten-Nutzen-Aspekten ist dieser Effekt jedoch sehr in Frage zu stellen, da sich das Vertrauen auch ohne positive Gegenmaßnahmen relativ schnell wieder einstellt, sofern keine weiteren negativen Meldungen mehr vorliegen.

Unternehmen, die ganzheitlich Risikokommunikation betreiben und bei denen transparente Produktionsprozesse und kontinuierliche Qualitätssicherung zum Leitmotiv erklärt wurden, was auch glaubhaft eingehalten wird, sind in einer immer komplexer werdenden Umwelt nachhaltig aufgestellt. Die Informationspolitik, die Medienpolitik und die Kommunikatoren bzw. das Vertrauen in das Unternehmen spielen hierbei eine entscheidende Rolle. Dies ist insbesondere durch die untersuchten Netzwerkeffekte in der Multiagentensimulation zur Bedeutung von Meinungsführern bestätigt worden. Ganzheitliche und transparente Risikokommunikation ist hierbei ein wesentliches Element. Durch eine derartige Risikokommunikation haben die Medien weniger Interesse an einer intensiven negativen Berichterstattung, sodass das Vertrauen sich schneller wieder erholen kann. Risikokommunikation auf gesamtwirtschaftlicher Ebene ist nach dem Grundsatz auszulegen, bei kleinen Risiken zu beruhigen und bei substantiellen Risiken zu warnen.

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Annexes

A.1 Trust in food safety information

Q43. Suppose that each of the following has provided information about potential risks associated with salmonella in food. Please indicate to what extent you would trust that information. (1=Completely Distrust; 7=Completely Trust)

	UK	Italy	Germany	Netherlands	France	EU
Shopkeepers	4.64	4.72	4.48	4.54	5.01	4.69
Supermarkets	4.99	4.73	4.54	4.49	4.48	4.64
Organic shop	5.27	5.08	5.27	5.14	5.30	5.21
Specialty store	5.12	4.05	4.91	5.28	5.70	5.01
Farmers / breeders	5.07	4.67	4.90	4.56	5.56	4.97
Processors	3.95	4.01	3.90	3.97	3.00	3.74
Doctors / health authority	6.24	5.91	5.98	6.08	5.78	5.99
University scientists	5.53	5.92	5.77	6.04	5.58	5.77
National authority in charge of food safety	5.80	5.60	5.98	6.01	5.62	5.79
Government	4.39	4.29	4.67	5.36	3.90	4.50
Political groups	3.55	3.33	4.04	3.98	2.89	3.52
Environmental organisations	4.86	4.78	5.41	4.51	4.84	4.86
Animal welfare organisations	4.50	4.69	5.34	4.40	4.67	4.70
Consumer organisations	5.22	5.58	6.02	5.72	5.91	5.69
European Union authority in charge of food safety	4.62	5.52	5.54	5.41	4.97	5.21
Television documentary	4.96	4.84	5.26	5.05	4.87	4.98
Television news / current affairs	5.17	5.15	5.55	5.39	4.79	5.19
Television adverts	4.18	3.56	3.25	3.04	2.95	3.38
Newspapers	4.53	4.87	5.33	4.97	5.01	4.94
Internet	4.54	4.34	4.77	4.82	4.25	4.54
Radio	4.86	4.56	5.35	5.00	5.13	4.97
Magazines	4.55	4.28	4.81	4.39	4.48	4.49
Product label	4.81	5.19	4.48	5.01	5.50	5.03
<i>Average</i>	4.84	4.77	5.02	4.92	4.79	4.86

Figure A1: Trust in food safety information and information sources (Source: MAZZOCCHI ET AL. (2005))

		Cluster (Trust variables EU)			Total
		1	2	3	
Shopkeepers	Mean	4.26	3.52	5.56	4.62
	Std Deviation	1.36	1.34	1.05	1.51
Supermarkets	Mean	4.05	3.57	5.57	4.59
	Std Deviation	1.40	1.39	1.09	1.55
Organic shop	Mean	4.81	4.28	5.98	5.18
	Std Deviation	1.36	1.49	.94	1.45
Specialty store	Mean	4.45	3.95	5.82	4.91
	Std Deviation	1.38	1.36	1.01	1.48
Farmers / breeders	Mean	4.50	3.95	5.74	4.89
	Std Deviation	1.40	1.45	1.03	1.49
Processors	Mean	3.16	2.94	4.72	3.79
	Std Deviation	1.44	1.32	1.48	1.65
Doctors / health authority	Mean	4.68	6.22	6.51	5.95
	Std Deviation	1.42	.78	.64	1.21
University scientists	Mean	4.49	6.12	6.25	5.75
	Std Deviation	1.33	.93	.94	1.29
National authority in charge of food safety	Mean	4.18	6.12	6.42	5.75
	Std Deviation	1.45	1.04	.73	1.41
Government	Mean	3.10	4.64	5.26	4.52
	Std Deviation	1.48	1.71	1.50	1.79
Political groups	Mean	2.80	3.27	4.27	3.59
	Std Deviation	1.42	1.54	1.58	1.65
Environmental organisations	Mean	4.16	4.63	5.49	4.90
	Std Deviation	1.57	1.61	1.22	1.54
Animal welfare organisations	Mean	4.16	4.38	5.32	4.74
	Std Deviation	1.60	1.74	1.34	1.62
Consumer organisations	Mean	4.50	5.92	6.14	5.65
	Std Deviation	1.50	1.04	.93	1.32
European Union authority in charge of food safety	Mean	3.81	5.57	5.85	5.24
	Std Deviation	1.48	1.40	1.20	1.58
Television documentary	Mean	4.20	5.14	5.34	4.99
	Std Deviation	1.35	1.28	1.28	1.38
Television news / current affairs	Mean	4.25	5.40	5.61	5.19
	Std Deviation	1.38	1.22	1.22	1.39
Television adverts	Mean	3.04	2.83	4.01	3.41
	Std Deviation	1.54	1.59	1.67	1.70
Newspapers	Mean	4.22	5.00	5.32	4.94
	Std Deviation	1.41	1.33	1.28	1.40
Internet	Mean	3.83	4.59	4.91	4.54
	Std Deviation	1.60	1.56	1.51	1.61
Radio	Mean	4.09	5.06	5.31	4.92
	Std Deviation	1.41	1.32	1.23	1.40
Magazines	Mean	3.89	4.37	4.91	4.49
	Std Deviation	1.37	1.40	1.29	1.41
Product label	Mean	4.34	4.60	5.56	4.96
	Std Deviation	1.51	1.50	1.18	1.47

Figure A2: Trust variables in information sources for the identified consumer segments
 (Source: CAVICCHI ET AL. (2004b), D8)

A.2 Parameter space of the simulation

Table A1: Parameter space of the simulation.

<i>Parameters</i>	<i>Initial parameters</i>	<i>Structural parameters</i>
<i>Iteration/Duration</i>	Duration for the simulation run in days	-
$P(G A)$	The probability to buy an unsafe unit of a reliable supplier A	-
$P(G B)$	The probability to buy an unsafe unit of an unreliable supplier B	-
P_j	The probability that a supplier j is reliable (the trust value)	-
$Rnd P(G A)$	When this field is selected then each agent will receive random values for $P(G A)$ and $P(G B)$	-
$Rnd P_j$	When this field is selected then each agent will receive a random value between 0 and 1 as a starting value for trust	-
<i>Decision fct.</i>	-	The user can choose between different decision functions for the agents: Bayesian updating and Bayesian updating implemented in the “Theory of Planned Behaviour”
$P_j Segm i (i=1, \dots, n)$	If $Rnd P_j$ is not chosen then the user can set explicitly the trust values for each consumer segment	-
$SDev(P_j S_i) (i=1, \dots, n)$	In this text field the user can set the standard deviation for the trust value for segment i	-
<i>Supplier types ($j=1, \dots, 6$)</i>	The combo box offers the possibility to choose different supplier types, e.g. supermarket. The simulation then loads the data from the survey analysis for the trust values with respect to supermarkets. $P_j Segm n$ will be filled with the trust value for the supplier j , the supermarkets, and also for $SDev(P_j S_n)$ the standard deviation for j	-
<i>Forgetting parameter</i>	Forgetting is implicit in the Bayesian updating process, i.e. if the 0 is selected then there is no explicit forgetting but implicit when the Bayesian updating is done. The user can set a forgetting parameter explicitly. This parameter has no scale but the higher the parameter the higher the forgetting in time	-

<i>Info diff</i>	-	For these networks there can be selected if the information values shall be diffused among the agents or if they should just receive information from the centralized media sources	
<i>Mean</i>	-	In this text field there is the number of connections to friends	
<i>Variance</i>	-	In this text field there is the variance from the mean out degree links	
<i>Distrib</i>	-	In this field the user can choose between different distributions of the out degrees. These distributions take the mean value and the variance and assign to each agent a number of links to friends randomly	
<i>Pop. Size</i>	This text field can be used to set the number of the population members, i.e. the number of the whole consumer agent population	-	
<i>Off. gen1</i>	-	This text field can be used to set the average number of the first generation offspring	
<i>Off. gen2</i>	-	This third field is for the average number of the second generation offspring	
For Media 2 to Media 10:	<i>Netw. weight</i>	This value is the trust value for the media source, i.e. the relative weight for this information source which influences the aggregated information value	-
	<i>Sdev.netw. weight</i>	This is the standard deviation for the network weight of this information source. Each agent belongs to a segment or will randomly be equipped with an initial trust value. This initial trust value comes from a random distribution where the network weight enters as a mean value and the standard deviation as the second moment	-
	<i>Negative Info</i>	This is the starting value for two kinds of predefined information release distributions: double exponential distribution and exponential distribution, i.e. starting in the first iteration (day) with a negative information with the intensity -1 (e.g. first page of a newspaper with a picture of harmed people) and then continuing with less intense negative information regarding the safety of the food item under investigation	-
	<i>Positive Info</i>	The same holds for positive information but only for double exponential, since plain exponential is just a distribution of negative information releases	-

Distrib_k
(*k=1, ..., l*)

You can choose between two predefined information release distributions and one manual distribution. If choosing predefined distributions you will have the opportunities between "Double exponential" distribution and "exponential distribution". For these distributions you can also

		modify the following parameter
<i>Inversion</i>	This text field offers the possibility to set explicitly the day when the news release changes its sign, i.e. when negative information (food is unsafe) changes to positive information (food is safe)	-
<i>Negative slope</i>	The negative slope is the curve of the negative exponential distribution, i.e. here the user can change the intensity of the information release values in time by changing the slope (a lesser value decreases the curve and keeps thereby the decreasing of the intensity slower in time and vice versa)	-
<i>Positive slope</i>	The same holds for the positive slope but also just for the double exponential distribution since the plain exponential distribution just has negative information values	-
<i>Segmx</i> ($x=1, \dots, 6$)	In this text field the number of percentage for the first segment of the consumer population can be inserted manually. The same holds for <i>Segm2</i> , <i>Segm3</i> , <i>Segm4</i> , <i>Segm5</i> and <i>Segm6</i>	-
<i>Netw. Weight</i>	Like for the other centralized media agents	-
<i>Std. Dev</i>	Like for the other centralized media agents	-
<i>Survey data for countries</i>	-	If this opportunity is selected then the values for the chosen countries will be displayed in the text fields for the different segments otherwise the distribution of the percentage values for the segments of the population can be set explicitly. (Note: if the sum of the percentage values are less or more than 100 then the simulation will adapt the first segments until the sum will be 100!)

Source: own source.

A.3 Simulation results of the positive counter information scenario

Table A2: Simulation results of the positive counter information scenario after 100 days.

Run no.	Mean start Pj (all)	End Pj (all)	Mean start Pj Segm1	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
Days: 100	0.99	0.639929336	0.99	1	0.99	0.659419285	0.99	0.197108622
	0.99	0.635216949	0.99	1	0.99	0.659430616	0.99	0.181387444
	0.99	0.628033622	0.99	1	0.99	0.659430199	0.99	0.157443509
	0.99	0.631321848	0.99	1	0.99	0.65909275	0.99	0.168797952
	0.99	0.634237228	0.99	1	0.99	0.659330965	0.99	0.178237968
	0.99	0.637258414	0.99	1	0.99	0.659330654	0.99	0.188308951
	0.99	0.606437996	0.99	1	0.99	0.658905651	0.99	0.08607006
	0.99	0.640013824	0.99	1	0.99	0.658915876	0.99	0.197977559
	0.99	0.633111063	0.99	1	0.99	0.659327665	0.99	0.174487935
	0.99	0.633411333	0.99	1	0.99	0.659231583	0.99	0.17560093
	0.99	0.608274668	0.99	1	0.99	0.656392601	0.99	0.095124193
	0.99	0.634080076	0.99	1	0.99	0.659430712	0.99	0.177597756
	0.99	0.635311068	0.99	1	0.99	0.659406662	0.99	0.181729122
	0.99	0.627388098	0.99	1	0.99	0.659330824	0.99	0.155407699
	0.99	0.636613939	0.99	1	0.99	0.656460374	0.99	0.189509361
	0.99	0.632743841	0.99	1	0.99	0.659015	0.99	0.173628638
	0.99	0.631825576	0.99	1	0.99	0.657788189	0.99	0.171999032
	0.99	0.630654826	0.99	1	0.99	0.658863604	0.99	0.16684188
	0.99	0.625952878	0.99	1	0.99	0.657793308	0.99	0.1524174
	0.99	0.638334262	0.99	1	0.99	0.659430747	0.99	0.191778335
	0.99	0.63696621	0.99	1	0.99	0.659406538	0.99	0.187246405
	0.99	0.640727442	0.99	1	0.99	0.659011996	0.99	0.200244146
	0.99	0.630415	0.99	1	0.99	0.659429989	0.99	0.165381681
	0.99	0.635390959	0.99	1	0.99	0.659424539	0.99	0.181974569
	0.99	0.639706944	0.99	1	0.99	0.659427409	0.99	0.196357836
	0.99	0.626591822	0.99	1	0.99	0.659406756	0.99	0.15266486
	0.99	0.634890457	0.99	1	0.99	0.659430551	0.99	0.180299213
	0.99	0.626474536	0.99	1	0.99	0.658614019	0.99	0.153198764
	0.99	0.618143089	0.99	1	0.99	0.657372744	0.99	0.126875428
	0.99	0.627811247	0.99	1	0.99	0.659406764	0.99	0.156729599
	0.99	0.625520696	0.99	1	0.99	0.657793832	0.99	0.150976182
	0.99	0.638066539	0.99	1	0.99	0.65943075	0.99	0.190885921
	0.99	0.637800932	0.99	1	0.99	0.65940091	0.99	0.190035379
	0.99	0.639285511	0.99	1	0.99	0.657794046	0.99	0.196858649
	0.99	0.631982018	0.99	1	0.99	0.65933016	0.99	0.17072154
	0.99	0.620935919	0.99	1	0.99	0.658092472	0.99	0.13534518
	0.99	0.639432349	0.99	1	0.99	0.659316462	0.99	0.19557196
	0.99	0.627444873	0.99	1	0.99	0.659015622	0.99	0.155964686
	0.99	0.636944484	0.99	1	0.99	0.659424903	0.99	0.187152561
	0.99	0.634722777	0.99	1	0.99	0.659427323	0.99	0.179744047
	0.99	0.637165569	0.99	1	0.99	0.659231177	0.99	0.188115523
	0.99	0.628244549	0.99	1	0.99	0.659092724	0.99	0.15854032
	0.99	0.63703717	0.99	1	0.99	0.659427315	0.99	0.187458699
	0.99	0.63695355	0.99	1	0.99	0.659419277	0.99	0.187189343
	0.99	0.64031567	0.99	1	0.99	0.659430752	0.99	0.198383024
	0.99	0.625623455	0.99	1	0.99	0.65930331	0.99	0.149557656
	0.99	0.631062133	0.99	1	0.99	0.65940652	0.99	0.16756617
	0.99	0.632854909	0.99	1	0.99	0.659427712	0.99	0.173517364
	0.99	0.638945566	0.99	1	0.99	0.659430744	0.99	0.193816018
	0.99	0.636653059	0.99	1	0.99	0.659430387	0.99	0.186174747
MV		0.632285206		1		0.658997699		0.172120036
Stddev.		0.007365685		0		0.000754348		0.024148977
Recovery rate		0.638671925		1		0.665654242		0.173858622

Source: own source.

Table A3: Simulation results of the positive counter information scenario after 50 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Segm 1	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
50	0.99	0.426088501	0.99	0.771429295	0.99	0.368149086	0.99	0.090786892
	0.99	0.475789686	0.99	0.742857544	0.99	0.487124598	0.99	0.150986454
	0.99	0.559386913	0.99	0.883024591	0.99	0.571706798	0.99	0.167436422
	0.99	0.532001517	0.99	0.828607831	0.99	0.563441401	0.99	0.149280952
	0.99	0.529535689	0.99	0.942857232	0.99	0.449155728	0.99	0.141103844
	0.99	0.536426555	0.99	0.828571696	0.99	0.570554446	0.99	0.155774687
	0.99	0.540711233	0.99	0.914285848	0.99	0.507508298	0.99	0.14361094
	0.99	0.422931361	0.99	0.742857544	0.99	0.398297153	0.99	0.078424057
	0.99	0.433850756	0.99	0.800486069	0.99	0.35051333	0.99	0.103336554
	0.99	0.524417112	0.99	0.85710903	0.99	0.502224672	0.99	0.162167719
	0.99	0.524586516	0.99	0.885714464	0.99	0.4984422	0.99	0.133772277
	0.99	0.583233807	0.99	0.971428616	0.99	0.551114687	0.99	0.167812171
	0.99	0.482192218	0.99	0.799681982	0.99	0.482689376	0.99	0.111207474
	0.99	0.503695881	0.99	0.799996666	0.99	0.558676776	0.99	0.093867261
	0.99	0.440256415	0.99	0.71425211	0.99	0.466188408	0.99	0.090340779
	0.99	0.479043469	0.99	0.771425271	0.99	0.501355555	0.99	0.111900601
	0.99	0.499211343	0.99	0.857112866	0.99	0.45399971	0.99	0.134406471
	0.99	0.493771699	0.99	0.828607831	0.99	0.462503548	0.99	0.139609055
	0.99	0.46115414	0.99	0.85714308	0.99	0.389198206	0.99	0.083115632
	0.99	0.542411273	0.99	0.911595787	0.99	0.512532227	0.99	0.146554892
	0.99	0.517635431	0.99	0.85714308	0.99	0.513958668	0.99	0.125832731
	0.99	0.487603376	0.99	0.785616831	0.99	0.512706436	0.99	0.11063411
	0.99	0.397938394	0.99	0.685714776	0.99	0.3918842	0.99	0.069262508
	0.99	0.44124212	0.99	0.71428616	0.99	0.462708387	0.99	0.097646762
	0.99	0.480075831	0.99	0.742857544	0.99	0.511554335	0.99	0.136772246
	0.99	0.458661896	0.99	0.857215349	0.99	0.348577585	0.99	0.122114562
	0.99	0.562411298	0.99	0.885714464	0.99	0.592278755	0.99	0.150378906
	0.99	0.504012492	0.99	0.85714308	0.99	0.485256403	0.99	0.113908909
	0.99	0.539452618	0.99	0.914285848	0.99	0.499975817	0.99	0.148203451
	0.99	0.533643603	0.99	0.828905799	0.99	0.561652671	0.99	0.156493795
	0.99	0.380911182	0.99	0.714321512	0.99	0.273283997	0.99	0.117497514
	0.99	0.501019719	0.99	0.799966262	0.99	0.509606627	0.99	0.142230691
	0.99	0.498659867	0.99	0.800000683	0.99	0.506488637	0.99	0.137962017
	0.99	0.497526489	0.99	0.828571696	0.99	0.490445822	0.99	0.119567859
	0.99	0.485558437	0.99	0.742857544	0.99	0.506369518	0.99	0.161096551
	0.99	0.416488241	0.99	0.71432613	0.99	0.386056178	0.99	0.104514778
	0.99	0.439354426	0.99	0.777446443	0.99	0.390076691	0.99	0.10240443
	0.99	0.517171378	0.99	0.860418554	0.99	0.55957663	0.99	0.067243545
	0.99	0.409178806	0.99	0.659985102	0.99	0.412490858	0.99	0.112707401
	0.99	0.47718208	0.99	0.771428928	0.99	0.51236752	0.99	0.092844411
	0.99	0.509041629	0.99	0.828571696	0.99	0.487547724	0.99	0.161332773
	0.99	0.488705424	0.99	0.85714308	0.99	0.439908437	0.99	0.115791312
	0.99	0.487060429	0.99	0.828571634	0.99	0.446641305	0.99	0.135786336
	0.99	0.505127408	0.99	0.814469209	0.99	0.525269247	0.99	0.120729827
	0.99	0.406967764	0.99	0.742857502	0.99	0.353230494	0.99	0.077789886
	0.99	0.332726867	0.99	0.657143345	0.99	0.201997473	0.99	0.106758601
	0.99	0.58034579	0.99	0.942193836	0.99	0.582419437	0.99	0.15577048
	0.99	0.4289313	0.99	0.685714776	0.99	0.436659756	0.99	0.120334046
	0.99	0.541723577	0.99	0.914285806	0.99	0.530690297	0.99	0.119939805
	0.99	0.48081037	0.99	0.828571696	0.99	0.443006164	0.99	0.11919373
MV		0.485957287		0.812135474		0.470401245		0.123564782
Stddev.		0.053171955		0.076151583		0.080356916		0.02695763
Recovery rate		0.490865946		0.820338863		0.475152773		0.124812911

Source: own source.

Table A4: Simulation results of the positive counter information scenario after 30 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Segm1	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
30	0.99	0.487941001	0.99	0.942857793	0.99	0.39503454	0.99	0.065595617
	0.99	0.471732026	0.99	0.885714721	0.99	0.393783633	0.99	0.079692008
	0.99	0.409685083	0.99	0.71863418	0.99	0.383312591	0.99	0.080012375
	0.99	0.391849561	0.99	0.826854193	0.99	0.225325722	0.99	0.078621969
	0.99	0.330241716	0.99	0.714292021	0.99	0.22198239	0.99	0.008485573
	0.99	0.358410569	0.99	0.771428571	0.99	0.205934247	0.99	0.054445276
	0.99	0.419294228	0.99	0.828569182	0.99	0.307349499	0.99	0.072408965
	0.99	0.411081829	0.99	0.8	0.99	0.318060873	0.99	0.065868412
	0.99	0.343022823	0.99	0.714271063	0.99	0.212001553	0.99	0.062758024
	0.99	0.398228506	0.99	0.81769811	0.99	0.281239325	0.99	0.04533468
	0.99	0.444143648	0.99	0.799979114	0.99	0.373613299	0.99	0.11128768
	0.99	0.323200302	0.99	0.628571429	0.99	0.254865845	0.99	0.04665752
	0.99	0.439091041	0.99	0.799997753	0.99	0.387359715	0.99	0.078386423
	0.99	0.418101902	0.99	0.827393369	0.99	0.326290393	0.99	0.047708618
	0.99	0.398928819	0.99	0.742857143	0.99	0.356564829	0.99	0.047103764
	0.99	0.383060823	0.99	0.771428571	0.99	0.298841146	0.99	0.028221406
	0.99	0.321542051	0.99	0.632919894	0.99	0.231743845	0.99	0.063032475
	0.99	0.512305682	0.99	0.971428571	0.99	0.412596107	0.99	0.092990148
	0.99	0.374627913	0.99	0.8	0.99	0.245895092	0.99	0.02854877
	0.99	0.422009076	0.99	0.857142857	0.99	0.30830427	0.99	0.047008604
	0.99	0.390829269	0.99	0.828571429	0.99	0.267426909	0.99	0.024099503
	0.99	0.421684953	0.99	0.85714061	0.99	0.295674909	0.99	0.060665071
	0.99	0.352518907	0.99	0.714285714	0.99	0.267098907	0.99	0.0301143
	0.99	0.302679558	0.99	0.742857143	0.99	0.091541166	0.99	0.035467167
	0.99	0.360753917	0.99	0.857121899	0.99	0.134727876	0.99	0.045354987
	0.99	0.398335604	0.99	0.828571426	0.99	0.222442863	0.99	0.101602009
	0.99	0.40693323	0.99	0.8	0.99	0.306508537	0.99	0.065517475
	0.99	0.461109695	0.99	0.857142857	0.99	0.395568384	0.99	0.075535869
	0.99	0.440304273	0.99	0.857142857	0.99	0.331885976	0.99	0.080480604
	0.99	0.297833473	0.99	0.657142858	0.99	0.166683137	0.99	0.031647917
	0.99	0.402473629	0.99	0.714285787	0.99	0.398779628	0.99	0.043002444
	0.99	0.396307076	0.99	0.771428579	0.99	0.303737489	0.99	0.0666663174
	0.99	0.3682916	0.99	0.714285714	0.99	0.29191453	0.99	0.053738381
	0.99	0.401084632	0.99	0.8	0.99	0.325857591	0.99	0.023448252
	0.99	0.414702216	0.99	0.76969045	0.99	0.373476359	0.99	0.048646108
	0.99	0.443534171	0.99	0.857142857	0.99	0.337495118	0.99	0.084702931
	0.99	0.370435866	0.99	0.71428639	0.99	0.275857195	0.99	0.079618703
	0.99	0.371587671	0.99	0.8	0.99	0.229888112	0.99	0.037089439
	0.99	0.361928644	0.99	0.714091291	0.99	0.279742943	0.99	0.04695554
	0.99	0.380730197	0.99	0.742857148	0.99	0.301413911	0.99	0.05078442
	0.99	0.491853501	0.99	0.914824897	0.99	0.402613571	0.99	0.102500125
	0.99	0.42269255	0.99	0.828571429	0.99	0.339008186	0.99	0.046798948
	0.99	0.372201562	0.99	0.71863418	0.99	0.280863428	0.99	0.074591332
	0.99	0.330750557	0.99	0.742857151	0.99	0.189209011	0.99	0.015091334
	0.99	0.439661113	0.99	0.828571403	0.99	0.378714549	0.99	0.057036764
	0.99	0.41327581	0.99	0.771428571	0.99	0.341581919	0.99	0.079073793
	0.99	0.426256814	0.99	0.77148733	0.99	0.3377884	0.99	0.12670103
	0.99	0.439710379	0.99	0.885713804	0.99	0.301590824	0.99	0.080512529
	0.99	0.434774312	0.99	0.846463962	0.99	0.344336426	0.99	0.059980588
	0.99	0.367651108	0.99	0.771428571	0.99	0.231795497	0.99	0.055075615
MV		0.398827698		0.790601297		0.297706445		0.059733293
Stddev.		0.047444389		0.07314544		0.073346285		0.024867735
Recovery rate		0.40285626		0.798587169		0.300713581		0.06033666

Source: own source.

Table A5: Simulation results of the positive counter information scenario after 20 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Segm1	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
20	0.99	0.416948179	0.99	0.799538484	0.99	0.34153204	0.99	0.058578318
	0.99	0.430925408	0.99	0.939060742	0.99	0.249465176	0.99	0.049804456
	0.99	0.393544063	0.99	0.856681348	0.99	0.242979136	0.99	0.028876311
	0.99	0.392963533	0.99	0.77140295	0.99	0.294858111	0.99	0.065907206
	0.99	0.394152664	0.99	0.881917885	0.99	0.215576774	0.99	0.033431777
	0.99	0.362089803	0.99	0.800002856	0.99	0.192298317	0.99	0.049281307
	0.99	0.372755178	0.99	0.828571429	0.99	0.201426252	0.99	0.040853299
	0.99	0.373104896	0.99	0.754152194	0.99	0.28073566	0.99	0.036313825
	0.99	0.375795244	0.99	0.773419824	0.99	0.262543823	0.99	0.04402656
	0.99	0.392994818	0.99	0.811756858	0.99	0.280584277	0.99	0.035584737
	0.99	0.27992124	0.99	0.685714568	0.99	0.097175924	0.99	0.019698561
	0.99	0.26804702	0.99	0.600000001	0.99	0.156996139	0.99	0.010327902
	0.99	0.355199304	0.99	0.716227078	0.99	0.284033295	0.99	0.017027243
	0.99	0.342535089	0.99	0.754614001	0.99	0.201315244	0.99	0.026532844
	0.99	0.37236223	0.99	0.828571429	0.99	0.199084034	0.99	0.042276058
	0.99	0.360904652	0.99	0.857142857	0.99	0.1671319	0.99	0.008028289
	0.99	0.372785782	0.99	0.830562681	0.99	0.207153787	0.99	0.031950061
	0.99	0.350644212	0.99	0.8	0.99	0.185067485	0.99	0.019568641
	0.99	0.344466721	0.99	0.714285708	0.99	0.260575731	0.99	0.010884059
	0.99	0.294478708	0.99	0.657142861	0.99	0.166834615	0.99	0.020288639
	0.99	0.280165586	0.99	0.65714314	0.99	0.123745087	0.99	0.022849023
	0.99	0.35698125	0.99	0.773419824	0.99	0.212119951	0.99	0.040141095
	0.99	0.366929254	0.99	0.798194852	0.99	0.2234318	0.99	0.031199753
	0.99	0.281832511	0.99	0.628571459	0.99	0.149310319	0.99	0.031912961
	0.99	0.382051205	0.99	0.914285714	0.99	0.165222829	0.99	0.014077383
	0.99	0.397053673	0.99	0.857142857	0.99	0.239065424	0.99	0.044602581
	0.99	0.383045799	0.99	0.8	0.99	0.254944448	0.99	0.046050808
	0.99	0.367563923	0.99	0.771428572	0.99	0.226687229	0.99	0.060744645
	0.99	0.374161601	0.99	0.828571429	0.99	0.202669444	0.99	0.044090984
	0.99	0.371743193	0.99	0.771428854	0.99	0.241952423	0.99	0.056865821
	0.99	0.413727094	0.99	0.914285714	0.99	0.216055226	0.99	0.060359217
	0.99	0.414902367	0.99	0.914310264	0.99	0.245736818	0.99	0.029619627
	0.99	0.374068383	0.99	0.773419824	0.99	0.261935303	0.99	0.038980296
	0.99	0.32053575	0.99	0.685738836	0.99	0.200764205	0.99	0.034198953
	0.99	0.32092462	0.99	0.770967344	0.99	0.141422098	0.99	0.005294382
	0.99	0.355669243	0.99	0.828571422	0.99	0.152752029	0.99	0.040686783
	0.99	0.268383517	0.99	0.687705542	0.99	0.068866764	0.99	0.011944035
	0.99	0.249967236	0.99	0.542857143	0.99	0.165479917	0.99	0.006830884
	0.99	0.405295985	0.99	0.857142857	0.99	0.271632698	0.99	0.034081803
	0.99	0.367773491	0.99	0.771428602	0.99	0.227419366	0.99	0.060589007
	0.99	0.321153719	0.99	0.742851759	0.99	0.162432244	0.99	0.014347726
	0.99	0.356712432	0.99	0.771378401	0.99	0.178966194	0.99	0.08030608
	0.99	0.405736098	0.99	0.857142857	0.99	0.271102516	0.99	0.036167391
	0.99	0.371311506	0.99	0.773419824	0.99	0.26961171	0.99	0.020834897
	0.99	0.347782272	0.99	0.742862408	0.99	0.227248741	0.99	0.027477901
	0.99	0.369058775	0.99	0.771428572	0.99	0.252112977	0.99	0.03606411
	0.99	0.411410008	0.99	0.8586726	0.99	0.272540426	0.99	0.051618161
	0.99	0.293442701	0.99	0.630562682	0.99	0.177317357	0.99	0.035615623
	0.99	0.288114245	0.99	0.657142795	0.99	0.152136458	0.99	0.016221689
	0.99	0.338098061	0.99	0.771428602	0.99	0.175022275	0.99	0.022800847
MV		0.356044285		0.77568541		0.21234144		0.034116291
Stddev.		0.044380989		0.073988333		0.054564151		0.017077853
Recovery rate		0.359640692		0.783520616		0.214486303		0.0344609

Source: own source.

Table A6: Simulation results of the positive counter information scenario after 10 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Seg ml	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
10	0.99	0.364045701	0.99	0.77168041	0.99	0.250355754	0.99	0.021110146
	0.99	0.344072323	0.99	0.771497262	0.99	0.18667134	0.99	0.029044372
	0.99	0.316963452	0.99	0.691188566	0.99	0.20879432	0.99	0.006564805
	0.99	0.320145925	0.99	0.777953558	0.99	0.127566293	0.99	0.010713256
	0.99	0.35860823	0.99	0.885754794	0.99	0.136744111	0.99	0.002445376
	0.99	0.341555898	0.99	0.771510144	0.99	0.203705089	0.99	0.00E+00
	0.99	0.339052622	0.99	0.79969703	0.99	0.154413391	0.99	0.017046582
	0.99	0.334548071	0.99	0.828632469	0.99	0.121358297	0.99	0.006837676
	0.99	0.344455209	0.99	0.885754794	0.99	0.093346214	0.99	0.00589952
	0.99	0.34232992	0.99	0.828632469	0.99	0.147583776	0.99	0.002180781
	0.99	0.342930465	0.99	0.800071307	0.99	0.159998094	0.99	0.023020581
	0.99	0.37169245	0.99	0.885754794	0.99	0.172880692	0.99	0.0039001
	0.99	0.296761179	0.99	0.714387819	0.99	0.129304564	0.99	0.004896149
	0.99	0.303871428	0.99	0.771508778	0.99	0.073042652	0.99	0.027594759
	0.99	0.346803437	0.99	0.800071175	0.99	0.18099451	0.99	0.011434826
	0.99	0.31178542	0.99	0.741867477	0.99	0.137171242	0.99	0.01373956
	0.99	0.353211238	0.99	0.820958883	0.99	0.181833798	0.99	0.007446
	0.99	0.308613418	0.99	0.742948982	0.99	0.136878504	0.99	0.002245992
	0.99	0.278396453	0.99	0.714387819	0.99	0.080291211	0.99	0.00E+00
	0.99	0.278110711	0.99	0.685826657	0.99	0.108103133	0.99	0.00E+00
	0.99	0.38163288	0.99	0.857823918	0.99	0.218088749	0.99	0.016878157
	0.99	0.334362714	0.99	0.771510144	0.99	0.177435056	0.99	0.007439647
	0.99	0.352668855	0.99	0.857193632	0.99	0.140540048	0.99	0.011540225
	0.99	0.37646062	0.99	0.857193632	0.99	0.204493616	0.99	0.01623361
	0.99	0.276143498	0.99	0.657265494	0.99	0.114961961	0.99	0.019546294
	0.99	0.311253642	0.99	0.828632469	0.99	0.059623731	0.99	0.001213238
	0.99	0.318139854	0.99	0.771510144	0.99	0.133302268	0.99	0.004851697
	0.99	0.358684198	0.99	0.885754794	0.99	0.134007593	0.99	0.005891209
	0.99	0.352292987	0.99	0.80006994	0.99	0.199514827	0.99	0.008127727
	0.99	0.33525665	0.99	0.828632469	0.99	0.123854612	0.99	0.006287238
	0.99	0.255673204	0.99	0.600143169	0.99	0.124901178	0.99	0.006358942
	0.99	0.333837965	0.99	0.770365104	0.99	0.176189073	0.99	0.008480009
	0.99	0.32539839	0.99	0.792397721	0.99	0.130446389	0.99	0.008009839
	0.99	0.276887398	0.99	0.629560227	0.99	0.153277721	0.99	0.009647053
	0.99	0.276669281	0.99	0.657265494	0.99	0.130306966	0.99	0.003396398
	0.99	0.3020718	0.99	0.685826657	0.99	0.170357968	0.99	0.008023939
	0.99	0.347497799	0.99	0.828619587	0.99	0.161684513	0.99	0.002971215
	0.99	0.33077679	0.99	0.77139023	0.99	0.161587351	0.99	0.014118419
	0.99	0.381331789	0.99	0.857193632	0.99	0.219493516	0.99	0.014970958
	0.99	0.363107648	0.99	0.857193632	0.99	0.176928742	0.99	0.003882724
	0.99	0.362339352	0.99	0.828632469	0.99	0.19095014	0.99	0.018284797
	0.99	0.225786965	0.99	0.571582006	0.99	0.070952023	0.99	0.003000183
	0.99	0.410451085	0.99	0.914315957	0.99	0.248479645	0.99	0.011575416
	0.99	0.275500772	0.99	0.600143169	0.99	0.176327388	0.99	0.012453589
	0.99	0.314518658	0.99	0.770415758	0.99	0.121584122	0.99	0.007729002
	0.99	0.361696528	0.99	0.792397721	0.99	0.236656989	0.99	0.005091264
	0.99	0.374292084	0.99	0.828632469	0.99	0.21410328	0.99	0.031115241
	0.99	0.278109453	0.99	0.657265494	0.99	0.137153143	0.99	0.00E+00
	0.99	0.340684297	0.99	0.829488365	0.99	0.137495897	0.99	0.007466019
	0.99	0.391144274	0.99	0.914315957	0.99	0.199499606	0.99	0.004362755
MV		0.330452517		0.779256333		0.156704702		0.009501346
Stddev.		0.038046499		0.08415003		0.045064057		0.00764647
Recovery rate		0.333790422		0.787127609		0.158287578		0.009597319

Source: own source.

A.4 Simulation results of the natural fading away scenario

Table A7: Simulation results of the natural fading away scenario after 100 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Segm1	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
100	0.99	0.616673003	0.99	0.942889967	0.99	0.659396199	0.99	0.186242815
	0.99	0.606196878	0.99	0.914285714	0.99	0.65577794	0.99	0.18891533
	0.99	0.565256996	0.99	0.857142852	0.99	0.618150808	0.99	0.163014051
	0.99	0.603371192	0.99	0.914285714	0.99	0.659430749	0.99	0.175234768
	0.99	0.584268552	0.99	0.882769208	0.99	0.62292153	0.99	0.190922647
	0.99	0.608824036	0.99	0.914285714	0.99	0.659430749	0.99	0.193410913
	0.99	0.576235538	0.99	0.857208498	0.99	0.639684101	0.99	0.174410429
	0.99	0.571195618	0.99	0.842376917	0.99	0.627198827	0.99	0.189480358
	0.99	0.519005594	0.99	0.771428571	0.99	0.564696775	0.99	0.171205744
	0.99	0.617969039	0.99	0.94285628	0.99	0.656055802	0.99	0.194499368
	0.99	0.627476842	0.99	0.971424544	0.99	0.658538941	0.99	0.189965409
	0.99	0.553034684	0.99	0.800336236	0.99	0.639740668	0.99	0.163359224
	0.99	0.591593048	0.99	0.914285283	0.99	0.621520482	0.99	0.180203435
	0.99	0.573039696	0.99	0.885714286	0.99	0.605586805	0.99	0.170281046
	0.99	0.583502554	0.99	0.857142857	0.99	0.64286919	0.99	0.194994459
	0.99	0.606471171	0.99	0.942857138	0.99	0.637520096	0.99	0.17779713
	0.99	0.560776195	0.99	0.80000352	0.99	0.649704778	0.99	0.177927636
	0.99	0.575915541	0.99	0.885714286	0.99	0.603536439	0.99	0.18225929
	0.99	0.602569823	0.99	0.914285715	0.99	0.638018308	0.99	0.197544717
	0.99	0.515082009	0.99	0.742857143	0.99	0.591497648	0.99	0.160192774
	0.99	0.610935952	0.99	0.94285705	0.99	0.640479146	0.99	0.189227612
	0.99	0.531055014	0.99	0.800028794	0.99	0.571264498	0.99	0.170341207
	0.99	0.601080347	0.99	0.914285714	0.99	0.644810986	0.99	0.184655005
	0.99	0.548468469	0.99	0.785230838	0.99	0.625617588	0.99	0.182238399
	0.99	0.530458063	0.99	0.743156533	0.99	0.626953513	0.99	0.169731822
	0.99	0.585384204	0.99	0.857142857	0.99	0.659430658	0.99	0.181944911
	0.99	0.522527209	0.99	0.742860663	0.99	0.598963513	0.99	0.176295824
	0.99	0.600271192	0.99	0.885714286	0.99	0.659430752	0.99	0.198234762
	0.99	0.563628349	0.99	0.857167629	0.99	0.642108959	0.99	0.129605143
	0.99	0.585702101	0.99	0.885714286	0.99	0.623445245	0.99	0.191654218
	0.99	0.604951429	0.99	0.928091199	0.99	0.636508352	0.99	0.191138621
	0.99	0.525978166	0.99	0.771428571	0.99	0.582327877	0.99	0.17387803
	0.99	0.583658694	0.99	0.857142861	0.99	0.645213145	0.99	0.192780304
	0.99	0.594602687	0.99	0.914281257	0.99	0.625068386	0.99	0.186101039
	0.99	0.57928092	0.99	0.870602242	0.99	0.612070311	0.99	0.201151755
	0.99	0.605552567	0.99	0.914285708	0.99	0.659414729	0.99	0.182524712
	0.99	0.598853045	0.99	0.885677128	0.99	0.657949891	0.99	0.195278629
	0.99	0.552776912	0.99	0.856796326	0.99	0.570575552	0.99	0.177322515
	0.99	0.559108852	0.99	0.80003282	0.99	0.642388694	0.99	0.180871072
	0.99	0.55144301	0.99	0.799999999	0.99	0.623936226	0.99	0.176884437
	0.99	0.575171162	0.99	0.825634027	0.99	0.659387839	0.99	0.184711696
	0.99	0.549907347	0.99	0.8	0.99	0.636452202	0.99	0.157163587
	0.99	0.586912085	0.99	0.857134805	0.99	0.659427514	0.99	0.187050911
	0.99	0.592429124	0.99	0.885714286	0.99	0.645356035	0.99	0.188515039
	0.99	0.463055017	0.99	0.685714286	0.99	0.497384335	0.99	0.163234999
	0.99	0.60389108	0.99	0.914285714	0.99	0.643732743	0.99	0.195282066
	0.99	0.546419235	0.99	0.771432091	0.99	0.636131397	0.99	0.179240046
	0.99	0.582488081	0.99	0.857142857	0.99	0.65943069	0.99	0.172291134
	0.99	0.569928222	0.99	0.857142857	0.99	0.606025458	0.99	0.192731038
	0.99	0.523000974	0.99	0.800303416	0.99	0.56358273	0.99	0.152136078
MV		0.57374755		0.856423031		0.628122916		0.180521563
Stddev.		0.033151097		0.064251385		0.033005978		0.013639583
Recovery		0.57954298		0.865073769		0.634467592		0.182345013

Source: own source.

Table A8: Simulation results of the natural fading away scenario after 50 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Seg ml	End Pj Segml	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
50	0.99	0.398924091	0.99	0.657295185	0.99	0.363935471	0.99	0.138311206
	0.99	0.533944149	0.99	0.857108807	0.99	0.532879272	0.99	0.158161072
	0.99	0.278547917	0.99	0.614502621	0.99	0.131315931	0.99	0.058371411
	0.99	0.474032504	0.99	0.800003881	0.99	0.453465305	0.99	0.11772763
	0.99	0.497485396	0.99	0.814502625	0.99	0.496927102	0.99	0.128283306
	0.99	0.580312258	0.99	0.971079849	0.99	0.56062962	0.99	0.147379812
	0.99	0.533896419	0.99	0.857477421	0.99	0.548512469	0.99	0.139333192
	0.99	0.430591344	0.99	0.685714286	0.99	0.466766209	0.99	0.090743901
	0.99	0.447257175	0.99	0.742857148	0.99	0.419961374	0.99	0.134235642
	0.99	0.374218973	0.99	0.657132574	0.99	0.361147038	0.99	0.059403697
	0.99	0.478517576	0.99	0.799999958	0.99	0.492722808	0.99	0.086882027
	0.99	0.497705607	0.99	0.800003881	0.99	0.511530947	0.99	0.128894724
	0.99	0.568648964	0.99	0.914285714	0.99	0.590408063	0.99	0.140020473
	0.99	0.434765544	0.99	0.799999991	0.99	0.328572849	0.99	0.132550166
	0.99	0.600083499	0.99	0.971428567	0.99	0.639473736	0.99	0.120892311
	0.99	0.524477136	0.99	0.885714286	0.99	0.512712705	0.99	0.116758965
	0.99	0.420446958	0.99	0.713971457	0.99	0.396089282	0.99	0.106418997
	0.99	0.468982146	0.99	0.771428987	0.99	0.460742789	0.99	0.125740079
	0.99	0.493443259	0.99	0.800036179	0.99	0.50012658	0.99	0.127954309
	0.99	0.532608243	0.99	0.885714244	0.99	0.538465402	0.99	0.113817889
	0.99	0.543607848	0.99	0.857179036	0.99	0.562753079	0.99	0.15543869
	0.99	0.303581684	0.99	0.54254247	0.99	0.274499409	0.99	0.058723424
	0.99	0.522182453	0.99	0.914287452	0.99	0.4686911	0.99	0.127133198
	0.99	0.425648389	0.99	0.71428613	0.99	0.410603352	0.99	0.106456901
	0.99	0.533323908	0.99	0.857146738	0.99	0.536257141	0.99	0.152108501
	0.99	0.514293528	0.99	0.914285714	0.99	0.431019739	0.99	0.144788731
	0.99	0.419309682	0.99	0.742857142	0.99	0.365482554	0.99	0.104635962
	0.99	0.489085568	0.99	0.71428613	0.99	0.562379964	0.99	0.14084145
	0.99	0.524436128	0.99	0.828607566	0.99	0.538544942	0.99	0.153109168
	0.99	0.389320144	0.99	0.628909458	0.99	0.403457001	0.99	0.093306278
	0.99	0.479456669	0.99	0.745734686	0.99	0.492140429	0.99	0.154001263
	0.99	0.469862057	0.99	0.768738515	0.99	0.46707918	0.99	0.124419546
	0.99	0.492275943	0.99	0.828537379	0.99	0.478341809	0.99	0.116227423
	0.99	0.527277039	0.99	0.885714286	0.99	0.500326694	0.99	0.14054232
	0.99	0.459826626	0.99	0.771464751	0.99	0.452715289	0.99	0.104545375
	0.99	0.436866709	0.99	0.742857143	0.99	0.413935923	0.99	0.106630453
	0.99	0.589678047	0.99	0.971428529	0.99	0.599889198	0.99	0.132389473
	0.99	0.515648233	0.99	0.857142853	0.99	0.498707683	0.99	0.137001818
	0.99	0.508567279	0.99	0.857142902	0.99	0.493759659	0.99	0.119171276
	0.99	0.527831098	0.99	0.885714281	0.99	0.518146728	0.99	0.121599148
	0.99	0.429500764	0.99	0.685714286	0.99	0.468961066	0.99	0.084547968
	0.99	0.49771335	0.99	0.8	0.99	0.51391688	0.99	0.126141472
	0.99	0.499343444	0.99	0.828571429	0.99	0.524580756	0.99	0.085800598
	0.99	0.522570911	0.99	0.88571429	0.99	0.489040966	0.99	0.138021905
	0.99	0.422219001	0.99	0.771113898	0.99	0.356545429	0.99	0.09179412
	0.99	0.52517034	0.99	0.85998457	0.99	0.5358379	0.99	0.122108251
	0.99	0.421909653	0.99	0.714285714	0.99	0.384352627	0.99	0.12462078
	0.99	0.451202341	0.99	0.657142947	0.99	0.515500965	0.99	0.135923239
	0.99	0.582181314	0.99	0.914282062	0.99	0.61656572	0.99	0.1546153
	0.99	0.521119283	0.99	0.871645522	0.99	0.489316897	0.99	0.149274789
MV		0.482277972		0.800351511		0.473394701		0.121555993
Stddev.		0.066526712		0.098035268		0.090531034		0.025243584
Recovery rate		0.487149466		0.808435869		0.478176465		0.122783831

Source: own source.

Table A9: Simulation results of the natural fading away scenario after 30 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Seg ml	End Pj Segml	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
30	0.99	0.447108555	0.99	0.857143507	0.99	0.357390269	0.99	0.073405779
	0.99	0.397423699	0.99	0.8043489	0.99	0.275673084	0.99	0.064720014
	0.99	0.47591074	0.99	0.883997123	0.99	0.376846774	0.99	0.115384588
	0.99	0.431902692	0.99	0.799997825	0.99	0.3833653	0.99	0.059085328
	0.99	0.336884563	0.99	0.685752086	0.99	0.252041592	0.99	0.02885592
	0.99	0.399937075	0.99	0.857142616	0.99	0.240236737	0.99	0.052847672
	0.99	0.34637546	0.99	0.742854904	0.99	0.233545017	0.99	0.015451625
	0.99	0.434714057	0.99	0.8	0.99	0.372593997	0.99	0.081020527
	0.99	0.322700166	0.99	0.714285787	0.99	0.176292632	0.99	0.036659064
	0.99	0.421255779	0.99	0.890062751	0.99	0.269344786	0.99	0.051543804
	0.99	0.398960525	0.99	0.742857143	0.99	0.342778563	0.99	0.063293425
	0.99	0.384376575	0.99	0.714292029	0.99	0.346014876	0.99	0.044230526
	0.99	0.407264217	0.99	0.800539176	0.99	0.338067417	0.99	0.029173032
	0.99	0.394513173	0.99	0.799999759	0.99	0.267287039	0.99	0.069875979
	0.99	0.478454828	0.99	0.942915902	0.99	0.35887068	0.99	0.076098415
	0.99	0.455303376	0.99	0.828571429	0.99	0.394377417	0.99	0.090904268
	0.99	0.421110367	0.99	0.800058759	0.99	0.352350271	0.99	0.059224022
	0.99	0.39074085	0.99	0.747744783	0.99	0.292645882	0.99	0.088680389
	0.99	0.391063083	0.99	0.800006676	0.99	0.273718781	0.99	0.050870908
	0.99	0.423581942	0.99	0.846463962	0.99	0.318824889	0.99	0.052436148
	0.99	0.400244599	0.99	0.771428572	0.99	0.310744287	0.99	0.071613662
	0.99	0.349435583	0.99	0.685714358	0.99	0.259893826	0.99	0.061575727
	0.99	0.419728545	0.99	0.8	0.99	0.329193045	0.99	0.081703262
	0.99	0.366309409	0.99	0.714285714	0.99	0.291553929	0.99	0.047551778
	0.99	0.405392369	0.99	0.828571429	0.99	0.292045087	0.99	0.043921961
	0.99	0.39168203	0.99	0.742857143	0.99	0.328418375	0.99	0.05578533
	0.99	0.333336328	0.99	0.685773117	0.99	0.236883528	0.99	0.034688341
	0.99	0.395475494	0.99	0.742863209	0.99	0.346510056	0.99	0.0473116171
	0.99	0.42364206	0.99	0.829110604	0.99	0.329130109	0.99	0.060859368
	0.99	0.43621502	0.99	0.885714286	0.99	0.305229417	0.99	0.064615747
	0.99	0.385482231	0.99	0.742857143	0.99	0.311378276	0.99	0.054999448
	0.99	0.368170484	0.99	0.771428571	0.99	0.256797844	0.99	0.027637463
	0.99	0.375589242	0.99	0.796683047	0.99	0.239602317	0.99	0.042964547
	0.99	0.344221257	0.99	0.656948193	0.99	0.27291525	0.99	0.062563506
	0.99	0.446611952	0.99	0.857201616	0.99	0.390002642	0.99	0.033634873
	0.99	0.366207445	0.99	0.743455149	0.99	0.25992799	0.99	0.050077821
	0.99	0.372620475	0.99	0.742857143	0.99	0.275895103	0.99	0.053523964
	0.99	0.35256685	0.99	0.742857143	0.99	0.224061032	0.99	0.04715163
	0.99	0.389302952	0.99	0.714292021	0.99	0.339009638	0.99	0.06882457
	0.99	0.365138798	0.99	0.71428639	0.99	0.290747994	0.99	0.044589212
	0.99	0.436176295	0.99	0.8	0.99	0.378261733	0.99	0.079282293
	0.99	0.425278083	0.99	0.828571429	0.99	0.323720771	0.99	0.073252712
	0.99	0.37621281	0.99	0.742857143	0.99	0.302379195	0.99	0.034600306
	0.99	0.339224345	0.99	0.685714287	0.99	0.268003017	0.99	0.018077629
	0.99	0.328062718	0.99	0.657149164	0.99	0.262054479	0.99	0.021138144
	0.99	0.423477559	0.99	0.857142857	0.99	0.290910381	0.99	0.072196419
	0.99	0.38657837	0.99	0.8	0.99	0.264509467	0.99	0.046666854
	0.99	0.431844988	0.99	0.861491082	0.99	0.321434405	0.99	0.059403556
	0.99	0.406905437	0.99	0.771428571	0.99	0.355244804	0.99	0.041899186
	0.99	0.395403273	0.99	0.771428571	0.99	0.317771343	0.99	0.047277676
MV		0.395922374		0.780079941		0.303929907		0.055063092
Stddev.		0.037704748		0.065554707		0.049353981		0.019910905
Recovery rate		0.39992159		0.787959537		0.306999906		0.055619285

Source: own source.

Table A10: Simulation results of the natural fading away scenario after 20 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Seg ml	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
20	0.99	0.393801722	0.99	0.796153459	0.99	0.288204107	0.99	0.04758858
	0.99	0.388682123	0.99	0.881867707	0.99	0.209114504	0.99	0.022794498
	0.99	0.339482161	0.99	0.726042569	0.99	0.220743265	0.99	0.02702373
	0.99	0.291875459	0.99	0.657142858	0.99	0.14380947	0.99	0.038473815
	0.99	0.396049835	0.99	0.857137473	0.99	0.251262019	0.99	0.027033376
	0.99	0.441318191	0.99	0.881917885	0.99	0.342554569	0.99	0.04250944
	0.99	0.355141541	0.99	0.799949829	0.99	0.185171507	0.99	0.034496912
	0.99	0.365935562	0.99	0.742857143	0.99	0.276666436	0.99	0.030341031
	0.99	0.409608467	0.99	0.885713709	0.99	0.234172287	0.99	0.058827896
	0.99	0.353629088	0.99	0.771428572	0.99	0.233780875	0.99	0.006019273
	0.99	0.354364087	0.99	0.744386886	0.99	0.250533476	0.99	0.0204732
	0.99	0.40059701	0.99	0.885738836	0.99	0.235795453	0.99	0.026866696
	0.99	0.397361952	0.99	0.885714286	0.99	0.221597203	0.99	0.032676436
	0.99	0.413647916	0.99	0.885738835	0.99	0.255428896	0.99	0.047464032
	0.99	0.369365903	0.99	0.8	0.99	0.240100386	0.99	0.017769227
	0.99	0.304295092	0.99	0.657142858	0.99	0.195853119	0.99	0.019154999
	0.99	0.355517004	0.99	0.771656359	0.99	0.21029318	0.99	0.039448883
	0.99	0.386327154	0.99	0.828571429	0.99	0.245066651	0.99	0.035179421
	0.99	0.306914744	0.99	0.714280331	0.99	0.151646366	0.99	0.012801335
	0.99	0.30308128	0.99	0.714285715	0.99	0.140808932	0.99	0.012660511
	0.99	0.339473911	0.99	0.771428572	0.99	0.17000993	0.99	0.033234786
	0.99	0.364773988	0.99	0.856680801	0.99	0.165606562	0.99	0.023244704
	0.99	0.380376674	0.99	0.824775028	0.99	0.225895919	0.99	0.042139475
	0.99	0.382929888	0.99	0.72604257	0.99	0.302202618	0.99	0.076813573
	0.99	0.281483908	0.99	0.600000001	0.99	0.186054132	0.99	0.02121654
	0.99	0.332686219	0.99	0.743084649	0.99	0.193990966	0.99	0.015699179
	0.99	0.365960172	0.99	0.771428572	0.99	0.243138863	0.99	0.036205232
	0.99	0.406473662	0.99	0.885714286	0.99	0.232607421	0.99	0.050203547
	0.99	0.368957938	0.99	0.824775031	0.99	0.220480235	0.99	0.010395315
	0.99	0.371102345	0.99	0.885714279	0.99	0.161704409	0.99	0.015019348
	0.99	0.300716842	0.99	0.653346457	0.99	0.185907197	0.99	0.023260209
	0.99	0.408573758	0.99	0.885664053	0.99	0.240486312	0.99	0.048070434
	0.99	0.401089798	0.99	0.857142795	0.99	0.272598434	0.99	0.018934561
	0.99	0.414028435	0.99	0.857142858	0.99	0.290510307	0.99	0.041166092
	0.99	0.431387854	0.99	0.828109919	0.99	0.365276997	0.99	0.045674778
	0.99	0.349304304	0.99	0.800002663	0.99	0.174367863	0.99	0.027582065
	0.99	0.352388584	0.99	0.743084649	0.99	0.238644751	0.99	0.029277648
	0.99	0.3851866	0.99	0.828571459	0.99	0.242534243	0.99	0.034332015
	0.99	0.370187367	0.99	0.800177647	0.99	0.225734686	0.99	0.037060169
	0.99	0.385215014	0.99	0.8	0.99	0.269892407	0.99	0.03584224
	0.99	0.425783694	0.99	0.857142918	0.99	0.321857294	0.99	0.043778734
	0.99	0.273429151	0.99	0.600002633	0.99	0.179822094	0.99	0.00163499
	0.99	0.391555203	0.99	0.799538484	0.99	0.277367067	0.99	0.048794202
	0.99	0.352511726	0.99	0.77142582	0.99	0.225066626	0.99	0.012464566
	0.99	0.308001084	0.99	0.685252776	0.99	0.180851346	0.99	0.01621547
	0.99	0.452343988	0.99	0.857087305	0.99	0.380288375	0.99	0.064208333
	0.99	0.390742073	0.99	0.85714228	0.99	0.233918443	0.99	0.0295694
	0.99	0.320024543	0.99	0.771428572	0.99	0.109228296	0.99	0.039315465
	0.99	0.397174203	0.99	0.910027804	0.99	0.198613703	0.99	0.03049892
	0.99	0.32790832	0.99	0.742857143	0.99	0.163893513	0.99	0.035151968
MV		0.367175351		0.793650375		0.228223074		0.031732145
Stddev.		0.042310757		0.078701882		0.056380009		0.015058581
Recovery rate		0.370884193		0.801667046		0.230528358		0.032052672

Source: own source.

Table A11: Simulation results of the natural fading away scenario after 10 days.

Run no.	Mean start Pj	End Pj	Mean start Pj Segm1	End Pj Segm1	Mean start Pj Segm2	End Pj Segm2	Mean start Pj Segm3	End Pj Segm3
10	0.99	0.277272668	0.99	0.56372028	0.99	0.21115876	0.99	0.020216681
	0.99	0.398703444	0.99	0.914315957	0.99	0.201182225	0.99	0.027596934
	0.99	0.277957653	0.99	0.714387819	0.99	0.075025512	0.99	0.005543292
	0.99	0.305991624	0.99	0.715328847	0.99	0.146054759	0.99	0.015024539
	0.99	0.295894427	0.99	0.714387687	0.99	0.110717336	0.99	0.023692231
	0.99	0.364316675	0.99	0.828632469	0.99	0.199611902	0.99	0.014770483
	0.99	0.345825605	0.99	0.715242348	0.99	0.21255228	0.99	0.070324949
	0.99	0.340182331	0.99	0.849400131	0.99	0.119517372	0.99	0.00353735
	0.99	0.332223119	0.99	0.777953558	0.99	0.153706485	0.99	0.020473681
	0.99	0.307540823	0.99	0.714267905	0.99	0.15776114	0.99	0.007768857
	0.99	0.326369818	0.99	0.800071307	0.99	0.121854514	0.99	0.01231927
	0.99	0.289184334	0.99	0.742948982	0.99	0.068295233	0.99	0.017496197
	0.99	0.366866314	0.99	0.857193632	0.99	0.177800762	0.99	0.015394254
	0.99	0.311578686	0.99	0.771510144	0.99	0.118099447	0.99	0.00E+00
	0.99	0.358513208	0.99	0.857193632	0.99	0.160659342	0.99	0.00754889
	0.99	0.32850502	0.99	0.777953558	0.99	0.146712126	0.99	0.016240104
	0.99	0.288439873	0.99	0.742723373	0.99	0.066237252	0.99	0.017678848
	0.99	0.366382288	0.99	0.857193632	0.99	0.186330616	0.99	0.003829336
	0.99	0.32540575	0.99	0.777953558	0.99	0.151545556	0.99	0.00E+00
	0.99	0.378900482	0.99	0.857193632	0.99	0.214533839	0.99	0.012652889
	0.99	0.390344442	0.99	0.857192265	0.99	0.245354099	0.99	0.01484405
	0.99	0.353580984	0.99	0.857193632	0.99	0.140776731	0.99	0.014304525
	0.99	0.256976566	0.99	0.600108387	0.99	0.12923936	0.99	0.005682847
	0.99	0.320433007	0.99	0.800071307	0.99	0.11327105	0.99	0.002543941
	0.99	0.299269462	0.99	0.685826657	0.99	0.159929592	0.99	0.010849249
	0.99	0.281406477	0.99	0.657265494	0.99	0.140705644	0.99	0.007055262
	0.99	0.328334821	0.99	0.857193632	0.99	0.079905306	0.99	0.001167309
	0.99	0.291889747	0.99	0.742948982	0.99	0.088765044	0.99	0.002632794
	0.99	0.365818549	0.99	0.885754794	0.99	0.157627468	0.99	0.002115857
	0.99	0.33240562	0.99	0.771510144	0.99	0.163384215	0.99	0.017308647
	0.99	0.31357237	0.99	0.742948982	0.99	0.135256857	0.99	0.020667756
	0.99	0.311875195	0.99	0.771510144	0.99	0.116838227	0.99	0.003177549
	0.99	0.380910854	0.99	0.857193632	0.99	0.207079744	0.99	0.028050573
	0.99	0.342184794	0.99	0.800071307	0.99	0.176603532	0.99	0.001162002
	0.99	0.300197377	0.99	0.714387819	0.99	0.138133206	0.99	0.006050061
	0.99	0.352879379	0.99	0.857193632	0.99	0.142773838	0.99	0.009635882
	0.99	0.302831907	0.99	0.714387819	0.99	0.144763683	0.99	0.007096272
	0.99	0.322202829	0.99	0.742948982	0.99	0.161629045	0.99	0.018668399
	0.99	0.292160875	0.99	0.742948982	0.99	0.090935873	0.99	0.00100392
	0.99	0.293640384	0.99	0.685826657	0.99	0.147893698	0.99	0.006127535
	0.99	0.330252029	0.99	0.742948982	0.99	0.178678356	0.99	0.025608203
	0.99	0.293457	0.99	0.685826657	0.99	0.1450709	0.99	0.008809519
	0.99	0.387489619	0.99	0.828632469	0.99	0.269359065	0.99	0.010641939
	0.99	0.342319439	0.99	0.820958883	0.99	0.128767779	0.99	0.033050356
	0.99	0.307573693	0.99	0.685826657	0.99	0.188475738	0.99	0.005226181
	0.99	0.29900095	0.99	0.742948982	0.99	0.107167269	0.99	0.004867541
	0.99	0.333476138	0.99	0.742948982	0.99	0.207786353	0.99	0.002395902
	0.99	0.311760161	0.99	0.714387819	0.99	0.172286857	0.99	0.004746747
	0.99	0.357132547	0.99	0.800927202	0.99	0.19102071	0.99	0.033169259
	0.99	0.339743092	0.99	0.771595277	0.99	0.191818116	0.99	0.008494682
MV		0.326423489		0.768621152		0.153213076		0.012585271
Stddev.		0.03332347		0.073653904		0.044627223		0.012082899
Recovery rate		0.329720696		0.776385002		0.154760683		0.012712395

Source: own source.

A.5 Object oriented modelling

In order to model such a multi-agent simulation it is useful to follow an object oriented way. The object orientation is best suited to represent agents, in this case consumers. Objects have certain states represented by their attributes and certain behavioural functions represented by their methods. They can process information and messages and they can also communicate with other objects. This communication can be done by using the event handling concepts, i.e. they can register at other objects to be notified if some kind of event occurs and they can then react in a predefined way.

Software development can be done in many different ways. The more complex the problem is the more effort has to be invested in order to solve the problem. It is often the case that many developers are working on the same problem. A structured software development process which can be divided into several tasks which can be handled in parallel can therefore support an effective and complete proceeding of analysing and designing software. In this approach an object oriented software development process will be presented. This process keeps track of the whole proceeding from the requirements analysis including the iterative discussions and project meetings with the stakeholders over the object oriented analysis (OOA) up to the object oriented design (OOD). It is use case driven and follows a stepwise discovering of the features and boundaries of the system that has to be developed. The coding is often easier to perform than the modelling and it is also less time consuming. Like a blueprint the modelling provides a framework for the programmer. The programmer then animates the predefined functions.

The example used here to show the proceeding of the software development process is only one business process several other business processes had to be developed in order to display the entire multi-agent simulation. Social processes which should be analysed by using computer simulations can be divided into basic processes – here called business processes – these sub-processes are identified by the requirements analysis. The business processes are a collection of organisational and technical interrelated activities. These processes will be sub-processed into use cases, so that a definite set of use cases form a business process (OESTERREICH 2001). The interaction of the use cases can be illustrated in a use case diagram. The use cases are then decomposed using activity diagrams which show sequences of actions forming these use cases. Parallel to this sub-processing the class-design (the different objects and their relations) are developed iteratively. At last the messaging concept is formulated which makes the objects respectively the agents communicate and thereby create a complex system.

1 Example of one business process: Bayesian updating as a trust updating mechanism for the individual agent

The Bayesian updating process for trust updating of the individual agents serves as an example for a sub-process respectively a business process to show this proposed software development process. Consumers in this multi-agent simulation update their trust in different kinds of suppliers by processing new information concerning the reliability of these suppliers.

2 Assumptions

Utility maximisation of agents will be the basic assumption used in this approach here. But some aspects have to be mentioned regarding this assumption. Agents behave rational but different from theoretical respectively mathematical approaches they are not homogeny. Homogeneity is a strong assumption. Simulations like multi-agent simulations offer the possibility to work with heterogeneous agents. The heterogeneous agents also behave rational but depending on their predefined processing capacity it is possible to have some different kind of rationalities like observed in the real world.

3 Requirements Analysis

There are important features to keep in mind while building a multi-agent simulation. Performance, flexibility and robustness have to be guaranteed in order to get the desired results. These features are partially contrary. Comparing for example performance and flexibility, then one has to admit that performance can better be achieved by procedural programming like in C, on the other hand it is more flexible to program in an object oriented way and also the modelling is more easy, because of the existing development architecture for example like in *Java*. This is one of the mayor decisions. Another important decision is to answer the question if the system should be developed from scratch or if an existing tool should be used which is consequently a black box.

Like in most decision cases it is also here that there are pros and cons for every alternative. If the system should be developed from scratch then there is full overview over the coherences and features, in particular the source code and the architecture is known in detail. This system is then especially developed for the concrete problem and avoids the overload of a Meta system. On the other hand an existing tool provides an already existing architecture with class libraries, observers, graphical user interfaces and memory-management but this has to be discovered and that takes a long time with intense workload and it holds the danger that it is not appropriate for the problem.

These decisions need some more information. And this information can be found out by the requirements analysis. The requirements analysis is the first step of the software development process. All the stakeholders have to be involved in order to discover the requirements the system should fulfil. The object oriented analysis (OOA) follows an iterative way. There are several rounds and especially with the stakeholders several meetings that help identifying all aspects which are not known or even can't be known in advance. The reason is that some conditions arise after other preconditions were formed, so that it was not possible in advance to determine these conditions. It is similar like building a cobweb. The basic objective is clear but the whole cobweb is formed by several rounds around the core going stepwise to the outer boundaries of the cobweb or in this case to the outer boundaries of the system which had to be developed.

Software development was done on an abstract level. And one method to do so is analysing and modelling processes. They can ideally be handled in computer science. A complex problem, namely the development of this multi-agent simulation, can be broken down into several processes respectively sub-processes. Here a behavioural model consisting of low-level individual agents who form by interaction a complex system with an aggregate outcome should be analysed.

4 Object oriented modelling

On the basis of the requirements analysis the object oriented modelling process starts with object oriented analysis (OOA). The entire social process will be sub-divided into basic sub-processes. One of the basic sub-processes is called a business process. An example for one of these business processes is the trust updating of the individual agent. The following graphic gives an overview of the entire analysing process for this one identified business process.

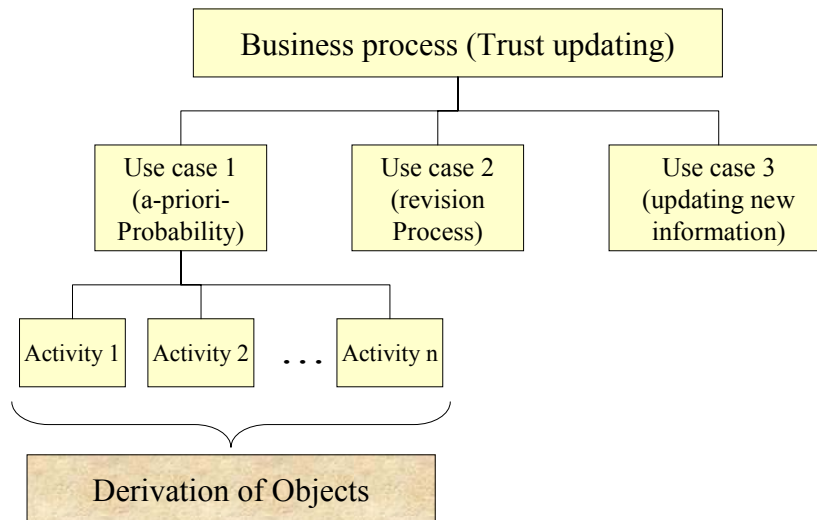


Figure A3: Object oriented modelling

Like stated above processes are very important for the development of a system. A complex problem will hierarchically be splitted into sub processes. A business process is a collection of organisational and technical interrelated activities that are in a temporal and logical dependency. A business process can itself be sub-divided into several use cases, whereby a use case describes the requirements the system should fulfil. In a further decomposition the use cases are broken down into activities from which the objects respectively their states can be derived.

In this way the properties of a system can be identified and visualised, which facilitates the communication with the stakeholders. The development of the system is a dynamic approach which follows an iterative procedure. Step by step the properties of the system will be detailed and refined until the boundaries of the system are fixed.

Use cases form a business process; the following use case diagram visualises the interaction of the single use cases and the actors respectively objects.

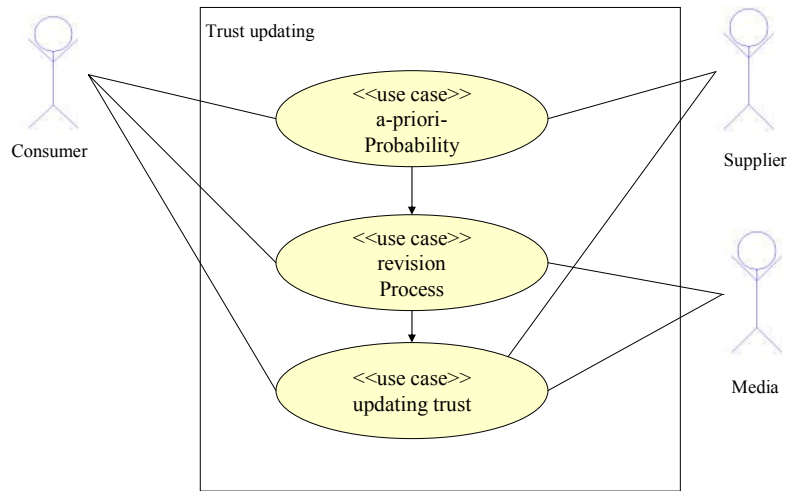


Figure A4: Use case diagram

The business process ‘Trust updating’ consists of three use cases which map the Bayesian updating process. Starting with an a-priori-probability of trust in suppliers continuing with new information, say a failure of a product, and the updating of new information respectively revision process and consequently the updating of the trust in this supplier. The relations to the actors are characterised by lines. The arrows show the <<include>>-relation, i.e. one use case can be included in another like in this example.

In another iteration the use cases itself will be detailed respectively decomposed. This can be done in an activity diagram. One use case consists of several activities which are interconnected in a sequence. This sequence can be branched and the branches must be endowed with conditions. In this example the use case << a-priori-probability>> serves to visualise this procedure.

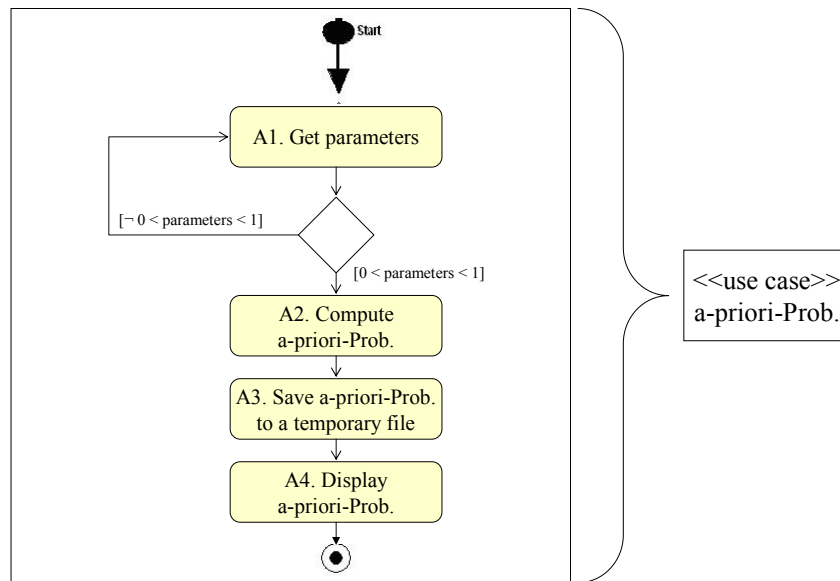


Figure A5: Activity diagram

This simple example is of course not complete but one can imagine that in several iterations all the conditions and branches can be identified and finally all the relevant objects can be identified. This has to be done for every business process like for example for the network set-up and the exchange of information.

Classes are the abstract blue prints of objects. They contain the attributes respectively the state of an object, say for example age, family status and risk attitude. They also contain operations like behavioural functions and statistical functions supporting the overall statistics for the aggregate outcome. The objects are derived from the classes and instantiated in an arbitrary number, i.e. objects are concrete instances of a class.

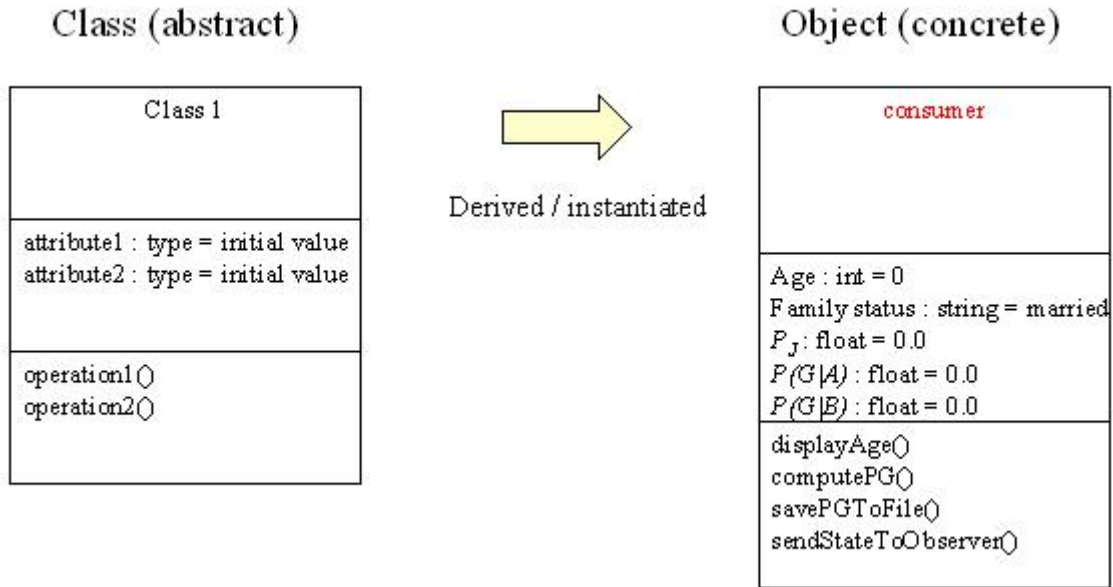


Figure A6: Object of type ‘consumer’

The most important classes respectively objects of the system and its relations can be displayed in a class model. There is a class called ‘graphical user interface’ which is related to the observer class here called *controller*. The observer class itself is related to a collection of classes which display the main part of the simulation.

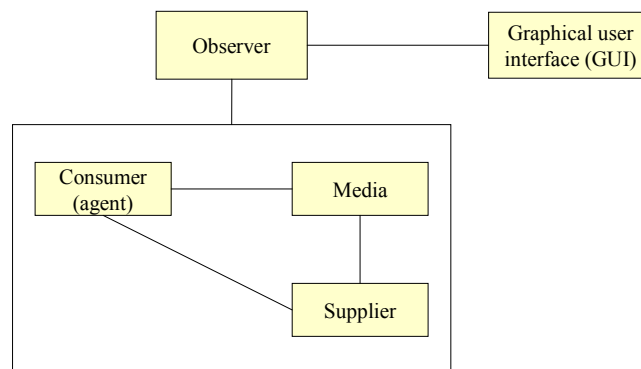


Figure A7: Class diagram

This is again only a snapshot and not a full model but it shows how to model such a class system. With this class concept it is possible to model simulations with artificial agents. Objects

possess a previously defined number of operations. Some of these operations can be modelled in a way that they can handle messages, i.e. they can get messages, process them and send them to other objects. Communication can happen via these messages; locally, in restricted areas or globally, this depends on the design of the operations. In this context the Event handling concept plays a crucial role. Objects can register at other objects to be notified if something happens, for example a change of the state of an object. When an event occurs, e.g. news releases by media agents, the registered object will get a message and can then process it in the defined way. This messaging concept can be used to simulate the communication about food safety information:

- Generate a set of objects of the type ‘consumer’ and also generate facilitating objects that support the simulation and all the features that are desired.
- Generate a set of messages which makes the consumers communicate. This communication again produces messages and will lead to some kind of dynamics.
- During this simulation procedure some overall statistics can be done, the results can be collected and thus an aggregate market outcome in which form ever will be produced.

The multi-agent simulation was programmed in *Java*. This is an object oriented programming language which offers a rich bibliography of already existing classes that support the concepts described above. The multi-agent simulation was developed from scratch.

A.6 Example set-up of the multi-agent simulation

1 The Installation Process

The simulation model is compatible with most current software such as Windows, UNIX, Linux, or Macintosh. System requirements comprise at least 256 MB-RAM and one GB central memory. Since the simulation model is composed in *Java*, the computer inevitably needs to have installed the so-called *Java Virtual Machine (Java VM)*, which can be downloaded free of charge from on <http://java.sun.com/products/>. Choose *Java VM* from the menu *Hot Downloads* and follow the instructions on the SUN-homepage to install the *Java VM* on your drive C:\. To start the installation process, insert the CD-ROM which will then open a directory called *SimTrust.zip* on your desktop. This file is to be unzipped and then saved to drive C:\, again. It contains both the simulation software “SimGUI3.jar” which is a *Java* archive file and Excel-files to create a scenario of different information distributions for centralised media agents that will later be thoroughly elucidated.

To start the simulation open the unzipped file *SimTrust* and double click on *StartSimTrust.bat*. This batch file will automatically invoke *SimGUI3.jar* which is the simulation software. Alternatively open a DOS window, change to directory C:\SimTrust\ and write the following command line "java -jar SimGUI3.jar". It opens the graphical user interface (GUI) of the

simulation model (Note that the simulation software needs to be uploaded which takes a little time due to the complex environment! Also the simulation runs need a little while depending on the parameter setting.). Please follow the example to explore the model.

2 Simulations via Graphical User Interface (GUI)

The GUI of the simulation model is illustrated in figure A8.

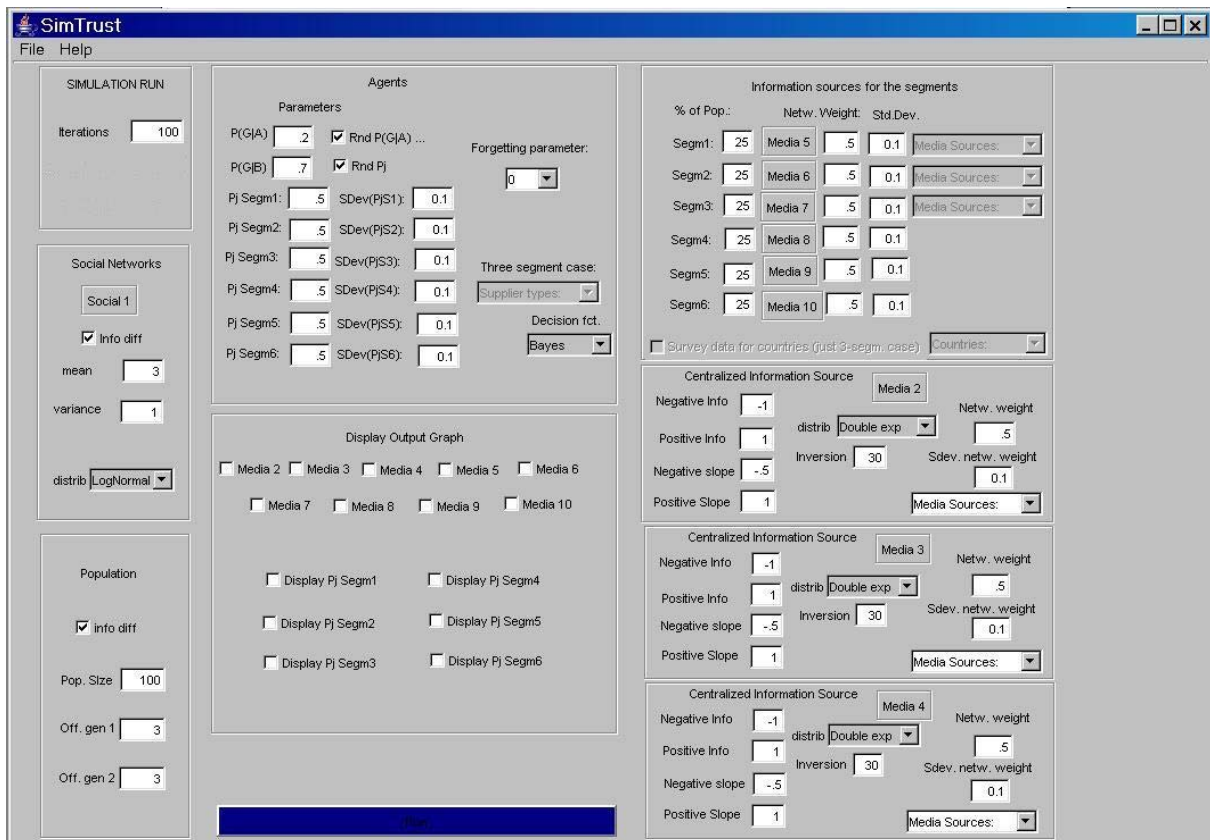


Figure A8: Graphical User Interface of the simulation.

The GUI consists of nine panels which are shown in figure A8: 1) Simulation Run, 2) Agents, 3) Social Networks, 4) Population, 5) to 7) Centralized Information Sources, 8) Centralized Segm Info Sources and 9) Display Output Graph. All panels offer the opportunity to manually adjust the respective parameters as explained in the following.

2.1 Simulation Run

This panel (figure A9) contains a variably set number of iterations. In the case illustrated below, the value 100 indicates that the simulation will cover a period of 100 days.

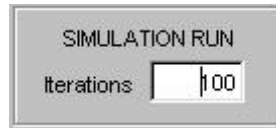


Figure A9: Simulation controller panel

2.2 Agents

This panel displays the possible parameter settings for the agents (figure A10).

$P(G|A)$: The probability to buy an unsafe unit of a reliable supplier A.

$P(G|B)$: The probability to buy an unsafe unit of an unreliable supplier B.

P_j : The probability that a supplier j is reliable (the trust value).

Conditions: $P(G|A) < P(G|B)$ and $P(G|A) + P(G|B) < 1$.

These values can be set by the user; they are the initial values for the Bayesian updating for each agent. This Bayesian updating is used as a reinforcement learning mechanism based on new information in a single decision situation and it produces an updated trust value for each agent.

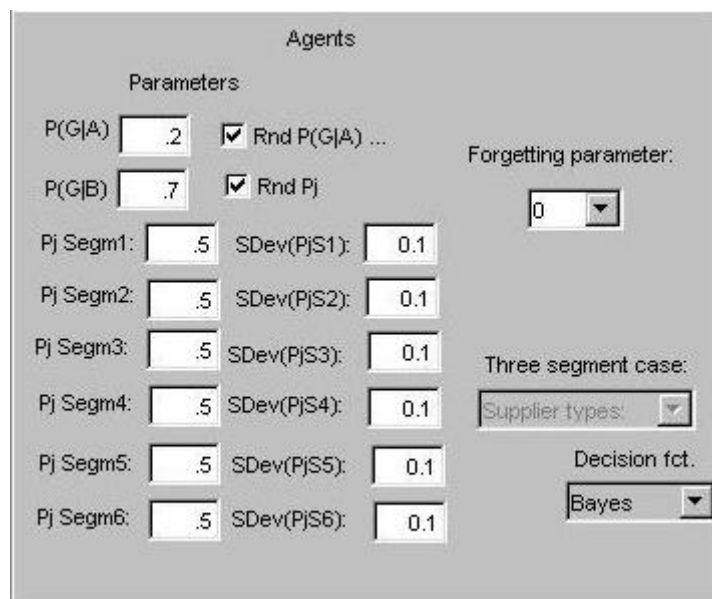


Figure A10: Agent's panel

Rnd P (G|A): When this field is selected then each agent will receive random values for $P (G|A)$ and $P (G|B)$.

Rnd Pj: When this field is selected then each agent will receive a random value between 0 and 1 as a starting value for trust.

Decision fct.: The user can choose between different decision functions for the agents: Bayesian updating and Extended Bayesian updating.

Pj Segm 1: If *Rnd Pj* is not chosen then the user can set explicitly the trust values for each consumer segment.

SDev(PjS1): In this text field the user can set the standard deviation for the trust value for segment 1.

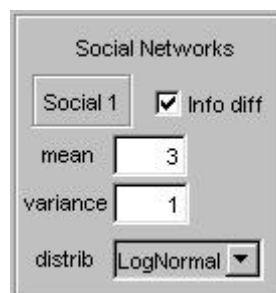
The survey segmentation analysis has identified three trust segments. These segmentation data can be uploaded for the respective country into the multi-agent simulation.

Supplier types: The combo box offers the possibility to choose different supplier types, e.g. supermarket. The simulation then loads the data from the survey analysis for the trust values with respect to supermarkets. *Pj Segm n* will be filled with the trust value for the supplier j , the supermarkets, and also for $SDev(PjSn)$ the standard deviation for j .

The simulation takes the trust values which are in the text fields, i.e. when the run button was pressed the values can't be changed but before even when the segments are chosen it is possible to overwrite the values. This is the highest degree of freedom, i.e. the user can always overwrite the values. This holds for all the text fields until the run button was pressed then the simulation starts.

2.3 Social Networks

This panel displays the parameter options for the social networks of each agent. The social networks might be friends' network or colleagues' network or other social networks. These are random networks that are not determined like the family network, i.e. each agent randomly receives a variable number of links which connects him to agents that are no family members. The members of these social networks are again the members of the agent population, which already form the family (demographic) network.



Screenshot of the 'Social Networks' parameter panel. The panel is titled 'Social Networks' and contains the following elements:

- A button labeled 'Social 1'.
- A checkbox labeled 'Info diff' which is checked.
- A text field labeled 'mean' with the value '3'.
- A text field labeled 'variance' with the value '1'.
- A dropdown menu labeled 'distrib' with 'LogNormal' selected.

Figure A11: Social network panel

Info diff: For these networks there can be selected if the information values shall be diffused among the agents or if they should just receive information from the centralised media sources.

Mean: In this text field there is the number of connections to friends.

Variance: In this text field the user can type in the variance from this mean out degree value of links.

Distrib: In this field the user can choose between different distributions of the out degrees. These distributions take the mean value and the variance and assign to each agent a number of links to friends randomly.

2.4 Population

This panel has one check box, which is to activate the diffusion of the info value (see figure A12).

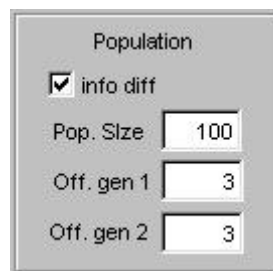


Figure A12: Population panel

Info diff: To enable and disable the diffusion of information in between the agents; if it is disabled then the agents just receive information from the centralised media objects.

Information communication: The agents can communicate their information status and update it according to the internal mechanisms. The updating of the information value follows an algorithm: each agent collects the information values of its neighbours and computes the mean information value. This will be done for each network, i.e. asking the family, asking the friends from the social networks and asking the information value of the centralised media agents. Each aggregated information value from each network in which the agent is present will be weighted with its corresponding weight, then the mean of these weighted information values will be assigned to the updated information value of this agent. This will be done for every agent.

Pop. Size: This text field can be used to set the number of the population members, i.e. the number of the whole consumer agent population.

Here the family structure (the demographic network) will be formed with three generations. The agents will be grouped together in a family structure with a grandparent's generation, a parent's generation (offspring 1) and a children's generation (offspring 2).

Off. gen1: This text field can be used to set the average number of the first generation offspring.

Off. gen2: This third field is for the average number of the second generation offspring.

2.5, 2.6 and 2.7 Centralised Information Sources

The centralised information source panel displays the properties of the media agent, i.e. the media and the parameter setting area for the properties of the information releases (see figure A13). The information release distribution is a time related distribution – one iteration is one day.

Centralized Information Source

Media 2

Negative Info

Positive Info

Negative slope

Positive Slope

distrib

Inversion

Netw. weight

Sdev. netw. weight

Media Sources:

Figure A13: Centralised information source panel

Netw. weight: This value is the trust value for the media source, i.e. the relative weight for this information source which influences the aggregated information value.

Sdev.netw.

weight: This is the standard deviation for the network weight of this information source. Each agent belongs to a segment or will randomly be equipped with an initial trust value. This initial trust value comes from a random distribution where the network weight enters as a mean value and the standard deviation as the second moment.

The user can chose between different media sources. Depending on the media source the data from the survey will be loaded into the text field. For these global media sources (they reach everybody) the data will be the same but of course different for the different media sources.

- Negative Info:* This is the starting value for two kinds of predefined information release distributions: double exponential distribution and exponential distribution, i.e. starting in the first iteration (day) with a negative information with the intensity -1 (e.g. first page of a newspaper with a picture of harmed people) and then continuing with less intense negative information regarding the safety of the food item under investigation.
- Positive Info:* The same holds for positive information but only for double exponential, since plain exponential is just a distribution of negative information releases.
- Distrib:* You can choose between two predefined information release distributions and one manual distribution. If choosing predefined distributions you will have the opportunities between ‘Double exponential’ distribution and ‘exponential distribution’. For these distributions you can also modify the following parameter.
- Inversion:* This text field offers the possibility to set explicitly the day when the news release changes its sign, i.e. when negative information (food is unsafe) changes to positive information (food is safe).
- Negative slope:* The negative slope is the curve of the negative exponential distribution, i.e. here the user can change the intensity of the information release values in time by changing the slope (a lesser value decreases the curve and keeps thereby the decreasing of the intensity slower in time and vice versa).
- Positive slope:* The same holds for the positive slope but also just for the double exponential distribution since the plain exponential distribution just has negative information values.

Manual distribution: *‘import distr.’*

This method offers the highest degree of freedom to set an information distribution. The user can open an Excel-file which is in the same directory like the simulation (SimTrust) and set explicitly the information value for each day of the whole iteration time. After the setting of the information distribution the user has to save the file as a .txt document (ASCII) which will then be read by the simulation during runtime, e.g. open Media2.xls which is filled with zeros and insert information values within the range of -1 and 1 for the days of information report-age then save the file as Media2.txt (important: do not change the xls-file, the zeros should be maintained!). The Excel-program will ask you if it should overwrite Media2.txt – this is necessary in order to set the new information distribution.

In this panel the intensity of the information which will be released can be set explicitly, i.e. negative information can have a different intensity than positive information. The inversion text field offers the possibility to set the changing of the sign, i.e. when negative information

becomes positive (food is not safe – food is safe). Another feature is the possibility to choose different information release distributions: exponential, double exponential, imported empirical data distribution (explicitly set by the user via an Excel sheet) as information release strategies.

The slope of the curves can also explicitly set and finally the weight of the network for the agent can be set explicitly. The weight of the network can be interpreted as a placeholder for the importance of this information source for the agents, i.e. the higher the weight is, the higher is the influence of this information source regarding the trust building of the agent. TV has for example can have a higher weight than a local newspaper. The Centralized information source can also be a shopkeeper; in this case the empirical data from the survey regarding trust of different information sources plays a crucial role, i.e. if the butcher is more trustful than the newspaper, then this weight value should be higher for the shopkeeper agent (e.g. Media 2).

The intensity of the information can also be set explicitly: -1 for negative information and 1 for positive information are the highest values. If a Centralized information source like the shopkeeper should release information then the intensity of the information is probably less than information release from the television, e.g. for positive information – shopkeeper 0.5 and television 0.8.

2.8 Information sources for different consumer segments

The data analysis of the Trust-survey was done by WP4. The objective was to identify socio-demographic and personality segments which determine differences among consumers' attitudes towards specific food risks and with respect to the trust they place upon various information sources (according to Technical Annex). WP4 applied two different approaches: one which led to four segments and one which led to three segments. The approach with the four different consumer segments identified “the conservatives”, “the young intellectuals”, “the well-off” and “the stop-workers”. The basis for the segmentation was a cross country comparison. For the five EU-countries (United Kingdom, Italy, Netherlands, France and Germany) which have participated in the survey there are different sizes of the segments. The 3-segment case was done with respect to identify consumer segments according to trust. The 4-segment case is of no relevance since the results were not satisfying according to WP4.

The user can choose between these country scenarios by selecting *Survey data for countries* for the 3-segment case (see figure A14).

	% of Pop.:	Netw. Weight:	Std.Dev.:	Media Sources:	
Segm1:	25	Media 5	.5	0.1	Media Sources: ▼
Segm2:	25	Media 6	.5	0.1	Media Sources: ▼
Segm3:	25	Media 7	.5	0.1	Media Sources: ▼
Segm4:	25	Media 8	.5	0.1	
Segm5:	25	Media 9	.5	0.1	
Segm6:	25	Media 10	.5	0.1	

Survey data for countries (just 3-segm. case) Countries: ▼

Figure A14: Media policy panel

Segm1: In this text field the number of percentage for the first segment of the consumer population can be inserted manually. The same holds for *Segm2*, *Segm3*, *Segm4*, *Segm5* and *Segm6*.

Each segment can be addressed by a specific centralised information source, e.g. Media 5 for segment 1. In this way just the single addressed consumer segment (a subset of the population) receives the information released by this centralised media agent. A single segment directed information policy can thus be implemented using this media agent. The network weight can be set according to the intended influence of this information source regarding the trust building.

Netw. Weight: Like for the other centralised media agents.

Std. Dev.: Like for the other centralised media agents.

Survey data for countries: If this opportunity is selected then the values for the chosen countries will be displayed in the text fields for the different segments otherwise the distribution of the percentage values for the segments of the population can be set explicitly. (Note: if the sum of the percentage values are less or more than 100 then the simulation will adapt the first segments until the sum will be 100!)

It is possible to employ up to six segments. The population of consumer agents will be assigned to the segments according to the percentage number in the respective text field. The simulation starts to assign the agents of the population to the first segment then to the second

segment on so on. If for example the percentage number for the first segment is 50 and the percentage number for the second segment is 51 then there are just two segments, i.e. the first segment with 50 % of the population and the second segment with the remaining 50 % of the population, the rest will be cut. And even if the other text fields are filled with number they won't be applied, i.e. if the hundred percent is assigned then the population is also fully assigned to the segments.

2.9 Display media graphs and segment trust values

In order to reduce the number of output graphs the simulation software is predefined with only a limited number of output graphs. But the user can select also the output graphs for the information release distribution by the media (centralised) agents and for the segment trust values (see figure A15). (Note: Media 2, 3 and 4 are reaching all the agents of the consumer population – global information sources – whereas Media 5, 6, 7, 8, 9 and 10 are each restricted to one consumer segment, see figure A15).

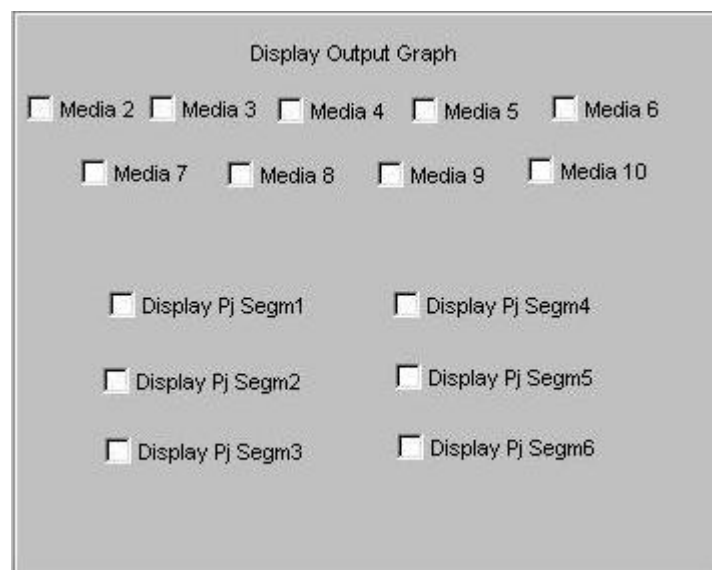


Figure A15: Display media graphs panel

Media 2: The user can select the output graph for Media 2.

Display Pj Segm1: The user can select the output graph of the average trust value of this consumer segment.

2.10 Run-Button

If the GUI mode is selected (this is predefined), then the parameter changes can be done via the graphical user interface (at least some of the parameter changes). The simulation will then be started via the run button (figure 16).



Figure A16: Run-Button

3 Output area

After pressing the Run-Button the simulation starts computing and after the processing time which depends on the parameter constellations and the iteration time, it produces some output files and graphics. Before pressing the Run-Button it is possible to change the input parameters various times but once the Run-Button is pressed the simulation takes the input parameters and computes the output for this scenario.

3.1 Information release strategy

The information release strategy was selected and parameterised by the user and will be visualised by the simulation in an output graph. An example is displayed in figure 17 where a double exponential distribution was chosen with decreasing intensity of the information when time continues.

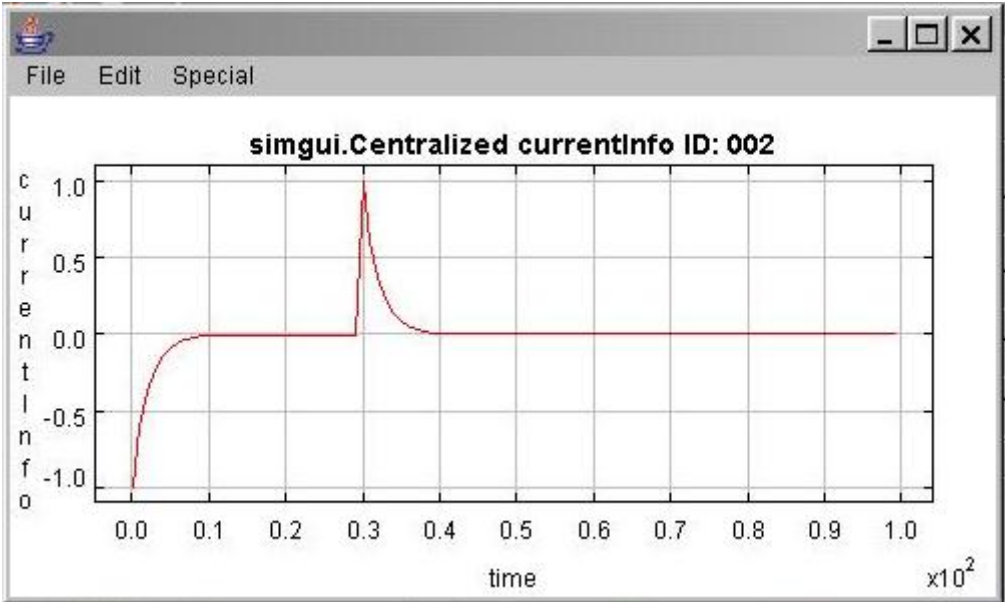


Figure A17: Information release strategy

This information release distribution starts with an intensity of -1, i.e. a very strong negative news reportage regarding a food scare. The time scale is the x-value times 10^2 , e.g. $0.1 \cdot 10^2 = 10$ which means at 0.1 on the x-axis the information value (intensity) at day 10 can be derived from the y-axis. In this example at day 10 this information source respectively the centralised media agent does not longer report about this food safety issue whether negative nor positive. At day 30 (set by the user in the inversion text field) this media agent reports that the food under investigation is safe, i.e. positive information again with strong information intensity (may it be in the television at prime time).

3.2 Trust building on the individual level

The agents update their own trust value based on the new information and on the information which comes from their networks.

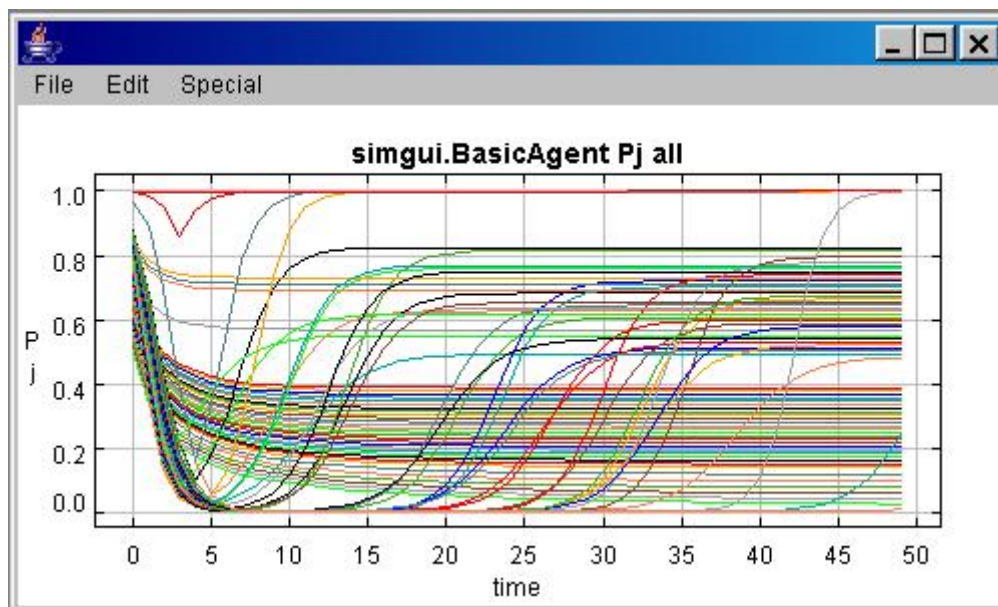


Figure A18: Trust building on the individual level

Figure A18 displays the development of the trust value (P_j) of the single agents. The consumer agents update their trust value each day; they are equipped with the starting parameters heterogeneously. In the example above there was an initial population of 100 agents which are represented each by a single coloured line and the duration of the simulation run amounts to 50 days.

3.3 Aggregated trust

On the aggregated level the development of the average trust value of the population emerge by taking the new information release into account on the micro level and communicating and updating accordingly.

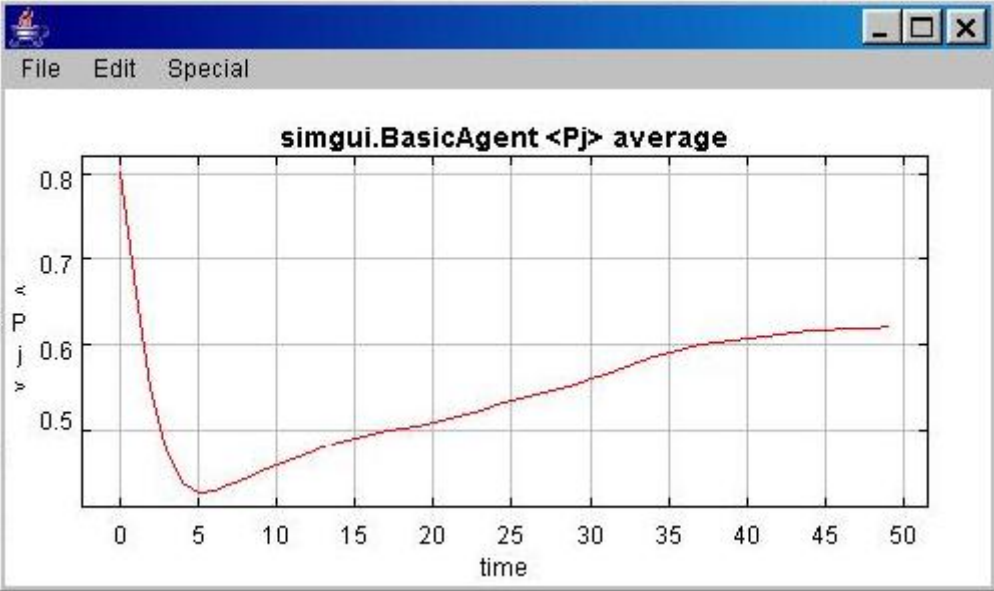


Figure A19: Aggregated (mean) trust

4 Summary

This example set-up of the multi-agent simulation shall give an overview of the capacious simulation model which is designed to illustrate the consumer’s intention to conduct a particular behaviour. At the present stage, the behaviour in question the consumer’s intention to purchase chicken following either alarming or assuasive information about the product’s innocuousness.

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