Faculty of Computing & IT

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Self-Organized Food Safety Systems: An Agent-Based Model

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Declaration of Authorship

This is to certify that this project titled, “Self-Organized Food Safety Systems: An Agent-Based Model” is done in partial fulfillment of the requirements for the award of the degree of M. Sc. in Computer Science and the same has not been submitted elsewhere for the award for any other degree.

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I dedicate this study from bottom of my heart to loving

parents and my wife for their endless

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I also dedicate this work to my whole family and friends

their supportive words and encouragement

during my study period.

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me since I was kid till the moment of writing

these simple words.

Abstract

This thesis presents an agent-based model of food safety management. The model proposed by McPhee-Knowles, 2015 involving consumers, regulators and stores is extended to evaluate the phenomena of "the wisdom of crowd" towards conditions leading to more efficient and dependable system. Through multi-parameter simulation, it is revealed that consumers, regulators and stores effect one another in interesting ways. The model presented by McPhee-Knowles, 2015 is successful in combining various sub-systems which are relevant; such as, inspection system, immune system, effect of consumer avoidance, and stores signaling on their own, and investigated inspectors behavior influence on the food safety. We extend this model to investigate about consumers and store owners, the social dimension. We propose that consumers and owners of the stores accepting existence of "the wisdom of crowd", can make good decision; good for themselves, but at the same time, beneficial for the society as a whole. For example, more vigilance in correction measures by stores (if contaminated) ensures a majority consumers still loyal to the contaminated store. We also replaced stores self-signaling by social networking, acting as a medium to spread the information and helping other consumers finding stores which are not contaminated. As a whole these findings also conform to self-organizing behavior of the population. It is evidenced that an active society has a capability to self-organize even in the absence of any regulatory compulsion. The implications of these findings are enormous. System components taking a self-organized corrective corrective action resists against system going towards a highly skewed distribution, thus, improving its stability and robustness.

Key words: Food safety, Agent-based modeling, wisdom of crowd. social simulation

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List of Abbreviations

CSS	**Computational Social Science**
ABM	**Agent-Based Modeling**
H1	**Hypothesis number 1**
H2	**Hypothesis number 2**
FDA	**Food Drug Administration**
FRMQ	**Food Risk Management Quality**
WHO	**World Health Organization**
BSE	**Bovine Spongiform Encephalopathy**
SMAS	**Superficial Musculo-Aponeurotic System**
FIFO	**First-In, First-Out**
ASC	**Aquaculture Stewardship Council**
FTA	**Free Trade Agreement**

Chapter 1

Introduction

1.1 Introduction

Food safety is a growing concern. The population of the world is increasing exponentially. This growth is uneven, where, the population in economically poor countries is growing more rapidly than the economically stable countries McPhee-Knowles (2015). It means that the countries which can spend more on food safety are less vulnerable, and, already have better systems and healthcare facilities. Whereas, countries which have issues in their economics systems and healthcare, are most likely to suffer more due to exceptional growth in population.

Scientific advancements provide opportunities towards standardized harvesting and logistics procedures, and safeguarding against contamination in stores. But still a lot needs to be done McPhee-Knowles (2015). This is evident from on going concerns in government circles Marks (2015) and Kim (2013) and communities Borrusso and Quinlan (2013) and Unnevehr and Grace (2013). At operational level, no doubt, the regulatory authorities of a country have a major role, which should have an effective, and robust mechanism to deal with modalities of food contamination.

Over the past years, the global food distribution and supply chain has become very complex due to an increase in the population in general, and more specifically, an increase in farmers, suppliers, traders and consumers. This has led to several food safety crises recently. Due to this,

a debate is underway towards many solutions, including, making more strict laws, rethinking about prevalent industrial practices and a fresh approach to understand consumers' behaviors Birk-Urovitz (2011). For example, the scandal in the European Union when horse meat was found in ready-made foods that were classified as beef products, led to the request for a new law that is more stricter Birk-Urovitz (2011).

Assessment and correction of food contamination is usually done using food inspection programs in which, stores providing food get central attention. However, it is observed that due to lack of standards, the allocation of inspection resources and agreeing on contamination thresholds has become a challenge Hoag et al. (2007) and Thanh (2015). On the other hand, consumers are equally important Thanh (2015). The psychological factors representing the perceptions Van Kleef et al. (2007) and Kher et al. (2013) and attitudes Bredahl (2001) of consumers about the food quality is as important as food inspections mechanisms.

Most social systems including food delivery and consumption evolve with time, based on society's needs and restrictions. However, most of these systems are far from perfection due to:

- Diversity of human race, which manifests into a heterogeneous population in terms of resources, and capabilities.
- Inherent lack of balance in human cognition due to selfishness and drawbacks in social and political justice.
- Existence of a gap between social / scientific knowledge and development of an individual, which practically keeps these system in a state often not optimized.
- Flaw in human knowledge and judgment.

Computational Social Science (CSS) McPhee-Knowles (2015) is a young discipline, which focus on using computations to solve social problems. It uses the power of abstraction and modeling to mimic real systems in a formal way so that computers can understand and process

them. Agent-Based Modeling (ABM) McPhee-Knowles (2015) is a front-runner modeling technique used in CSS. In ABM, real objects of interest are modeled as agents having a simplified representation of their characteristics, behaviors, and interactions. Many of individual agents then interact (work together) in a sequential time progression transiting from one state to another representing an evolving society.

The problem of food safety has been tackled with ABM Utomo, Onggo, and Eldridge (2017). Naturally, the entities of interest i.e. farms, warehouses, trucks, stores, workers, consumers and regulators, etc. Depending on the problem scale, some entities would be relevant and some are not.For example, food safety from a consumer view point can only focus on the landscape in which a consumer is interacting with the food items. Recently, such a simplistic model is presented by Knowles McPhee-Knowles (2015). The model only have three type of agents; consumers, stores and regulators. The purpose of the model is to investigate the effect of information sharing between stores and regulators on the quality of food consumed by the consumer.

This thesis presents an agent-based model of food safety management. The model proposed by McPhee-Knowles (2015) involving consumers, regulators and stores is extended and updating to evaluate the phenomena of "the wisdom of crowd" towards the conditions leading to safer and more dependable food system. Knowles considers two information modalities from stores to regulators. First is when a store starts "signaling" on its own if it is contaminated. In this case, a regulator would promptly visit the store to sterilize it. The second is when contaminated store does not signal and regulators' visit are purely random. In both cases, the consumers, if encountering a contaminated store, register that store in the "bad_stores" list (maintained at global level and accessible by all the consumers at the same time), and never visit it again. This adhere to well accepted notion of **the wisdom of crowds** Surowiecki (2005).

However, we have updating Knowles model as following. Knowles does not model the effect of consumers not visiting a store in the store's decision itself. The model keeps a store in

contaminated state until it is visited by a regulator. The store does not have to take any action against decreasing number of consumers. We categorize stores as "vigilant" and "indifferent", where vigilant stores are responsive to the wisdom of crowds and take effective and timely means to improve the quality of the product. To support this mechanism, we have related a store's contamination with the quality of the product it has. Also, the quality does not abruptly switches between the extremes (contaminated and sterilized), but improves and degrades progressively.

With these enhancements, the model proposed in this thesis is able to investigate the effect of vigilance of stores on consumers' health. Our hypothesis is that **more vigilant service providers** – in a situation of decreasing crowd interest due to degradation in the quality of service – **would keep a large fraction of population** – people who do not have prior experience with the service provider – **a potential customer when compared to a service provider who is indifferent**. The consequence of it would be a more fair distribution of customers across competing service providers, thus, improving dependability of the overall system. In the second phase of the model, we consider, social networking as means of disseminating the information about "good" stores. Instead of a store signaling its contamination status, consumers' experience makes it good or bad. This information is private to the consumers and can be shared with their friends. We expect **social networking-based information sharing would improve the consumers' experience as a whole**.

In the following, we specify these hypotheses more explicitly:

- **Hypothesis 1 (H1):** More vigilant crowd, both consumers' and stores, would not only improve the quality of food provided and consumed.
- **Hypothesis 2 (H2):** Social networking-based information sharing would improve the consumers' experience further, consequently rapidly improving the quality of food provided.

In the rest of this chapter we provide a background of the domain of interest, followed by a list of challenges faced in food safety. We present exact problem statement then, followed by the motivation of the modeling strategy used. The outlook of the thesis ends this chapter.

1.2 Research Contributions

This thesis presents an agent-based model of food safety management. The model proposed by McPhee-Knowles (2015) involving consumers, regulators and stores is extended to evaluate the phenomena of **"the wisdom of crowd"** towards the conditions leading to safer and more dependable food system.

We categorize stores as **"vigilant" and "indifferent",** where vigilant stores are responsive to the wisdom of crowds and take effective and timely means to improve the quality of the product. To support this mechanism, we have related a store's contamination with the quality of the product it has. Also, the quality does not abruptly switches between the extremes (contaminated and sterilized), but improves and degrades progressively.

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1. More vigilant crowd, both consumers' and stores, would not only improve the quality of food provided and consumed but would be a more fair distribution of customers across competing service providers, thus, improving dependability of the overall system.

2. Social networking-based information sharing would improve the consumers' experience further, consequently rapidly improving the quality of food provided.

1.3 Background

A food safety system is a complex global system which contains several interconnected elements interacting with each other. The most important elements are trading and storage, consume ability, spatial and economic aspects of people and their interactions. This results in to a complex system, which is not easy to study McPhee-Knowles (2015). Food safety is an absolute requirement for consumers as they want fresh and healthy food products. However, identifying safe food for consumers can be a difficult exerciseBleda and Shackley (2012). Any small failure during any stage of the system can lead to widespread transmission due to interconnected trading system and large-scale movement of people.

In the United States, the Centers for Disease Control and Prevention estimates that there are on average 48 million cases a year caused by food contamination; 128,000 enter into the hospitals, and 3,000 patient die due to food-borne diseases on yearly basic Bonabeau (2002). This means that 1 out of every 6 Americans get sick each year due to food-borne disease. The Canadian Public Health Agency estimates that 1 out of every 8 people suffers from the disease each year or that 4 million Canadians get sick every year due to food-borne diseases Bonabeau (2002) . Both organizations agree that the cause of food-borne disease outbreaks is the lack of reporting and mismanagement.

Most of these diseases are caused by a variety of common bacteria such as Escherichia coli, Salmonella and viruses such as hepatitis A and Noroviruses, parasites such as Trichinella and

Toxoplasma gondii. Most of these are carried of the food that we eat. Many diseases are mild, such as diarrheal diseases; but some are also fatal especially when the disease attacks pregnant women, children, and people with weakened immunity and old people. Referring to differences with reporting and monitoring systems, it may be difficult to compare data between countries because the greater number of reported cases can simply be the result of a better monitoring system not because of there are more of diseases Rocourt et al. (2003).

1.4 Food Safety Challenges

To reduce the spread of food-borne diseases, we must focus on three areas Basak, Datta, and Ghose (2015):

1. Following pollution crises through use of technology or other scientific discoveries.
2. Use various intervention strategies such as discovery and recall of food.
3. Estimate the level of the consumer acceptance.

Following pollution events:

Investigation and tracking of food contamination are primary reasons that help to decrease the danger to the consumer that is linked to eating unhealthy food products. There are difficulties when conducting food tracking processes such as lack of reporting of disease, several types of food types, and groups of customers. Many consumers do not get information about contaminated food until the organization release a recall or contact with consumers by distribution channel. Today, it is easier for the company / store to communicate with the consumers through bonuses programs that enable the company to follow the consumer and purchases as well as store their contact information. However, it is not necessarily that all shoppers from the market have bonuses programs Basak, Datta, and Ghose (2015) . The second difficulty related to

consumers who do not report about expose them to unsafe food consumption. Many diseases are not reported or diagnosed because many consumers do not go to health care providers, so the actual number of consumers infected is unsure or incorrectBasak, Datta, and Ghose (2015). The third difficulty focuses on the increasing grouping of food and consumer sets. The Disease Control Center uses a variety of systems to link pollution with areas, consumers and foods that responsible for diseases and track the impact of food-borne diseases with regard to food safety policies Blayneh, Cao, and Kwon (2009).

Interference strategies:

A set of rules provided by the Food Drug Administration (FDA) to measure whether food contamination result in a recall or not. However, there are issues For example, the FDA may not documented how its internal procedures and guidelines help to decide whether there is enough of proof to emission a food recall. Additionally, there are many real removals optional processes of contaminated food by the food supply companies. These optional operations can lead to many incorrect signals and cause companies lose money as well consumers support Blayneh, Cao, and Kwon (2009). It is difficult to understand the right time to start a specific intervention strategy due to the various types of complexity of the process. For example, when the time is best to remove goods from the store after notification of distribution channels, companies and agencies find that some contamination has get placeBlayneh, Cao, and Kwon (2009). Using data collected from previous contamination events, it is possible to give basic standards to find out how to respond to this type of event. Finally, need for modern technology for inspection and detection is always desirable and this type of technology will allow for a removal of contaminated food in the production step before it transfers to the consumer Blayneh, Cao, and Kwon (2009).

Level of the consumer acceptance:

Food agencies give general comments of the food and despite the recall; consumers do not pay much attention to these warnings. Many consumers still use unsafe food products because they believe that no dangerous if using it or unknown about any recall notifications Talley (2016).

1.5 Problem Statement

This thesis presents an agent-based model of food safety management. Food safety is a complex problem due to many actor involved, including, farmers, distributors, warehouses / cold storage, inspection apparatus and consumers behavior. Due to complexity of the problem, it is observed that detection of food contamination and corrective actions are often not coordinated and less efficient. The problem is further complicated due to involvement of many human factors.

Modeling such a complex system is not easy; that is why, not many solution exist. A recent agent-based model McPhee-Knowles (2015) models behavior of consumers, regulators and stores to analyze the effect of inspections on consumers health given that contaminated stores signal themselves. This adhere to the notion of the wisdom of crowd, but indirectly. We formalize this wisdom more naturally, by stores' observations of loosing their consumers. Hence, we integrate the effect of consumers not visiting a store in the stores' decision. But not through signaling, but through improvement in the quality of the product.

Another improvement in the model inclusion of disseminating the information about "good" stores using a social networking concept. In this way, a store noted as a "bad" store by a consumer, need not be bad all the way. As soon as once a bad store improve its quality, it can be suggested by friends, thus providing a mean of recommendations through a friends network.

1.6 Motivation

ABM has been met with enthusiasm in some fields of the social sciences, but has not yet been extensively used in public policy. Although some success has been seen in modeling land use management, public health, and water policy, there have been fewer applications in business and policy analysis (Moss 2008). This is especially true with respect to food policy.

The strength of ABMs is that they provide a way to represent complex systems more simply, by focusing on the system's individuals and their behaviours (Railsback & Grimm 2012). Axelrod (2003) states that most modeling in the social sciences is informed by rational choice theory, not because many scholars feel that its assumptions accurately represent human behaviour, but because it allows for deduction. Adaptive behaviour offers a viable alternative to optimization; but it requires simulation since the consequences of adaptation cannot be deduced. ABM offers an opportunity to relax the assumptions of rational choice theory to more realistically model how individuals make decisions. By using straightforward behavioural rules, ABMs can model decision-making in a more realistic manner.

ABM's ability to deal with heterogeneous populations that can use individual data, rather than aggregate data, is a unique feature with strong application to the social sciences. In many cases, social science problems are dealing with heterogeneous populations where variation is masked by aggregate data. The individual-based perspective marks an important departure from many theoretical positions in sociology and policy studies, which view society as a "hierarchical system of institutions and norms that shape individual behavior from the top down" (Macy & Willer 2002, p. 144). Since people react to changes in their environment, and these reactions can cause further changes, this leads to difficulties in backtracking and applying different solutions to complex problems (Rittel & Webber 1973). Methods that can incorporate change over time and control for these changes are able to more accurately capture social processes, and this is one area where simulation holds a lot of promise.

Although many people consider prediction to be a primary goal of modeling, depending on

the data available and the goals of the modeling exercise, it is not the only one. Epstein (2008) notes that there are many other reasons to build models, including explaining a phenomenon, guiding data collection, discovering new questions, illuminating uncertainties and dynamics, demonstrating trade-offs, challenging theory, and opening new opportunities for policy discussion. Importantly, since all models are simplified abstractions, Epstein (2008) notes that "all the best models are wrong. But they are fruitfully wrong." Stylized models that are designed to offer insight to a complex system or problem so that further discussion of policy alternatives, legislative changes, or other adjustments may take place may still be very useful, even if they are incapable of prediction.

A general overview of applications of modeling and simulation to solve real life problem is presented by Ipek Bozkurt and Jose J. Padilla Bozkurt and Padilla (2013) focused on Epistemological, Ontological, Teleological and Methodological themes. More related to the our research is the work of Mercedes Bledaa and Simon Shackley Bleda and Shackley (2012) using agent-based simulation to study formation of risk perceptions; one of the many social theory driven models which have been simulated Zia et al. (2017), Zafar et al. (2017), Zia et al. (2016b), and Zia et al. (2016a). Additionally, in systems, many simulation models are proposed i.e., recent model of supply-chain proposed by Houtian Ge, et. al. Ge et al. (2016).

An agent-based model simulating an agri-food supply chain is presented in Utomo, Onggo, and Eldridge (2017). Another agent-based model to measure the effects of incentive and communication programs towards food safety is proposed by Tim Verwaart and Natalia I. Valeeva Verwaart and Valeeva (2011). Heterogeneous agents are used representing various modalities of motivations and openness to communications. Jessye Bemley Talley's thesis Talley (2016) presents agent-based models to investigate on different aspects of consumer behaviors in the spread of contamination and conditions, in which the public health department must intervene to stop the spread.

Only a few authors have used ABM in the domain of food safety. Knowles's Model of

Food Safety Inspections McPhee-Knowles (2015) is novel, simple and intriguing. We extend this model to investigate about consumers and store owners, the social dimension. We propose that consumers and owners of the stores accepting existence of “the wisdom of crowd”, can make good decision; good for themselves, but at the same time, beneficial for the society as a whole.

1.7 Thesis Organization

The rest of the thesis is organized as follow, chapter 2.1 presents related work and motivations, followed by chapter 3.1 presents details of the model.Chapter 4.1 describe the model in ODD protocol. Chapter 5.1 explains the simulations results, followed by conclusions in chapter 6.1.

Chapter 1 includes the executive summary, which talks about the spread of foodborne diseases and the factors that cause them and the systems that have been developed to control them. This has been documented by previous studies and investigations.In this chapter also wrote background about research subject. Food safety challenges. In this section, the researcher focused on three main areas to reduce the spread of foodborne diseases where its importance to strengthening the food safety system. Also mentioned some of the difficulties facing the world when they want control of contaminated food. Motivation this section researcher wrote about some of the studies to identify weaknesses in the food supply chain based on food fraud. Problems statement of In this section, researcher provides some of the problems which will be addressed through simulation system.

Chapter 2, reviewed a number of previous studies and what are authors wrote in the area of food safety and presente researcher opinion and what will be added to the field of food safety in this thesis.

Chapter 3,section 1 discuses (Knowles’s Model of Food Safety Inspections) ,Which is shown

two methods of information from stores to regulators. The first is when the store starts "Signaling" on its own if it is contaminated. In this case, the regulators will directly visit the store to clean it. The second is when the contaminated store does not "Signaling" and the regulator's visit it purely random.

section 2 discuses the proposed model (Without Wandering) and effect of the social relationship network on protecting consumers from contaminated food. In this model, researcher deletes Wandering process and use a relationship between consumers enable them to exchange information. Also, the update process enables a progressive quality improvement or degradation of food provided by the store.

Chapter 4,presents, Design overview, design concept and details (ODD Model Description) In this chapter, the researcher will provide a detailed explanation of the model he is developing by NetLogo program.

Chapter 5,presents simulation Analysis the fundamental findings and future work for all models.

Chapter 6,presents Conclusion. This capter displays the results of this research and the impact of the model which developed by a researcher on the safety of food area.

Chapter 2

Literature Review

2.1 Literature Review

thesis written by Alexia Brunet Marks, 2015. (A New Governance Recipe for Food Safety Regulation). This thesis discuses that, food safety is an important issue, and the countries of the world give large importance to developing strong laws to deal with it. This topic is an inseparable part of the subject matter of this research thesis. Mr Marks , the International economic Law does not have enough to adequately address global food safety needs today , because of financial constraints that hinder the increase in the number of food inspections, official international obligations often limit government efforts to raise food safety standards. On the other hand, companies can adopt a measure to meet consumer request and supply chain needs, that showing greater flexibility in adopting the highest food safety standards availableMarks (2015).

Hoag, Michelle A., Corwin Porter, Padma P. Uppala, and David T. Dyjack.(A risk-based food inspection program). This thesis discusses the inspection processes on facilities of food to prevention of diseases that transfer by food.MR Michelle and etal written about food Inspection was developed by a program based on risk and assessment tool that was implemented in San Bernardino County, California. Interviews were conducted with people working in the field of health to get a basic concept for the different inspection procedures used throughout the

country. This model classifies food stores as high, medium or low risk based on food characteristics, service population feature, date of company and operational risks identified from the previous. This model supports the decision-making processes of health departments regarding the allocation of inspection resourcesHoag et al. (2007).

Verwaart, T., and Valeeva, N. I. (2011). (An agent-based model of food safety practices adoption). This thesis discusses a topic related to what the researcher discuss in this research thesis which is food safety. On this topic, the researchers discussed the proposal of the agent model that combines between the economic stimulus results with a psycho-social survey in an approach based on the theory of behavior planned simulation to compare the possible outcomes of alternative communications, programs and incentive systems. Tracking food safety, effect of the social network and the search for availability of resources to implement food safety measures this model allows to heterogeneity in the agent populationVerwaart and Valeeva (2011).

Van Kleef, E., Houghton, J. R., Krystallis, A., Pfenning, U., Rowe, G., Van Dijk, H., ... and Frewer, L. J. (2007). (Consumer evaluations of food risk management quality in Europe). This thesis discusses the model of psychological factors that impact on consumer assessment of the quality of food risk management using structural equation modeling techniques. The authors discussed about Comparison of consumer evaluations for food risk management in the countries where comparison has been applied on some consumer in different countries where it has been shown that some factors appear to be leading perceptions of effective food risk management in all countries surveyed, such as proactive protection of consumers, which have been positively related to consumer evaluation of risk management quality. While the risk of ambiguity and reaction management was negatively associated with the perceived food risk management qualityVan Kleef et al. (2007).

Kher, Swaroop V., et al. (Consumer perceptions of risks of chemical and microbiological

contaminants associated with food chains: a crossâĂŘnational study). This thesis talks about chemical and microbiological contaminants in food chains. The author's written about implement effective systems to identify food chain weaknesses to chemical and microbiological contaminants. Where they investigated on four food chains in five different countries. This shows that consumers have higher concerns about chemicals compared to microbes and pollutants Kher et al. (2013).

Bredahl, L. (2001). (Determinants of consumer attitudes and purchase intentions with regard to genetically modified foodâĂŞresults of a cross-national survey). This thesis explains how consumers develop opinions and make decisions about genetically modified food. The author display a survey conducted in several countries to investigate the formation of consumer attitudes towards genetic modification in food production and procurement. A number of consumers from 4 different countries were interviewed on several foods identified and the results indicate that attitudes towards genetically modified foods are quite strong, although there is no basis in the actual product experienceBredahl (2001).

Borrusso, Patricia, and Jennifer J. Quinlan. (Development and piloting of a food safety audit tool for the domestic environment). In this thesis, the authors speak of a large number of consumers abusing food at home based on their studies. The researchers found that there was a need for a regulated tool to evaluate spread and determine the nature of food safety risks in the local environmentBorrusso and Quinlan (2013).

Unnevehr, Laurian, and Delia Grace, eds. (Finding solutions for improved food safety). The researchers foxes on Aflatoxins and other fungicides, which are important health risks related to food safety with large impact on developing countries. Authors see that low-income people are exposed to liver cancer because they consume large amounts of essential foods such

as corn and peanuts because of there are aflatoxin in these foods Unnevehr and Grace (2013).

Kim, R. Food risk management quality (FRMQ) of government and the private firms: ConsumersâĂŹ perspectives in China and Korea). This research spoke about the globalization of the food trade, which makes consumers more vulnerable to unsafe foreign food products. Consumers are increasingly worried about the safety of food products from both local and external sources. To solve this problem, the private sector in the agro-food industry is increasingly implementing special food risk management as part of marketing strategies that make by studying how consumers differentiate from public and private sector financiers Kim (2013).

Thanh, Tran Ngoc Cam. (Food safety behavior, attitudes and practices of street food vendors and consumers in Vietnam). This thesis discussed the risks that come with food consumption in the streets of developing countries such as Vietnam in the process of disease transmission by food. The researchers conducted 3 studies to verify the safety of food in some areas in Vietnam. First study, knowledge of food safety, attitudes of consumers and sellers. Second study, to control of food handling practices of vendors, and third, microbiological quality assessment of selected street foods. The results of those studies showed that sellers did not have much knowledge in the safety foods. The study shows that the majority of vendors suffers from poor food handling practices and is working in an unhealthy environmentThanh (2015).

Skovgaard, Niels. (Foodborne Disease Outbreaks, Guidelines for investigation and control). This thesis, which was published by the World Health Organization (WHO), discussed the spread of acute diarrheal disease and its causes and what its relation with food borne diseases. In this thesis, the author focused on the investigation of foodborne diseases due to the loss of such an investigation and will be carried out by food inspectors, health professionals, laboratory staff and others who may participate. In the investigation and control of foodborne

disease and aims to investigate the control of food borne diseasesThanh (2015).

Vos, E. (2000). (EU food safety regulation in the aftermath of the BSE crisis).This thesis discuss the main elements of the new policy pursued by the European Union's Food Safety Commission after modified after the outbreak of the mad cow crisis. The author referred to the improvement of the policies of the Food Safety Committee and the European Court of Justice when the outbreak of the mad cow crisis to overcome any manipulation of the rules of food safety where the manipulation of food safety rules may lead to political crises between the source Countries and consumer countriesVos (2000) .

Alban, Lis, F. M. Baptista, A-M. Olsen, and J. V. Petersen. (Human health risk of residues in Danish porkâĂŞin theory and practice). This thesis presents a project to control the residues of pharmaceuticals in food products from products foods by animal that pose a potential threat to human health. The author focused on educating farmers on the impact of potential waste detection. Where a study was conducted to evaluate the human health risks of waste in Danish pork and found that the risk rate for human health is low if there is good education for farmers or pig farmers Alban et al. (2011).

NordenskjÃűld, Jenni. (Implementation of a quality management system in food production). This research discuss objective of this study is to investigate how the quality process is implemented food safety. The Author wrote about management system is a good way to guarantee the quality and health of food production it also increases the possibility of tracking food products through the whole food chain. Food provides a safety standard means to prevent problems and crises and can also help in deal with the requirements of the authorities, market and othersNordenskjöld (2012).

Mohammed, Rezgar, and Yuqing Zheng. (International Diffusion of Food Safety Standards: The Role of Domestic Certifiers and International Trade). This thesis contains the implications of a country's choice of food safety rules. Where authors spoke about the results that food safety violations would cause, such as large economic losses for producers, disease to consumers and reduced consumer confidence in the safety of food storesMohammed and Zheng (2017). Petrescu, Dacinia Crina, and Ruxandra Malina Petrescu-Mag. (Organic food perception: fad, or healthy and environmentally friendly? A case on Romanian consumers). The main purpose of this thesis is to reveal the consumer's impression about organic food. The authors spoke about do are considered that Organic food products in North-West Region from Romania that it offers health and environmental benefits?. The results of this study indicate that a large number of consumers of organic foods believe that organic foods it is better than traditional foodPetrescu and Petrescu-Mag (2015).

Gillespi, ZoÃń, Olga Pulido, and Elizabeth Vavasour.(Risk assessment approaches for carcinogenic food contaminants). This thesis spoke about the proposal of the Canadian Health Organization to define a unified approach for risk management for evaluation of carcinogens in food. In this thesis, authors discussed that a united approach may simplify better risk management strategies for controlling human exposures to food sources of carcinogens. It is clear from consumers' reactions that carcinogens are the most worrying Gillespi, Pulido, and Vavasour (2011). Taylor, Michael R., and Stephanie D. David. (Stronger Partnerships for Safer Food).This research includes the reform of federal laws that deal with the safety of food priorities people attention in the US. In this thesis, the researchers spoke about national policies and reform efforts to key federal agencies affected in food safetyTaylor and David ("Stronger Partnerships for Safer Food").

Bleda, Mercedes, and Simon Shackley. (Simulation modelling as a theory building tool: the

formation of risk perceptions). This research discussed BSE and contaminated animal products. In this thesis, the researchers discussed a computer-based social simulation model to analyze the formation of general risk perceptions using the BSE incident as a case study. The quantitative operational model provides a multidimensional concept for perception of risks, variables and related relationships that affect their appearance and maintenance over time Bleda and Shackley (2012) .

Ge, Houtian, James Nolan, Richard Gray, Stephan Goetz, and Yicheol Han. (Supply chain complexity and risk mitigationâĂŞA hybrid optimizationâĂŞsimulation model). This thesis shows a hybrid simulation model representing the Canadian new wheat supply chain, aims at identifying cost-effective testing strategies. In this research authors spoke about a number of tests were conducted by wheat processors by developing a set of pollution testing strategies to support the wheat historical quality by using a hybrid simulation model in the Canadian supply chain Ge et al. (2016).

Howlett, J., D. G. Edwards, A. Cockburn, P. Hepburn, J. Kleiner, D. Knorr, G. Kozianowski et al. (The safety assessment of novel foods and concepts to determine their safety in use). This research discussed an approach that based on ensuring the safety of foods which depended on a significant parity between new and traditional food products that are good for human consumption and requires a comparison of available information on new food and traditional food related, and identification of any additional information. The researchers spoke in this thesis about a model that guarantee the safety of food by highlighting the differences between the new food and its match from traditional food which is the same type. The purpose is to determine that food or new derivatives are at least as safe as their traditional counterpartsHowlett et al. (2003).

Verbeke, Wim, Lynn J. Frewer, Joachim Scholderer, and Hubert F. De Brabander. (Why consumers behave as they do with respect to food safety and risk information). This thesis presents the risk of residues of veterinary drugs in meat occupying a high position in food on consumers. The researchers discussed a better explanation of food risk analysis on how consumers behave in terms of food safety and risk information. This thesis provides descriptions of these behaviors based on the nature of risk and individual psychological processes and discuss possible solutions to rebuild consumer trust in food safety and the linking of views and opinions Verbeke et al. (2007).

Food is a source of life and life without safe food will not continue. The food distribution channels got high attention both in practice and in literature.Mr. Akkerman and others reviewed in this research thesis the approach of food distribution management linking it to the difficulties faced by the industry, the authors here focused on three parts sustainable, food quality and safety of food. Strategic network design, tactical network planning, and operational transportation planning. The literature discusses on these three levels of resolutions and for each level, the authors study and discuss research contributions of the case of the art and identify difficulties for future researchAkkerman, Farahani, and Grunow (2010).

Through research and studies that were done, the previous century has seen fast developments in the techniques of danger evaluation and tools connected with the defense of food and its safety. These developments have started to have a more impact on the decision-making process. In this thesis Mr. Robert and others talked about the processes which are used by risk directors in both government and industry.The complex issues that which are facing the management of food safety in this time basis on an international are supposed to require more advanced evaluation tools than currently used. This is one of the important difficulties that need to be met to enhance risk adoptionRocourt et al. (2003).

Health knowledge is very important for people and ignorance of some issues related to human food and the source of its continuation in life causes great disasters. . In this thesis, Dr. Nina and etal discussed the worry of food safety and ethical self identity in the forecast of beliefs and purpose of purchase in the context of organic manufacture. An understandable model is a pediment and examined by equation modeling structural. The results obtained for food safety the most important foreteller for the position. By comparison, health awareness appears to be the weakest part when compared with similar previous studies results. In addition, ethical self-identity has been found to foretell equally positions and plan to purchase organic manufacturer, production insures that respondents' identification of ethical issues effects on their positions and next consumption choices Michaelidou and Hassan (2008).

Food safety is a debilitating issue facing government food industry consumers. As consumers' experience is not enough to evaluate food safety dangers; their desire for food safety is an important driver of trust in the food distribution channel. In this study Mr.Wallace M.S and etal focused on farmers and cattle breeders check in the causative relationship between reason that defines consumer confidence in food safety and hence the possibility of purchase. Through joining modern theories into several disciplines, six factors, namely: integrity, supplying data, efficiency, kindness, reliability, and trustiness adopted for this study. The conceptual model was tested with a sample of 194 people form structural equation model using LISREL 8.30. The findings of the researcher confirm that animals breeders and farmers can benefit from strategies increase trustworthiness by giving information and showing the integrity and kindness to consumers and this positively affects the consumer purchasing decision Yee, Yeung, and Morris (2005).

The awareness of the consumer and his knowledge of organic foods is very important to motivate him to buy organic products. Mr.Zanoli and others display in this research thesis the results

of an Italian research on consumer awareness and knowledge of organic food and similar behavior. Uses the means-end chain pattern to joining characteristics of goods to the demands of buyers. To be able to give expectations around the consumer's reason to buy organic products. The meeting was attended by 60 shareholders using a hard scale model to measure the mean-end of the chain. The results of the scales are collected and encoded in these semi-qualitative meetings and presented in a set of hierarchical value maps. Sometimes it is difficult to find organic goods and is known pricey but maximum of consumers find them positively.Where they are linked healthy with organic products on different levels of abstraction and they are interested in good food products because enjoyment and comfort are their most important values. The results show some differences between consumer sets about organic product experience and knowledge Zanoli and Naspetti (2002).

Value of quality in food products required by the consumer, we find most consumers are looking for healthy food with good nutritional value. Ms Ana M and etal are discussed in this thesis the evaluation of the value of quality / safety of beef consumers to measure their willingness to pay the price of a named beef. Through a survey conducted between food customers within a single family where consumers are divided based on their safety and knowledge of specific food products per group. For each set, their ready to pay for classified beef is counted. Lastly, the main factors that explain such a decision are examined. The results show that the fear of food and foretell the negative effect of farming production on the environment. Health fears have a lot impact on consumer purchasing decisions. However, many consumers do not want to pay a price premium for beefLammerding and Fazil (2000).

The data provided about the safety of meat and different foodstuffs plays the main role in affecting on consumer confidence and desire to purchase. In this research thesis Mr. Gellynck and etal their idea focuses on the note that in spite of the large increase of information by put

signs, pursuit systems, quality warranty planner and effect on consumer trust in meat as a safe and healthy product are limited only. Excessive in the complexity of information connected with food leads to a misunderstanding of functional pursuit by looking at traits such as food chain control and organizational efficiency is very important, but not as a foundation for the retail market. With all this we find that the feature of the process, such as the origin and approach of production, important for specific section of the market in response to worry about the quality of meat. Quality insurance planner and signs linked with it negatively affect the perception of consumers. According to what has been written that the great benefit of the retailers of these schemes is supported by the capacity and efficiency of the management of procurement rather than quality or safety. Future studies can investigate the distribution of benefits and costs linked with the meat quality initiative between members in the chainGellynck, Verbeke, and Vermeire (2006).

The models implemented previously to evaluate the risk expectations of the consumer of food products very many and the studies conducted in this field more.In this research thesis authors (Glynn T and etal) talked about develop and implement a model of consumer risk perceptions about the safety of beef and to identify the motivation behind consumers' desire for safer food. Authors explain how agent demographics ,state of home and also depend on alternative sources of information about food safety and its impact on the challenges consumer perceptions in America, Canada and Japan. In that, three states agent have danger understanding grown by their level of confidence on noticeable and belief characteristic information. In addition, indirect personal experiences about food safety have a large effect on danger perceptions. The results that are finding very important for decision makers in developing more effective strategies to control supply chain management and public policies aimed at Sustainability consumer confidence in food safetyTonsor, Schroeder, and Pennings (2009).

The discovery of the factors which are impact on consumers' response to food safety risks is very important when any specialized organization in this field wishes to develop strategies to

address the risks of food contamination lower probability. Mr. Gregory A. In this thesis, a survey of 2000 consumers was executed in mid-2003 and the results were givenBaker (2003). Refrigerated food products play a large role in our daily life as most of the foods we eat are frozen especially when import from other countries and the possibility of playing a large role in some cases as the main reason of diseases spread through food. In this research thesis the rules of refrigerant administration policy are the control and guarantee the safety system of the optimization of the distribution of refrigerated food products is developed within the cold chain. In this system, a new approach based on the actual danger evaluation in the critical points of the cooling chain is used to promote products to the next stage of distribution. This model is based on the evaluation of the goods time, the time of the temperature and the change in the properties of the product. Use of oracular models for the increase of pathogens gives precedence to products in a way where danger is reduced in the time of consumption. The efficiency of SMAS was evaluated against another one in the externally (FIFO) present approach to food distribution. In a case study on the risk of lystar fibrosis of pork cooked using Monte Carlo simulation technique. In addition, the two approaches were examined to their effect on the quality of the products in the remaining validity conditions at the time of consumption. The results explained that an approach of SMAS approach significantly reduced the dangers of ListerIsosi illness while the products at a time of depreciation decreased significantly compared to the FIFO approachKoutsoumanis, Taoukis, and Nychas (2005).

The four bases of food safety microbial danger evaluation are risk determination, exposure evaluation, and risk properties. These actions describe a systematic method for determination opposite outcome and their linked possibilities grow from eating of foods that may be unhealthy with the causes of microbial diseases. Mr. Anna .M and etal in this thesis shows a study of the first 2 levels: exposure evaluation and risk determination, and considerations for various methods that can be used to analyze the related dataLammerding and Fazil (2000) .

Considered very important application region for Operational administration and Science research the supply of farming food chains. The dependence on agent-based simulations in ASC research has increased over the last time. Mr. Dhanan Sarwo Utomo1 and etal are reviewed in this thesis the present ASC research which used the ABS simulation system. The survey starts by analyzing the features of models and modeling contained in the literature. They are explains that the research of the current model is differentiated by the intensive use of the individual supply chain., samples of middle- and high-income states Non-processed food goods, experimental information, Issuing decisions that linked with investment and production planning, and use of verification from the black box. The results were achieved through this study that, many fields are not undergoing enough research such as seller and buyer relationships, competition, cooperation and service. In addition, ABS models reported did not include the main active agents in ASC such as retail stores and food processors and also those models have at this time not included important supply chain management theories such as resource-based satisfaction and transaction cost economics as a part of their diagramUtomo, Onggo, and Eldridge (2017).

Globalization has helped to increase access to global markets for farming food traders, and external products have become in consumer's hands and he is more exposed to it. According to this trend is assumed to continue with the accession of main trading states to the regional trade agreement to expand export markets and create a large trading cluster.Mr. Renee BoYoung Kim in this research thesis written about the Korea-China Free Trade Agreement (FTA) in late 2012 and its effect on consumers in both countries are assumed to combine the agro-food markets of the two countries, increasing consumer worry about the safety of food products from local and external sources. One of the most important things that both governments must ensure to build a sustainable and effective food supply chain to develop a food risk management system that takes into account the stakeholders in each nation. Consumers 'understanding of food risk

management techniques managed by the public and private sector may have an important impact on consumers' acceptance of the current food supply system. The private sector largely applies food risk management in the agro-food industry as a necessary part of marketing strategies. This thesis tries to address important guidelines that may provide instruction for the future development of the private and public food risk management quality (FRMQ) system in China and Korea through studying the way in which consumers differentiate between FRMQ from the public and private sector. The results of this study show that consumers in both nations show different evaluations and expectations on the FRMQ systemKim (2013).

Referring to the previous literature which was reviewed in this thesis research, studies have been conducted and many models have been developed to avoid foodborne diseases. Despite the efforts made in this field, we find many weaknesses in the models that were developed previously. Where it cannot combat the transmission of diseases through food well and some of the models applied by specialized institutions in this field, we find that consumer afraid of them. The new points that will be discussed and analyzed in this research are that there will be a social relationship network consisting of relationships between consumers, consumer inspectors, consumers, stores, consumers, stores, and inspectors. This network will help significantly in the safety of food if there is cooperation between government and citizens and businesses in addressing the problem of food safety.

Chapter 3

Models of Food Safety Inspections

3.1 Knowles's Model of Food Safety Inspections

The model is based on three agent breeds, (i) consumers, (ii) regulators, and (iii) stores. A consumers executes processes of CONSUME and HEAL, a regulator performs TEST, and a store acts to SPREAD and SIGNAL.

Consume and Heal: A consumer consumes food of a store if she is healthy, while waiting to be healthy again if she is contaminated with the food already taken. For consumption of the food, she chooses a random store in her proximity (defined by her range of accessibility) which is not identified as contaminated by one of the regulators / store or already listed in bad stores from her prior experience. If the chosen store is not contaminated, she lists it as a good store. Otherwise, she is considered as sick if contamination (a random value of plausible health hazard) imposed by the food is more than her immunity, consequently listing the chosen store in the list of bad stores. A consumer also performs healing if it is sick, and her counter of healing is still less than prescribed threshold. Fig. 3.1 depicts this process.

Spread and Signal: A store may becomes contaminated at a random instance. It may also decide to signal its state of being contaminated. Fig. 3.2 depicts this process.

Test: A regulator visits a random store in her proximity (defined by her range of accessibility which is more than consumer's) that is already signaling. If no such store exists, it visits

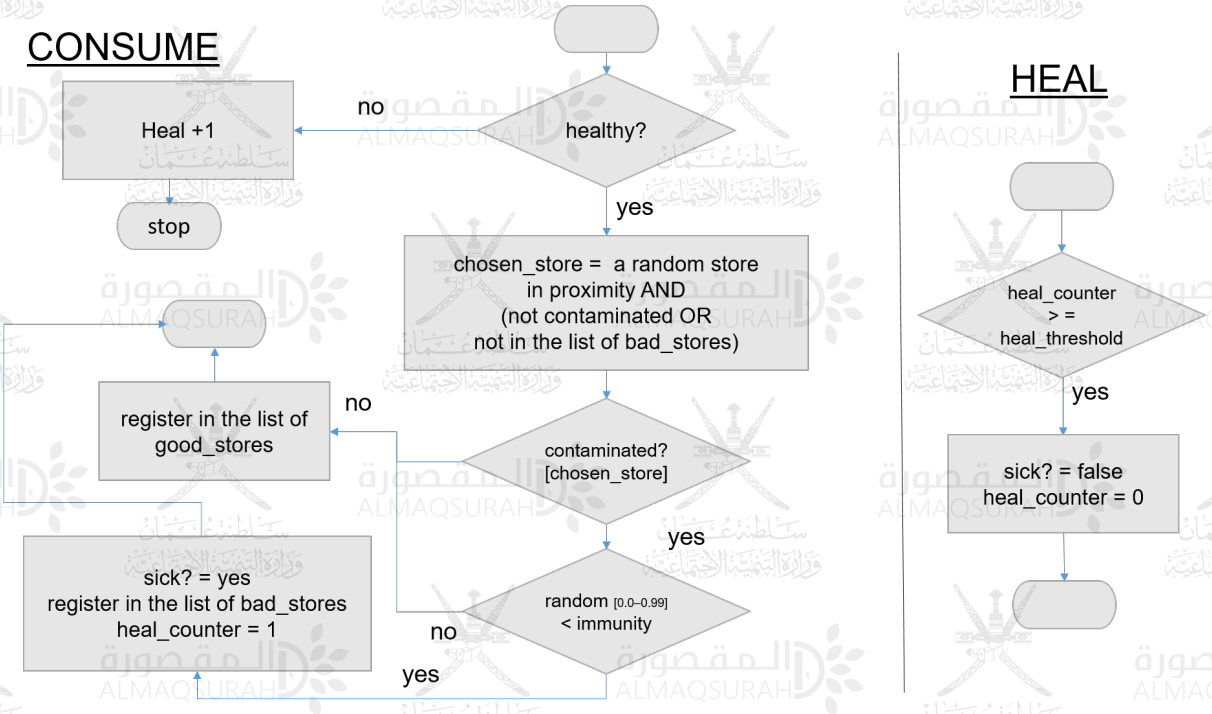

Figure 3.1: Knowles's Model of Food Safety Inspections. Process of Food Consumption and Healing by Consumers.

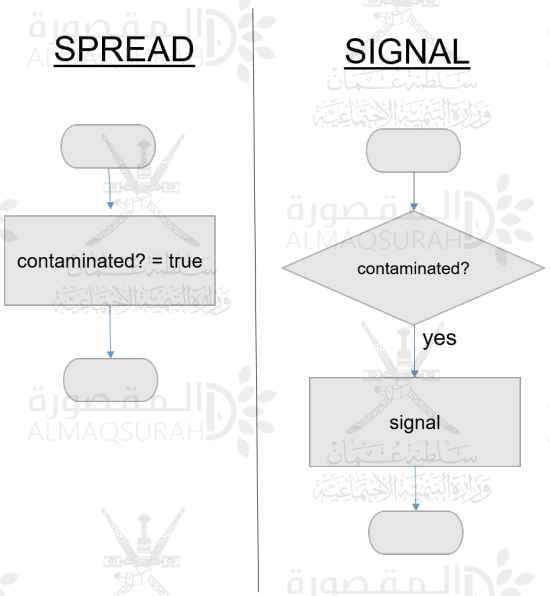

Figure 3.2: Knowles's Model of Food Safety Inspections. Process of Spreading and Signaling by Stores.

any random store in her proximity. As a result of her visit, the store becomes sterilized. Fig. 3.3 depicts this process.

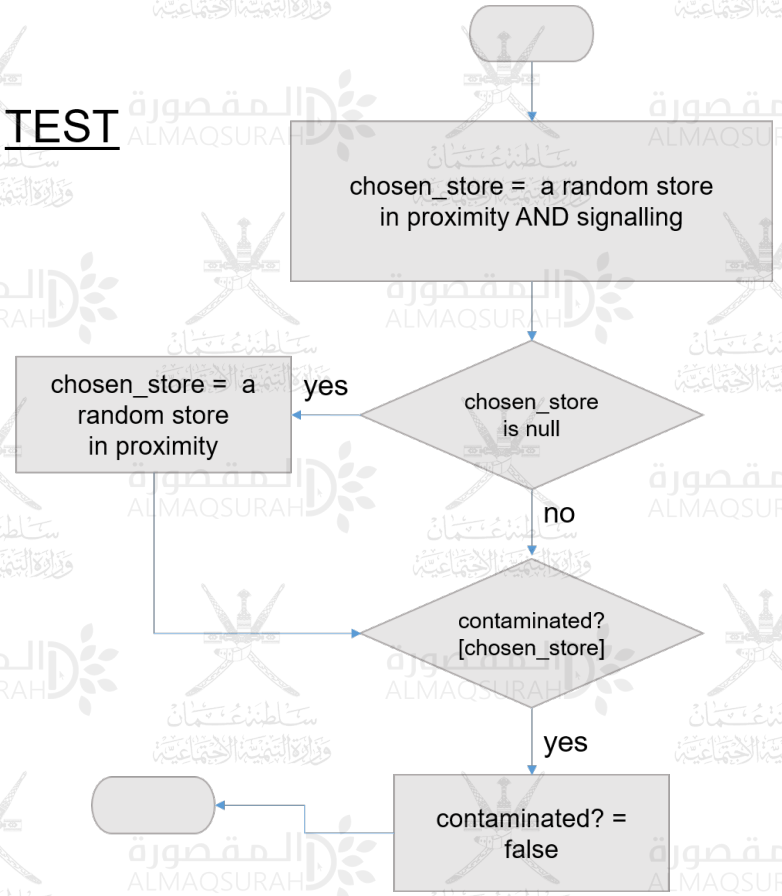

Figure 3.3: Knowles's Model of Food Safety Inspections. Process of Testing by Regulators.

Knowles considers two information modalities from stores to regulators. First is when a store starts "signaling" on its own if it is contaminated. In this case, a regulator would promptly visit the store to sterilize it. The second is when contaminated store does not signal and regulators' visit are purely random. Naturally, stores signaling themselves would be the best choice, but its practicality can be debated. We take it as our base case.

3.1.1 The Proposed Model: with Wandering

The proposed model does not include signaling process. We add a new process for stores.

Quality Update: The UPDATE process enables a progressive quality improvement or degradation of food provided by the store. The progression in one direction (improvement

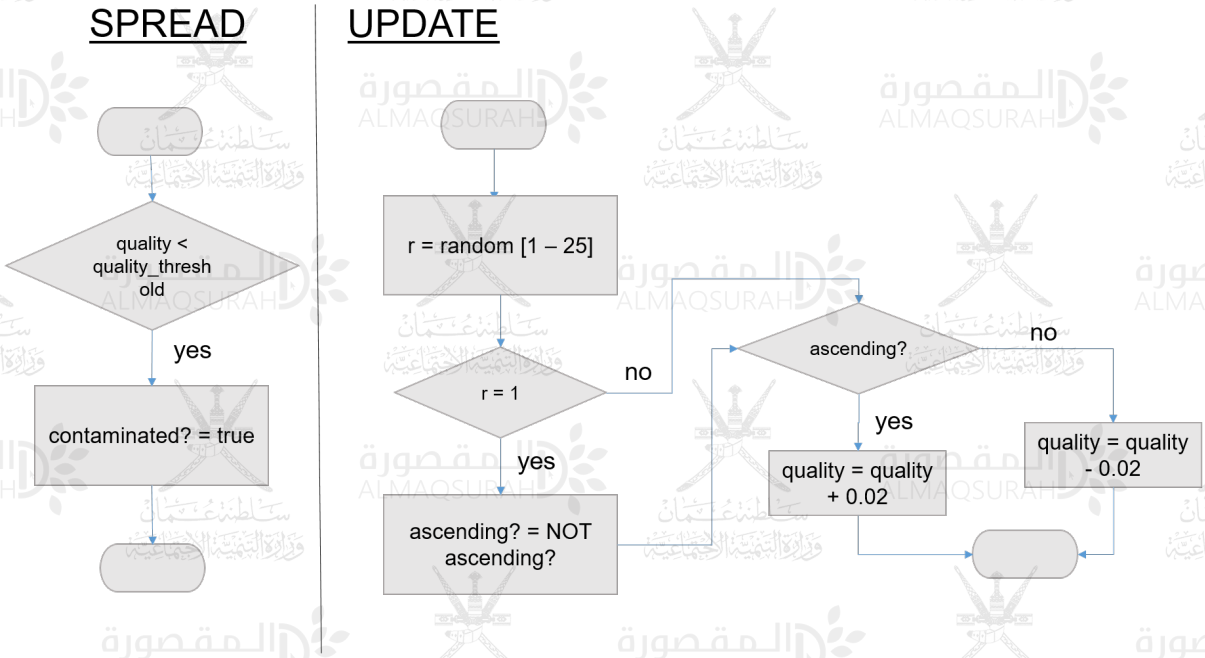

Figure 3.4: Proposed model of Food Safety Inspections. Process of Spreading and Quality Update by Stores.

or degradation) proceeding for a longer period of time before switching from one direction to the other. Evaluation of the quality of the food is then integrated with other processes as well. Such as, the SPREAD of contamination is no more an unconditional decision. A store becomes 'really' contaminated, if quality of the store is less than *quality_threshold* (a static value between 0.1 to 0.9). The changes in Knowles's Model are highlighted in Fig. 3.4 which also have depiction of update process.

Similar changes are implemented in TEST by regulators in which a store's quality needs to be above threshold to take it as sterilized. The changes in Knowles's Model are depicted in Fig. 3.5.

Further, the UPGRADE process is also modeled to reflect the effect of crowd (customers at a particular time) at the store. If "c" is the number of consumers at a store, and the quality of food at the store is less than the threshold, then a "vigilant" store would like to have drastic change in the quality, improving it quantitatively proportional to the crowd (say equivalent to

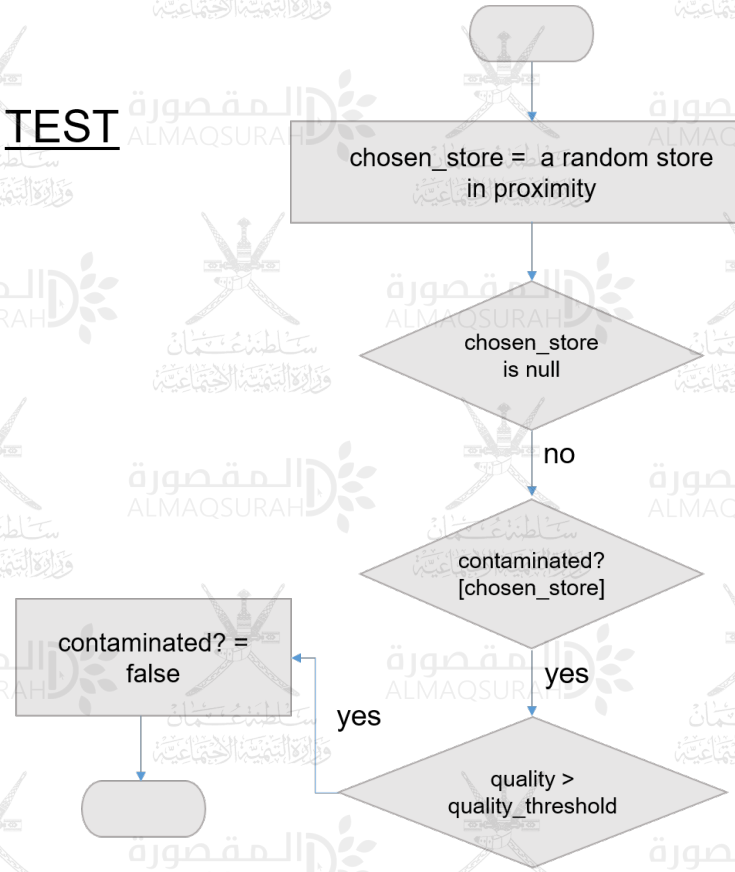

Figure 3.5: Proposed model of Food Safety Inspections. Process of Testing by Regulators.

reciprocal of “c”). These differences are highlighted in Fig. 3.6.

3.1.2 The Proposed Model: Further Extension (Without Wandering)

There are two aspects that we considered in the further extension of the model. In the previous model, if a store in the neighborhood of a consumer which is safe (not currently contaminated and in the list of bad stores) was not found, the consumer used to “wander”. Wandering is a process of choosing another location randomly in the current tick and start searching for a candidate safe store in the next tick. This is counter intuitive, just like considering that a store start signaling as soon as it get contaminated.

The first contribution of this model is then the deletion of wandering process. This will

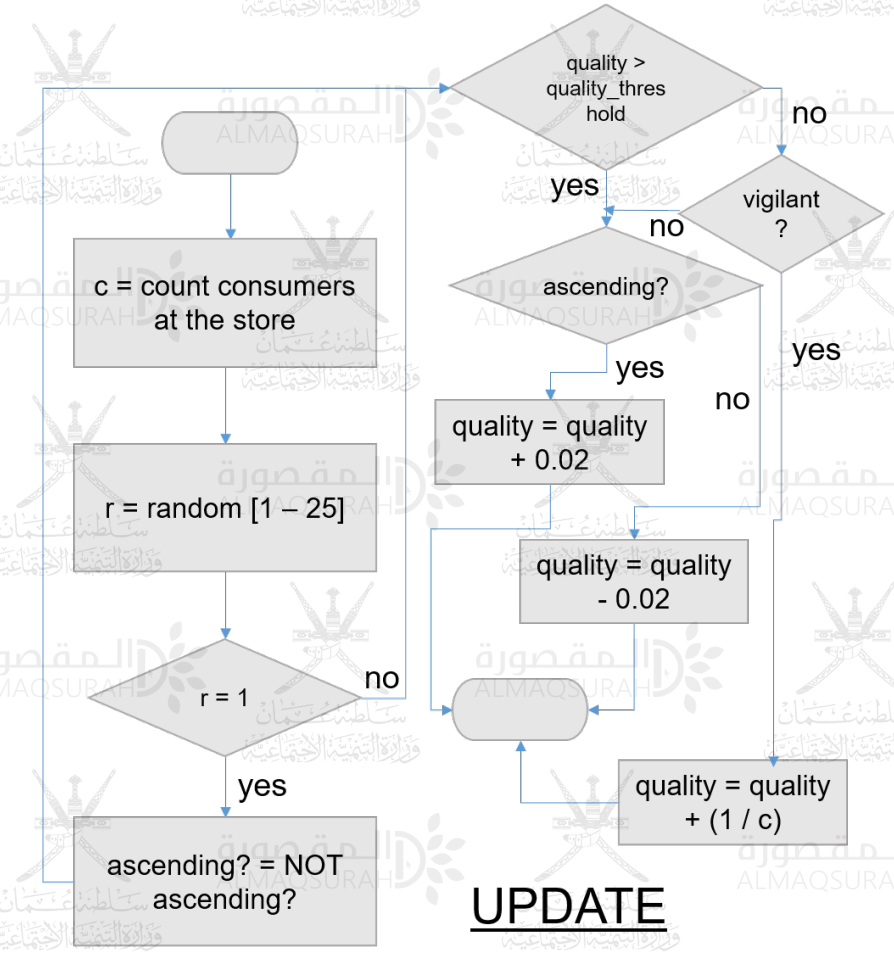

Figure 3.6: Proposed model of Food Safety Inspections. Quality Update Process. Further Extension.

definitely increase the number of consumers who are not able to find a safe store. Now the question is that how we can compensate this loss. We propose to use a social network model to achieve it.

Social Networking

Agents perform calculations and act in a sequence; the order of the sequence randomly shuffled for each iteration. A network between agents is at the setup time. All agents form links with the other agents as described in the following.

Let “friends” is a 2D array or table data structure of an agent, which contains all of its friends, according to the following:

connections-to-make = number-consumers * connectivity-index

connections-to-make-locally = local-connections / 100 * connections-to-make

connections-to-make-remotely = (100 - local-connections) / 100 * connections-to-make

Figure 3.7 shows a sample setup in which blue connections are local and red connections are remote. It means that all consumers are having friends now, which is a static connectivity happening at the simulation startup and remains till the end of a simulation run. Some friends are in local (in the proximity of initial placement of a consumers), while the remaining are distant. The connectivity with the friends makes a consumer take recommendations from one of his friends instead of wandering (in case no store is available).

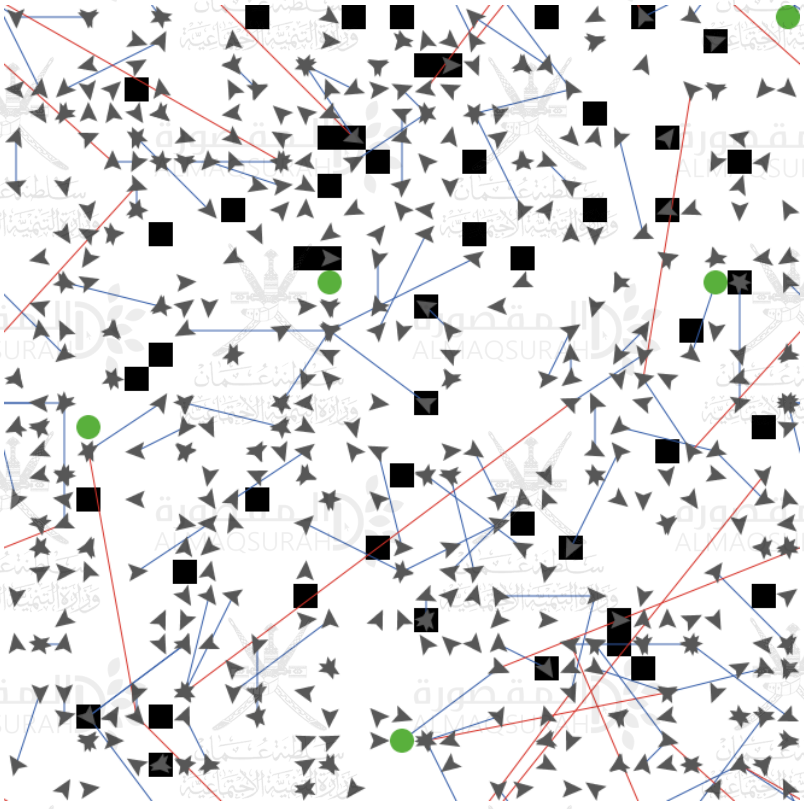

Figure 3.7: connections setup (Social Networking)

Consume (New)

A new consume process is proposed shown in Figure 3.8. The changes highlighted in *italic* represent the changes:

A consumer consumes food of a store if she is healthy, while waiting to be healthy again if she is contaminated with the food already taken. For consumption of the food, she chooses a random store in her proximity (defined by her range of accessibility) which is not identified as contaminated by one of the regulators / store or already listed in bad stores from her prior experience. If the chosen store is not contaminated, she lists it as a good store. *She also lists it in "green_stores", stores which she has visited herself and found healthy*. Otherwise, she is considered as sick if contamination (a random value of plausible health hazard) imposed by the food is more than her immunity, consequently listing the chosen store in the list of bad stores. A consumer also performs healing if it is sick, and her counter of healing is still less than prescribed threshold. *If during the choosing process, the chosen store is null (not store found in the proximity), she would ask a randomly chosen friend of her to provide a random store from the list of "green_stores".*

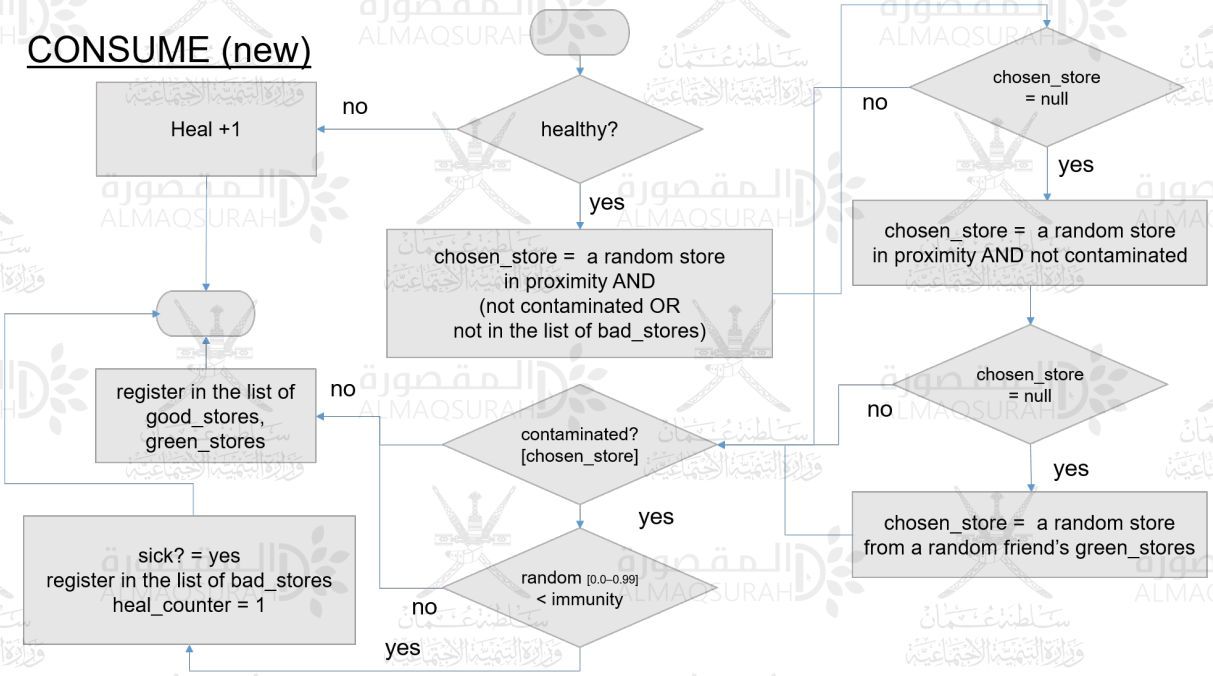

Figure 3.8: Proposed model of Food Safety Inspections. new consume process

Chapter 4

Design

4.1 ODD Model Description

This part includes an explanation of the ODD model to show the results of the objectives and execution of a basic model of food safety inspection that by using the NetLogo program through which the researcher will implement a simulated environment that interacts between the consumer's, inspectors and stores.where comparisons can be made between different scenarios and ideas of these scenarios can be utilized to inform policy dialogue.

4.1.1 Overview

1. **Purpose:** The aim of this model is to explan the role and effect of data at the optimal scale for regulators in the food system.

Table 4.1: Elements of the ODD protocol

Overview :	Purpose. State variables and Scales. process overview and sheduling.
Design concepts :	Design concepts.
Details :	Initialization. Input. submodels.

Table 4.2: Model Variables Description

Model variables description	
Variable name	description
Range	use a range of patches by agents that for looking for stores potential destination.
Immune system	There is a possibility that ranges between 10% to 50% of consumers become patients who are on the land of contaminated patch.
Sick	Consumers become sick if they go into a contaminated store, and the random number generator is less than the immune system number.
Bad store patches	list of contaminated stores that have mad consumers sick in the past.
Destination	Replace every time step; set the most proper store within the consumer area that is not a part of the contaminated store patches.
Heal counter	The consumer continues unhealthy for three-time steps that do not move if he becomes sick.

Entities, state variables and scales

2. **Entities:** Include consumers, inspectors, and stores in the model and stores that are supposed to include suppliers and food products.

3. **variables state:**

a. Patches have a variable called it store 100 store patches spread in around the model. All the remaining patches represent an empty space in the model. The stores may be contaminated, clean or neutral are represented by three different colors in the model.

b. Consumers Consumer agents are a reproduction of turtle in NetLogo. There are 500 of consumers when start of the model run.

c. **Regulators:**regulators have the range in which they are scanning for patches or stores to be tested double this range is the scope of consumers.In In the proposed model, the researcher used 10 regulators.

d. **The minimal locative element:** Regulators and consumers both have a range through it which they can identify potential destinations.The simulation continues for a 1000-time step. The length of a single time step is not defined because this model is applicable to a particular mode.

e. **Inspectors and consumers relationship on social network:** In the model, a representation of the relationship between the consumer and the inspector, where the consumer can inform the inspector of bad stores to go to be check its either through the electronic communication or reporting in the office .in addition, if the consumer friend of the inspector or form his family can inform him personally.

f. **Consumers and consumer's relationship on social network:** If there is a relationship between consumers in the same range, the consumer who is affected by the particular stores can inform the other consumer for not going to those stores where they are in the list of bad stores.

g. Process Overview and Scheduling: When the model creating is finished, the following operations are executed in the following order:

1. One randomly store is selected at each time step and becomes contaminated.

2. stores which not have been visited in 10 time steps close in the model versions with store closures.

3. implement consumers their consume procedures, as follows:

- Destination-set: Consumers estimate all the stores within their scope and select a store patch that is not on their list of(bad stores).if no healthy store avileble , consumer wanders randomly and goes forward three patches.
- Eat: If the store is contaminated and the random number generated is less than the immune system becomes a consumer sick and register this patch to the list of contaminated stores. The agent sets its heal counter to one. if the consumer is ill the above two procedures can not implement.
- Inspectors test: In this model, the inspectors move randomly to the store within their range. If the pollutant inspectors change the contaminated variable from 1 to 0 and the store color changes to another color. If the store is health inspectors donâĂŹt do any things.
- Consumers who have been sick after three steps will heal.

4.1.2 Design concept:

There are a number of theories and concepts that are relied upon in the design of the model used it to effect on the variables and sub-models used in the model.

1. Embedded supply chain: In the model, the user sees only the stores directly, although there are suppliers and producers but they can not appear because consumers only interact with stores and restaurants because they are responsible for providing safe food products.This element greatly contributed to the simplification of model buildingMcPhee-Knowles, 2015.

2. Regulation System:Any country in the world has organizations responsible about food safety and these organizations have plans ,policies and laws that regulate the inspection of foods to reduce the consumption of contaminated foodMcPhee-Knowles, 2015.

3. Immune system :This field has yet to be really answered in the literature despite the great advances in predictive microbiology.The immune system is a method used to predict the spread of factors that cause for sick or kill consumer by eating contaminated food. Consumers such as children, pregnant women and the elderly are more likely to foodborne diseases because of their immune system is a weakness.However, the actual risk of disease from consumption of contaminated food is uncertain.The model was run by using a heterogeneousimmune system parameter and differs throughout the populationMcPhee-Knowles, 2015.

4. Consumer avoidance: Consumers avert bad stores if there is warry about cleanliness and the most important source of knowledge and change the behavior of food safety is the personal experience of the consumer with the diseases spread by foodmcphee2015growing.

5. Quality Update: The UPDATE process enables a progressive quality improvement or degradation of food provided by the store. The progression in one direction (improvement or degradation) proceeding for a longer period of time before switching from one direction to the other.

6. Asymmetrical data:It is impossible for consumers or investigators to know the store if it is contaminated or not before food consumption for that store. it will be interesting in

this theory to apply the integration of quality signals in future models to ensure product quality.

7. No consumption when consumer sick : It is assumed that the consumer stays at home during his sickness and avoids going to the stores because of the symptoms that accompany foodborne diseases such as vomiting and diarrhea.This was represented in our model, which prevents the consumer from visiting a contaminated store he visited before and became ill.

8. Emergence:The important results of the model are the total number of contaminated stores, sick agent, stores inspected whereas modification that is made between model versions on the based on changes in the rules that are followed by customers. In this case, the results are structured and not resulting from the beginning behavior.

9. Adaptation/learning:Consumers adjust their behavior by updating the list of bad stores patches if they get sick because they eat from a contaminated store where they add that store to their list of bad stores and avoid it in the future until inspectors visit and clean. agents also obviate stores which send signaling .

10. Objectives:Consumers' desire to avoid food-borne diseases is proportional to their adaptive behavior, which leads them to avoid visit stores that which caused them sick previously because of eating contaminated food from it.Stores patches need to avoid contamination if that is not possible avoiding injury to consumers by signaling despite the imposition.The assumption that should be applied is to impose different inspection strategies instead of allowing agents to choose what they want and inspectors should inspect very carefully.

11. Sensing: Both inspectors and consumers can sense when the patch is a signaling because both customers and regulators have the same sensation abilities. Consumers and inspectors can see if the store is contaminated when accessed.Despite, visiting a contaminated

store may make consumers sick, but inspectors can change or shift the contaminated variable to make the store from unsafe to safe again.Consumers can not sense if the patch has been investigated newly or whether nearby consumers are unhealthy.

12. Interaction : At this step, consumers interact with stores by visiting for consumes food. Inspectors also interact with stores by visiting for inspected the stores, but both inspectors and consumers do not interact directly with each other. But through this model, which contains a social relationship network, consumers can have a relationship and interact with inspectors, stores and other consumers.

13. Stochasticity is used in generates a random number to defines if the consumer will get the disease or not. If the consumer completes the wander procedure, he randomly defines the heading and moves 3 patches in that way. There are no organizations (organizations of agents that affect on situation or behavior of agents' members or affected by its members in the form)forecasting is not used.

14. Note: The following attributes are tracked using the behavior space at each time step and then analyzed these results:

- Number of cnsumers that are sick (Specific by brown color consumers in this model).
- Number of stores signalling at any one time(Specific by pink color in this model).
- Number of stores contaminated that are checked by regulaters (Specific by orange color in this model).
- Number of stores that are contaminated prevesly and are still contaminated at this time (Specific by red color in this model).
- Number of unsophisticated agents that whose not ever sick through the model course run.

4.1.3 Details:

1. Initialization: With 500 consumers and 100 stores and the experiment inspected for 10 inspectors done models run a process implemented. Also, the world is set to 33 * 33 for 1089 total patches with the center of the point of origin. The world covers together vertically and horizontally. Any simulation works on for 1000-time steps; in the past examination that measured works at every step, the model is shown to settle at the 1000 step tick.

- Consumers in the model are randomly distributed and this stage are similar at the beginning of the model. The bad-store-patches and tables destination is empty. They have following:
  - range set to 5.
  - sick set to 0.
  - heal-counter set to 0.
  - immune-system set to between .1 and .5.

- Patches: at initialization store is set to 1 and whole patches of a store have the polluted variable set to 0. Also chosen about 100 patches.

- Inspectors: whole inspectors distributed randomly everywhere in the world. They are have a domain of 10.

2. Sub models:

- Consumers : Healthy consumers are required to finish consuming procedure. Sick consumers must stay for 3-time steps on their final destination. The consumer procedure includes 2 sub-procedures:

- destination-set: Consumers should determine what patches are in their range.Should be stores are not in their list of bad stores and signaling that they are polluted. Then they select one of these destinations from the set of the patches and move to it.If there are no patches within the scope of consumer achieve the standards the consumer walk by selecting a random address and move 3 patches forward.
- Eating: In the eating procedure, the consumer determines whether the patch they have arrived on is polluted or not, if it is contaminated, and the random number created is smaller than the consumer's immune system. The consumer variable shifts to 1 of 0. This patch adds to list of a bad patch and shifts its color to Brown color.More than one consumer can access the same store at the same time.

- Inspectors: Inspections and examination procedures on store are carried out by regulators where inspector executes the testing procedures.

  Depending on the version of the model here, the regulator is required to test any signaling in pink or red within his scope because these signals mean that this store which has shifted color to pink or red is contaminated and if there is no signals the regulator choose a random store in his scope and checks it.

  When the regulator arrives at a store and finds it healthy he does nothing and if he finds it contaminated, he shifts the contaminated variable in the store to 0 and shifts the color of the patch from red or pink to orange.

- Patches: All patches clearly represent just empty space and patches that belong to the store patches that we will talk about them in this paragraph.

  Green patches represent uncontaminated or healthy stores and require one store per role to switch the contaminated variable to 1 of 0 and color to red if contaminated.

  In versions containing signals if the signal transmitted by the store shows that store color is pink, that means the store is pollution by this way agents can be informed that the

Table 4.3: Types of Model Versions

Types of model versions		
foundation line	Signal with sureness	Signal with mistake(erroer)
Agents avert (bad stores).	Store Signalling and avert(bad stores).	Store Signalling and avert(bad stores).
Regulators inspection randomly	first check stores signalling if it is not in scope randomly test.	first check stores signalling if it is not in scope randomly test.
Patches random pollution	Random pollution, reach to 5 market signal in each time step.	Random pollution, reach to 5 market signal in each time step but that signals are unsure.

store is contaminated otherwise they can not find out this information before visiting the store. To test patches for pollution 5 patches through time step are guide.If the specific patch is polluted or the store is polluted, it can inform the inspectors and consumers by changing its color to pink.In scenarios where signals are allowed with errors or are false. The signal procedure includes a random natant point number.

If the store or patches is not polluted, but the random number is smaller than the variable error signal, in this case, the store will send a signal that it is contaminated although it is not contaminated and if the store is contaminated and the random number is smaller than the "error-signal" variable, the store will not indicate is contaminated , although it should do.

Chapter 5

Simulation Analysis

5.1 Simulation and Analysis Proposed Models

5.1.1 The Proposed Model

Environment Details: The model is implemented in Netlogo Tisue and Wilensky, 2004. The simulation space consists of a cellular grid of size 33 x 33. More detailed runs were conducted using 100 repetitions 10 inspectors, 100 stores and 500 consumers. Each model run lasted for 1000 time steps and all data was collected at the end of the model run.A visualization of agents dispersion on the grid is shown in Fig. 5.1 for the case 1 and Fig. 5.2 for the case 4.

Simulation Cases:

Each simulation is run for 100 ticks. 1000 simulations are executed for one set of simulation parameters.

Following are the cases:

1. **Case 1:** Knowles's Model without Signaling.
2. **Case 2:** Knowles's Model with Signaling.
3. **Case 3:** Introduction of UPGRADE process, and the concept of progressive quality improvement or degradation of food.

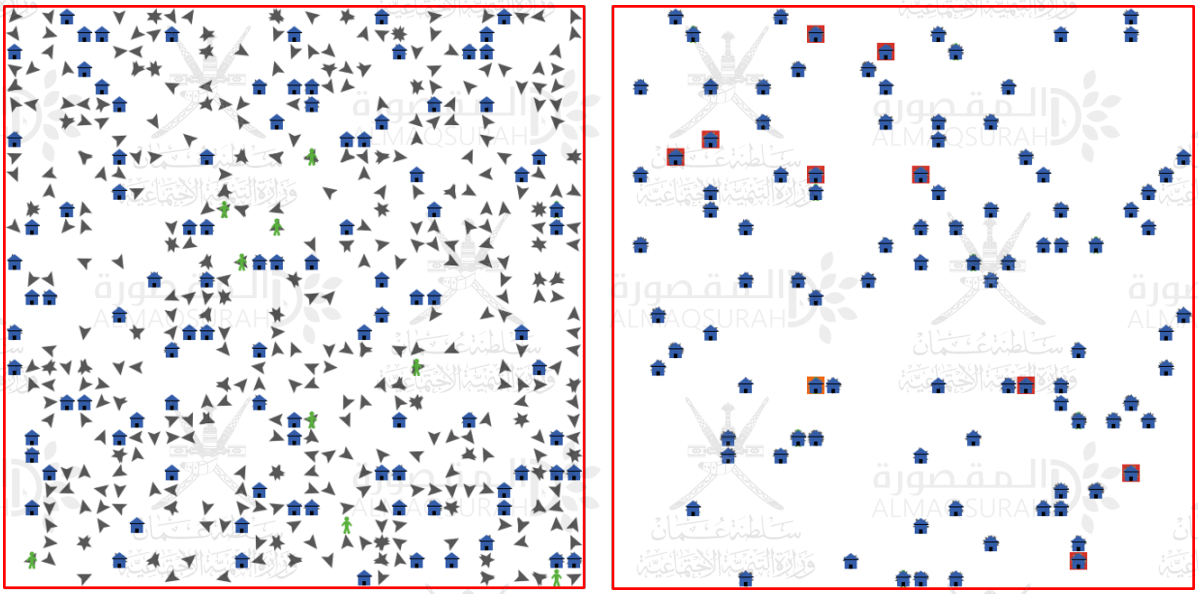

Figure 5.1: Case 1: Simulation space consisting of 100 stores (house shape), 10 regulators (person shape) and 500 consumers (regular agent shape). Left view shows the initialization of the simulation. Right view shows the situation at iteration 10. The stores with red background are contaminated, the store with orange background are sterilized; 29 consumers are already sick at this stage.

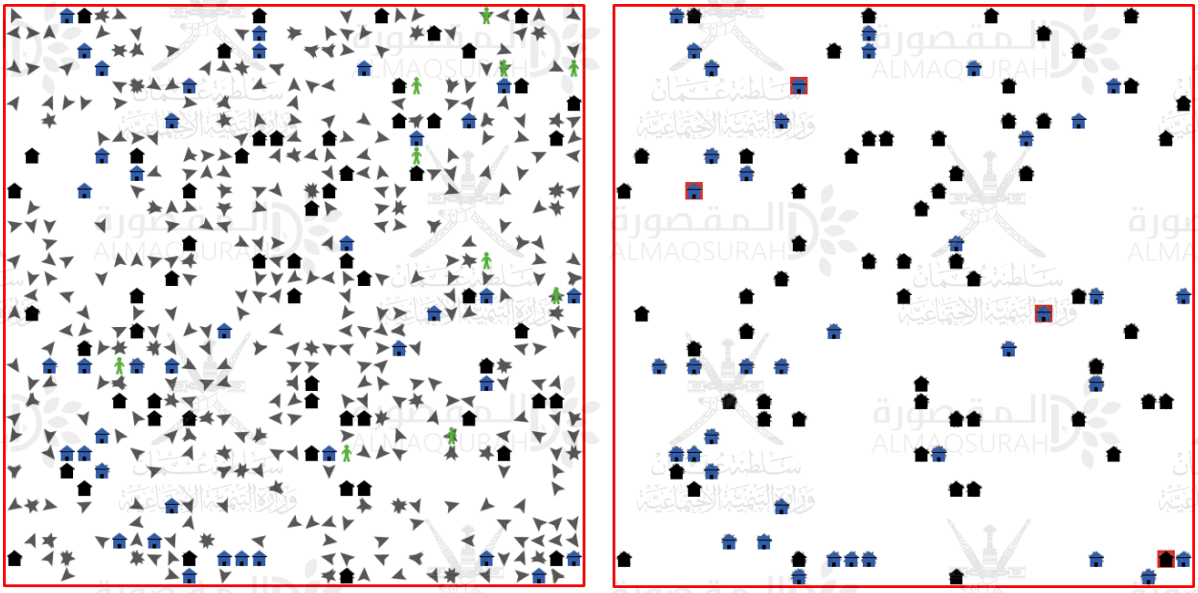

Figure 5.2: Case 4: Simulation space consisting of 100 stores (house shape, black stores are vigilant), 10 regulators (person shape) and 500 consumers (regular agent shape). Left view shows the initialization of the simulation. Right view shows the situation at iteration 10. The stores with red background are contaminated; 9 consumers are already sick at this stage.

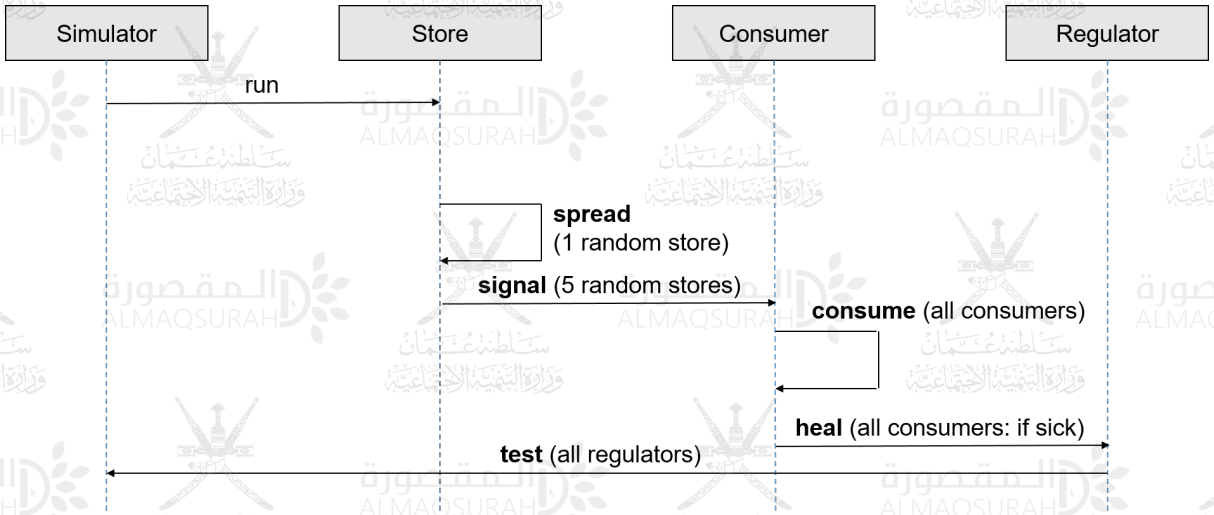

Figure 5.3: Sequence Diagram of Simulation Flow of Knowles model.

4. **Case 4:** UPGRADE process with effect of crowd to fine tune progressive quality improvement by vigilant stores.

5. **Case 5:** UPGRADE process with effect of crowd to fine tune progressive quality improvement by all stores.

A sequence diagram depicting the flow of simulation is shown in Fig. 5.3. The Simulator is responsible to start a run. Then one of the randomly selected store performed the process of spreading, followed by (optional) signaling by five stores. Then, all consumers follow consume and heal (only those who are sick). At the end, regulators perform test of stores.

All cases from case 3 to 5 do not use signaling and perform upgrade. A sequence diagram depicting the flow of simulation in that is shown in Fig. 5.4.

Case 1 is presumably the worst-case and Case 2 the best-case. However, even case 2 does not provide any mechanism of fair distribution of the consumers due to lack of vigilance from stores. Case 3 introduces mechanism of progressive improvement and degradation of quality (by stores). Built on case 3, Case 4 introduces the concept of vigilant stores. Case 5 provides a hypothetically enthusiastic scenario, in which all the stores are vigilant. So, from case 3 to 5, case 5 is presumably the best one.

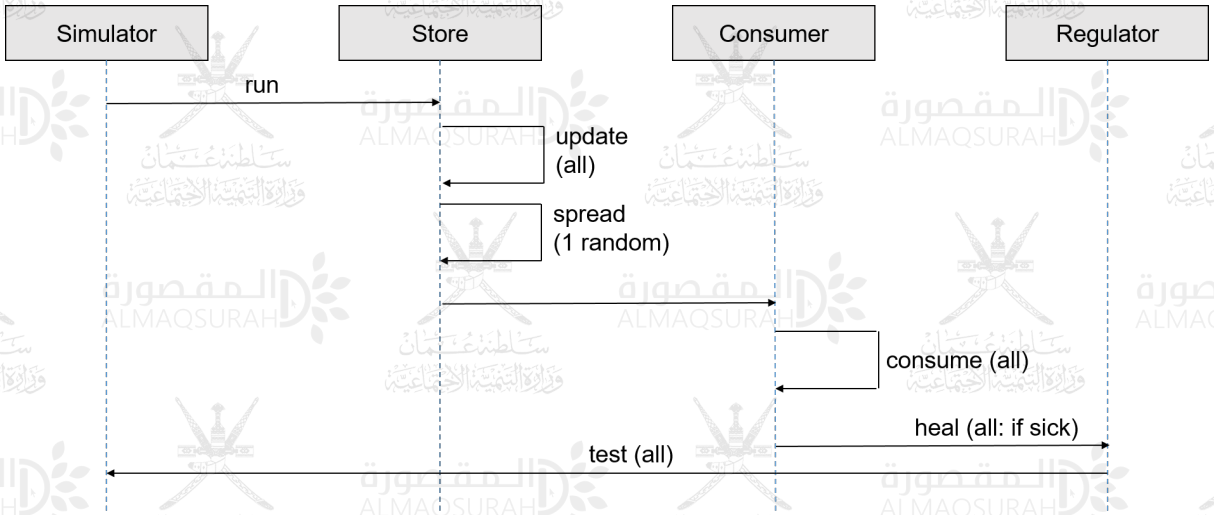

Figure 5.4: Sequence Diagram of Simulation Flow of our model using UPDATE and without signaling.

Simulation Results: The following parameters are user for the analysis:

- **Sick Consumers:** The number of consumers who are sick at each iteration.
- **Contaminated Stores:** The number of stores contaminated at each iteration.
- **Sterilized Stores:** The number of stores sterilized at each iteration.
- **Stores Usage:** Average standard deviation of stores usage, an average value of the whole simulation.

Our assumption about sick consumers and case 5 to be the best case between case 3 to 5 turn out to be true. However, case 5 also outperforms case 2. The reason is that in case 2, signaling alone does not guarantee a regulator in the proximity which could sterilize the store quickly. Whereas, in case 5, the vigilance of (all) stores just sensing a decline in the count of the consumer guarantee a self-correction mechanism which prevent many stores losing a substantial portion of their customers. Hence, at least for these settings of the simulation, we can conclude that an active society has capability of self-organizing without any regulatory compulsions. These results are depicted in the comparison graph shown in Fig. 5.5.

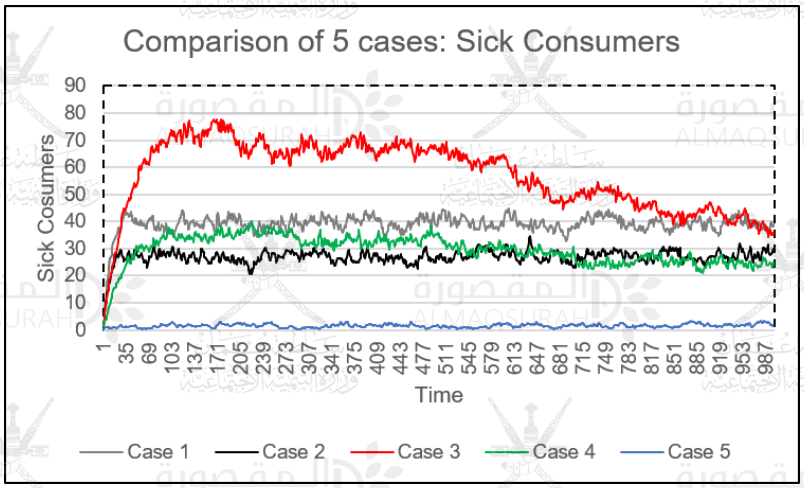

Figure 5.5: Simulation Results: Time Series of Sick Consumers, an average of 100 simulation runs.

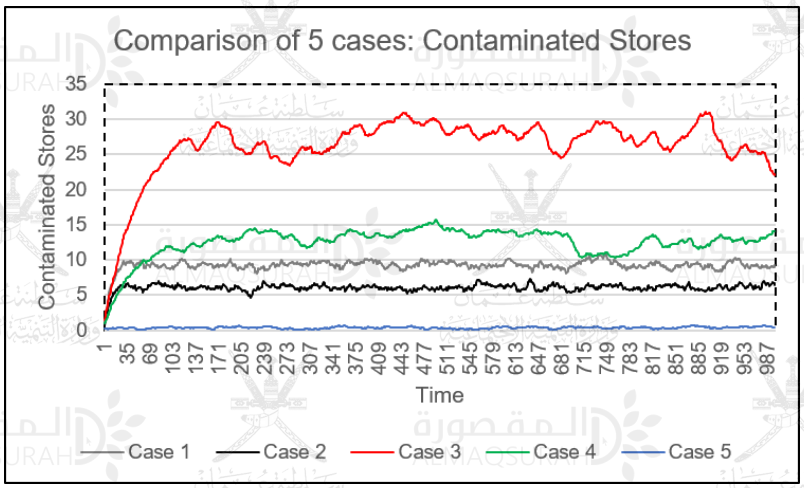

Figure 5.6: Simulation Results: Time Series of Contaminated Stores, an average of 100 simulation runs.

Also from Fig. 5.5, it is clear that case 3 is even worse than case 1. The reason is that progressive improvement and degradation in the quality imposes a further restriction on the contaminated stores delaying their status change from contaminated to sterilized. This fact is also evident from the graph shown in Fig. 5.6. All other cases are comparable with the graph shown in Fig. 5.5. The graph shown in Fig. 5.7 depicts the comparable trends in cases 3 to 5; the more the contaminated stores are the more these become sterilized. However, case 1 and 2 have higher values than even these 3 cases, and in terms of contaminated store (Fig. 5.6), this

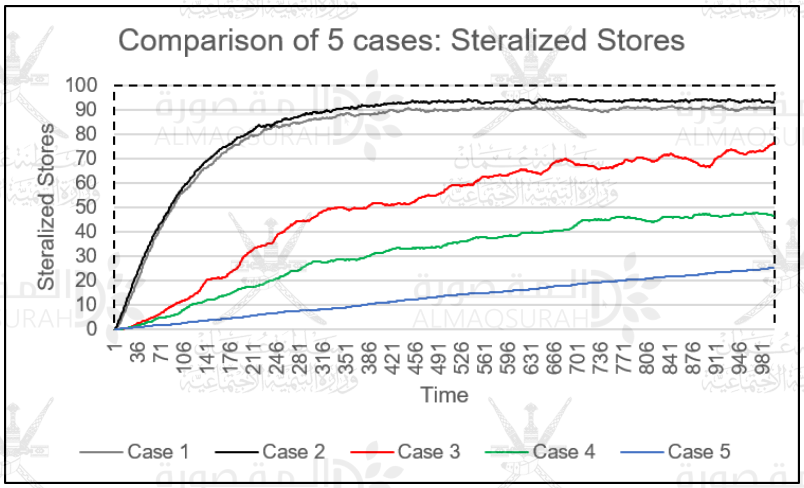

Figure 5.7: Simulation Results: Time Series of Sterilized Stores, an average of 100 simulation runs.

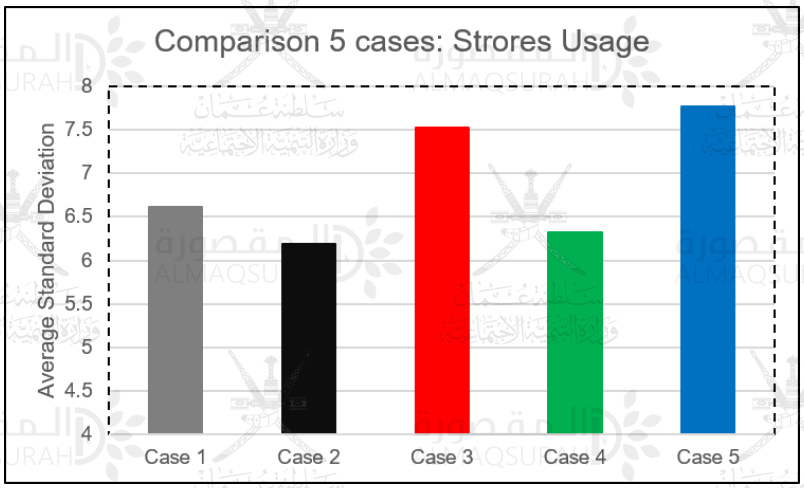

Figure 5.8: Simulation Results: Time Series of Stores Usage, an average standard deviation of 100 simulation runs.

is not comparable. Again the reason is the restriction imposed by progressive quality update, which inhibits the stores an abrupt status change from contaminated to sterilized.

Lastly, the fairness in stores usage is represented by average standard deviation of consumers presence at the stores. As shown in the graph in Fig. 5.8, the highest value comes against case 5. The standard deviation is stores usage represents the fairness in consumers presence in the stores. This means that the hypothesis that "more vigilance in correction measures ensures a large fraction of interested population available as compared to indifferent attitude"

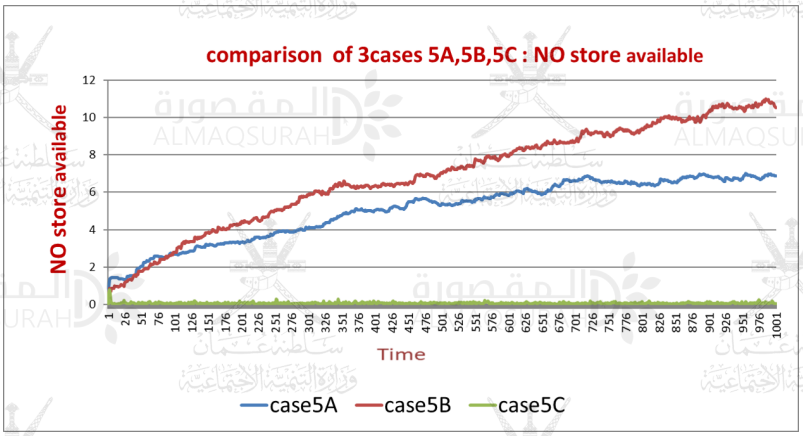

Figure 5.9: Simulation Results: Comparison of 3 cases (5A, 5B, and 5C). Time series of 100 simulation runs.

is verified. This may lead to increase in dependability and robustness of the system. However, this hypothesis not true for case 4, which turns out be the least. This means that the hypothesis should be rephrased as: "more vigilance in correction measures ensures a large fraction of interested population available as compared to indifferent attitude, provided that majority of the service providers are vigilant and sensitive to implications of "the wisdom of the crowds".

5.1.2 The Proposed Model (Extended)

In this model, we have used exactly the same settings as before. We have taken Case 5 as Case 5A now, and Case 5B, when case 5 is having no wondering mechanism. Case 5C is then the case which utilizes the friends network if no store is available in the proximity of a consumer. Naturally, we then have an additional parameter which is sued to show number of consumers not able to get a store even when they required it. We represent this parameter as consumers with **no store available**.

The basic purpose of this extension was to decrease the number of consumers which are not able to find a store in their proximity and take help from their friends. This is successfully achieved when we compare the three cases. Case 5B is the worst case. This is understandable duo to the lack of wandering mechanism. Even with wandering, we have substantial number

of consumers not able to find a healthy store. However, the new model proposed, ensures a real low value of number of consumers not able to find a healthy store through out the simulation time. These results are depicted in Figure 5.9. The other results are quite similar to what we have discussed before.

Chapter 6

Conclusion

An agent-based model of food safety management is presented in the thesis. The model extends a simple model of food safety McPhee-Knowles, 2015 involving consumers, regulators and stores.

In this thesis it uses two of idea:

First: the wisdom of crowd: when decreasing crowd interest due to degradation in the quality of service.Throght use our hypothesis, which states that (vigilant stores) we find that more vigilant service providers would keep a large fraction of population (people who do not have prior experience with the service provider) that is potential customer when compared to a service provider who is indifferent.

The consequence of it would be a more fair distribution of customers across competing service providers, thus, improving dependability of the overall system.

Second: Network of social relationships: The idea of "Network of social relationships" was used to analyze modeling components and simulation results. Therefore, positions leading to a more reliable system were identified.In particular, the following hypotheses were verified: use of social relationships was achieved successfully when the researcher compared the three cases 5A, 5B and 5C he found that the case 5B is the worst because it lack of a wandering mechanism and with the wandering mechanism we find that a large number of consumers are unable to find a healthy store.

Case 5C a best one where social relationships are available between representatives of the model enabling the consumer to find a healthy store through the exchange of data across the social relationships.

The result of this study is that the data exchanged through social relations is very useful for creating the personal organizational behavior of the population without need for an organizational authority and this results in resistance against the system towards a going towards a highly skewed distribution, thus, improving its stability.

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