THE ASSESSMENT OF FACTORS CONTRIBUTING TO FOOD FRAUD VULNERABILITY: A BAYESIAN MODELLING APPROACH ON A FOOD FRAUD DATABASE

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Abstract

Food fraud is defined as intentional behaviour designed to misrepresent or sabotage food items by third parties for economic gain. The growing incidences of food fraud over the last ten years lends support to the notion that traditional food safety intervention countermeasures have been largely inadequate. The increase in fraudulent incidents has further resulted in a change of focus in theory related to the investigation of food fraud from risk mitigation to vulnerability reduction. Food fraud is now classified as a separate category of food safety management systems in the literature. This shift in focus has also brought into question whether the traditional methods for combating food fraud also require a shift from common detection methods deployed by food safety managers to consideration of prevention and vulnerability reduction.

The food fraud vulnerability reduction literature has emerged from within the theoretical domain of Criminology and has relied on the Routine Activity Theory framework for identification of root causes for food fraud. The Routine Activity Theory suggests that there are three main factors to consider in the reduction of vulnerability to fraudulent activity. These are: opportunity; motivation; and countermeasures. Whilst this literature provides a framework from which to identify possible areas of vulnerability to food fraud, it does not provide a methodology that would allow food producers and processors to more accurately quantify and assess their vulnerability to food fraud. This study, therefore, takes up the call from researchers in this field to find better methods for the prevention of Food Fraud Vulnerability (FFV) factors by the development of a holistic model that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption.

Embracing a pragmatism view, this research adopted a sequential exploratory mixed methods approach. Phase one of the research commenced with a qualitative Barrier Analysis approach to extract the main Food Fraud Vulnerability factors within specific categories of food fraud as detailed in the US Pharmaceutical Food Fraud Database (USP FFD). The second phase of the research adopted a quantitative method, applying a Bayesian Network

(BN) modelling approach using SPSS Modeler 18.2. The data for the research was extracted from 580 incidents of global food fraud recorded between 2000 and 2018 in the US Pharmaceutical Food Fraud Database (USP FFD). Four food product categories were used for this study from the sixteen different categories provided by the database. These were: seafood; meat; alcoholic beverages; and dairy. These food categories represented just over fifty percent of all incidents recorded in the database. Approximately 80 percent of the data was used to train and develop the BN model, with the remaining 20 percent used for testing the validity and accuracy of the final BN model.

The Barrier Analysis technique conducted in phase one of this research identified new Food Fraud Vulnerability dimensions such as the physical form of products, supply chain complexity/transparency, corruption level of the detection country, culture and religion, price spikes, the requirement for coordination of law enforcement agencies, extensiveness of traceability, and food safety, which were subsequently indexed into the appropriate vulnerability categories of: opportunity; motivation; and countermeasures. The Bayesian network analysis conducted in phase two of the research, produced three main findings. First, the study confirmed that the Tree Augmented Naïve BN model can provide a robust assessment of vulnerability to food fraud with an accuracy of 86%. Second, the variable country of origin was identified as having the greatest influence on FFV factors. Third, the variable food fraud incident type was identified as having the least influence on FFV factors.

The findings from this research make two main contributions to the food fraud literature. Firstly, the identification and indexing of new Food Fraud Vulnerability dimensions has expanded the current knowledge regarding the root causes of Food Fraud Vulnerability. Further, this study has also provided valid empirical support for the inclusion of these factors in future studies investigating issues relating to vulnerability to food fraud. Next, the model based on the Barrier Analysis technique and BN modelling approach has provided a methodology to more accurately assess the root causes of food fraud for a range of food product types. This model allows future researchers to achieve more impactful results and to better understand the interrelationships of food fraud variables through the ability to manipulate both input factors and output (FFV) factors within specified conditions.

The study also makes two practical contributions for food companies, authorities in border protection, policymakers and quality assurance agencies through the identification of the main factors that are most likely to increase the vulnerability to food fraud under different conditions and for different product types. This information will assist these groups to implement the most appropriate countermeasures to combat the areas of vulnerability, and will also assist in the determination of likely FFV factors for future incidents.

Keywords

Food fraud, Food Fraud Vulnerability, Barrier Analysis technique, BN model, USP FFD

Certification Page

I certify that this study is entirely my own effort except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

Candidate Date

ENDORSEMENT

Principal Supervisor Date

Associate Supervisor: Date

Associate Supervisor Date

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

Acronym	*Full Name*
BN	Bayesian Network
BRC	British Retail Consortium
EMA	Economic Motivated Adulteration
EPC	Electronic Product Code
EU	Europe
FDA	Food and Drug Administration
FF	Food Fraud
FFV	Food Fraud Vulnerability
FSA	Food Standards Agency
GMA	Grocery Manufacturers Association
GS1	Global Solution One
NCFPD	National Centre for Food Protection and Defence
NSF	National Sanitation Foundation
PwC	PricewaterhouseCoopers
QR	Quick Response
RASFF	Rapid Alert System for Food and Feed
RFID	Radio-Frequency Identification
SPSS	Statistical Package for the Social Science
SSAFE	Safe Supply of Affordable Food for Everyone
USP	U.S. Pharmacopeia
USQ	University of Southern Queensland
WOE	Weight of evidence
DSAI	Dilution or substitution with an alternate ingredient
ODS	Other dilution/substitution

MGO	Misrepresentation of geographic origin
UNB	Use of non-declared, unapproved or banned biocides (preservatives, antibiotics, anti-fungal agents, etc.)
MAO	Misrepresentation of animal origin
MVO	Misrepresentation of varietal origin
MNC	Misrepresentation of nutritional content
MBO	Misrepresentation of botanical origin
FLC	Fraudulent labelling claims
DSAS	Dilution or substitution with an alternate substance (not food grade)
FAP	Formulation of an artificial product through the use of multiple adulterants and techniques
AEC	Artificial enhancement of perceived quality with colour additives
AEP	Artificial enhancement of apparent protein content
RMVL	Removal
ADD	Additives
CMCLS	Chemicals
EXPRD	Expired
CNTRFT	Counterfeit
SPCS	Species
HACCP	Hazard Analysis and Critical Control Point
VACCP	Vulnerability Assessment and Critical Control Points

1 CHAPTER 1: INTRODUCTION

1.1 Introduction

Food fraud is a global problem costing businesses approximately US $49 billion annually (McGrath et al. 2018) either in lost revenue or in the implementation of prevention and detection measures (McGrath et al. 2018; Moyer, DeVries & Spink 2017). Experts predict this cost to continue to grow noting that new prevention countermeasures and detection tools are needed as current protection of the food supply chain are clearly not working (Johnson 2014; PwC 2015; Spink & Moyer 2011; Spink et al. 2017; Tahkapaa et al. 2015; Van Ruth, Huisman & Luning 2017). Increasing incidences of food fraud are due in part to the global nature of the problem and the increasing economic gain being realised by fraudsters (Spink & Moyer 2011; Van Ruth, Huisman & Luning 2017). In spite of increased awareness of and attention being paid to the incidences of food fraud, experts predict that the full impact of food fraud is still under-represented as many incidents of food fraud remain undetected (Spink et al. 2017). New ways of detecting and reducing cases of food fraud are needed based on more holistic approaches that reduce the vulnerability to food fraud (Spink et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

This thesis takes up this call from industry and academic experts to find ways to better mitigate the level of vulnerability to food fraud for food products targeted at human consumption (Spink et al. 2017; Spink, Moyer & Peru 2016; Van Ruth et al. 2018). In this study, data recorded by the USP Food Fraud Database (FFD) will be used to develop a holistic model that will extend existing knowledge of Food Fraud Vulnerability (FFV) factors. The study will adopt a two-phase mixed method approach using a qualitative Barrier Analysis technique in phase 1 followed by a quantitative Bayesian Network modelling approach in phase 2. From this, a holistic model will be developed using Bayesian Network Modeling techniques that can assess FFV factors (or root causes of food fraud) and quantify the level of vulnerability to these causes for different food types. Table 1.1 illustrates the structure of chapter one.

Table 1.1: The structure of chapter one

Section	Purpose and Topics
1.1 Introduction	Introduction
1.2 Background	Research background and basic definition and concepts
1.3 Research problem	Research Problem and research questions
1.4 Justifications of Research	Research gaps and research contributions
1.5 Overview of Research Methods	Research Methodology
1.6 Outline of the Study	Snapshot of the study chapters
1.7 Conclusion	Summary

1.2 Background to the Research

Food fraud is a growing phenomenon that not only has the potential to threaten consumers' health, but also it can have a substantial negative impact on a company's finances, brand reputation, and/or competitive advantage (Johnson 2014; Lotta & Bogue 2015; PwC 2015; Spink & Moyer 2011; Ting & Tsang 2014). The health risks for consumers and the economic losses for food producers can be devastating. Spink and Moyer (2011) identified three main types of risk of food fraud that relate to consumers' health. These are: (1) direct risk or immediate exposure to the toxic or contamination hazards; (2) indirect risk or long-time exposure to the contamination hazards; and (3) technical risk because of misleading information about ingredients or allergens (p. R159).

Melamine in baby formula in 2008 in China is an example of food fraud that had a negative impact on public health. In this incident, fraudsters seeking economic gain, 'added melamine to milk to boost the apparent protein content' (Spink & Moyer 2011, p. R159). While the intent of fraudsters was only to gain profit, the impact led to ' a real public health vulnerability' (Everstine, Spink & Kennedy 2013; Spink & Moyer 2011, p. R158). Six babies died and 'close to 300,000 children became ill' (Everstine, Spink & Kennedy 2013, p. 725).

Food fraud can also have negative economic and reputational impacts on companies and can cause losses including: 'social loss and punishment; third party losses' (due to costly authenticity testing) (Van Ruth et al. 2018, p. 375); recall losses; and sales losses (Spink et al. 2017). The potential negative economic impact of food fraud on companies can be extreme, as evidenced in a recently reported case of apple juice adulterated with high-fructose corn syrup. This incident of fraud was estimated to return an additional US$18,000 per shipment to the fraudsters (Moyer, DeVries & Spink 2017).

The case of the horsemeat scandal in 2013 in the UK is an example of a case of fraud that resulted in economic gain to the fraudsters and reputational damage and economic disadvantage to the UK beef industry. In this case, the fraud increased the beef price in Europe by almost 45%, and the sales of frozen burgers by 13% (Moyer, DeVries & Spink 2017). However, the long-term reputational damage to the industry was more notable as food (beef) production companies (and not the fraudster) were liable and responsible in the case of food fraud (Spink & Moyer 2013).

These publicly reported incidents of food fraud have increased the general public awareness of food fraud issues and have heightened the interest from researchers to know more about the phenomena. Academic interest is still relatively new in this area with Spink and Moyer (2011) being the first authors to propose a definition of food fraud when they wrote about the famous incident of melamine being added to baby formula in China in 2008. Before this time, the cases of food fraud were identified through traditional food safety management system. The definition by Spink and Moyer (2011) has been largely adopted by the academy (e.g. Lotta & Bogue 2015; Moore, Spink & Lip 2012; Silvis et al. 2017; Smith, Manning & McElwee 2017) and posits that food fraud is 'the deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging; or false or misleading statements made about a product, for economic gain'(Spink & Moyer 2011, p. R158).

As leading researchers in this field, they further defended the notion that the factors and causes of food fraud are unique and important enough to consider it as a research domain in its own right, independent from the food safety management system discourse from where it originated (Spink & Moyer 2011). Their work highlighted that traditional food safety management systems were ineffective (Curll 2015; Esteki, Requeiro & Simal-Gandara 2019; Reilly 2018) in targeting and then minimising food fraud occurrences. They gave two reasons for this deficiency. First, food safety intervention (or detection) strategies are predicated on prior known (or conventional) toxic chemicals and hazards. Experience has shown that 'fraudsters continually seek ways to avoid detection by sourcing adulterants and other methods that are not listed among those conventional food safety contaminants' (Spink & Moyer 2011, p. R158). Thus different approaches and methods are required to both detect and mitigate against issues of fraud such as determination of vulnerability (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018) susceptibility to the fraud occurring in the first place.

The second reason is related to the different risk outcomes and motivations of fraudsters between food fraud and food safety incidents (Lord, Flores Elizondo & Spencer 2017; Manning & Soon 2016). When fraudsters are motivated to negatively impact public health, or when actions un-intentionally affect the health of others, then the act relates to issues of food safety. However, when fraudsters are motivated by hopes of economic gain without the intent to harm the health of others, and therefore they intentionally interfere with food products, then this is known as food fraud (Spink & Moyer 2011, p. R159).

The horsemeat scandal in the UK is an example of the failure of food safety strategies to address food fraud (Esteki, Requeiro & Simal-Gandara 2018; Lord, Flores Elizondo & Spencer 2017; Spink et al. 2017). In this incident, fraudsters had been adding less expensive horsemeat to beef products in order to realise more profit for a long period of time. While the horsemeat was ' clearly an illegally added 'adulterant-substance,' (Spink et al. 2017, p 215) there was no identified public health hazards' and therefore reactive strategies to combat this type of food fraud were not deployed (Lord, Flores Elizondo & Spencer 2017). In food safety management literature, reactive strategies are deployed ' whenever public health is threatened' (Spink & Moyer 2011, p. R159). In this example, the horse meat was only detected accidentally when food safety authorities conducted random sampling (Kerschke-Risch 2017) of the products to identify the proportion of beef for reporting purposes. It is speculated that the process of adulteration may have continued for even longer as the addition of the horsemeat had not impacted the public health and the routine sampling that identified the issue was inconsistent and somewhat random (Spink & Moyer 2011).

These differences between food safety and food fraud incidents have resulted in researchers calling for more innovative ways to combat and prevent food fraud (Spink & Moyer 2011; Spink & Moyer 2013; Spink et al. 2017; Tahkapaa et al. 2015). Innovative ways to address food fraud should focus on learnings from analysis of historical incidents of food fraud (Spink, Moyer & Peru 2016) as well as consideration of ways to prevent the root causes of food fraud as a means to determining the degree of vulnerability to fraudulent activity (Food Fraud Vulnerability - FFV) (Silvis et al. 2017; Spink & Moyer 2011; Van Ruth, Huisman & Lunning 2017;). This approach requires a shift in thinking from 'risk' 'mitigation' (or reactive strategies deployed by food safety management systems) to 'vulnerability' 'prevention' (Spink et al. 2017, p. 219).

As a first step in this process, Moore, Spink and Lipp (2012) introduced the USP Food Fraud Database (FFD) to assist in the analysis of historical food fraud incidents to facilitate innovative ways of protecting the food supply chain from the fraudulent intervention (Moore, Spink & Lipp 2012, p. R125). Identifying these 'weaknesses' or 'flaws' in the supply chain are known in the literature as areas of vulnerability (Van Ruth, Huisman & Lunning 2017, p. 70).

The Routine Activity Theory has provided a set of principles to assist in better describing and detecting areas of vulnerability to food fraud (Van Ruth, Huisman & Luning 2017). Applying this theory, vulnerability to food fraud is defined as, 'the outcome of convergence in time and space' of a motivated offender, a suitable target, and absence of a capable guardian (i.e. traceability technology) (Ellis et al. 2016; Van Ruth, Huisman & Luning 2017, p. 71). Thus for vulnerability to food fraud to exist, there need to be three factors in evidence: These are: opportunity; motivation; and the absence of countermeasures (Silvis et al. 2017; SSAFE 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

Studies exploring the factors that impact vulnerability to food fraud are just emerging in the literature with the key factors most relevant when considering vulnerability to food fraud published as recently as 2017. The seminal study by Van Ruth, Huisman and Luning (2017) built on the principles of the Routine Activity Theory and described three different factors could be used to impact vulnerability to food fraud. Further studies by Ruth et al. (2018) and Silvis et al. (2017) extended this work and created the SSAFE Food Fraud Vulnerability Assessment (FFVA) tool. This tool is designed for self-assessment of vulnerability to food fraud based on a managers' perspective.

Although the above studies addressed and analysed the important FFV factors, they did not address the ways to prevent or minimise the vulnerability to food fraud. Studies that could address this gap have been cautioned by researchers in the field to adopt a holistic approach to consider a range of viewpoints (Van Ruth et al. 2018). This proposed study takes up this call, combining the work of researchers exploring the assessment of FFV factors, with those who have used the Routine Activity Theory frameworks to gain a richer view of the factors that can increase the vulnerability to food fraud for food products designed for human consumption (Spink, Moyer & Peru 2016).

The proposed research will integrate this knowledge to create a holistic model that assesses the level of vulnerability to food fraud which will be tested for validity against real-world food fraud data recorded by a global food fraud database. The results of this research will lead to the development of a holistic model that can assess the level (degree) of vulnerability to food fraud for a range of food categories using Bayesian Network modelling. This information will also identify the most relevant factors to consider mitigating or eliminate that vulnerability.

1.3 The Research Problem

The main aim of this research is to develop a holistic model that can assess the level (degree) of vulnerability to fraud for food products targeted at human consumption. In order to do so, this research will develop a holistic approach to identify and assess FFV factors. Although there are studies that have attempted to develop a model in order to prevent the risk of food fraud

(Bouzembrak & Marvin 2016; Marvin et al. 2016), these studies have focused on identifying the types of food fraud incident (such as (1) improper, fraudulent, missing or absent Health Certificate (HC), (2) Illegal importation, (3) Tampering, (4) improper, expired, fraudulent or missing Common Entry Document (CED), (5) Expiration date, (6) Origin labelling, (7)Theft and Resale) rather than attempting to assess the potential vulnerability of various categories of food to fraudulent activity. This is the gap in the extant literature that this study will address (Silvis et al. 2017; Spink, Moyer & Peru 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). Therefore the main research question for this study is:

How can the vulnerability to food fraud for food products designed for human consumption be assessed?

In order to address the research question, a number of sub-questions need to be answered. These are:

Sub-question 1: What are the factors that influence the vulnerability to food fraud food products designed for human consumption?

A recent study by Marvin et al. (2016) exploring 'the value of using a Bayesian Network (BN) modelling' to mitigate risk of food fraud (p. 463), suggested that the type of fraudulent incident may also be an important influencer when attempting to develop a holistic model that can assess the level of vulnerability to food fraud. Further, they also suggested that the development of a holistic model would also benefit from an understanding of the relationships between the variables known to be relevant. Thus, sub-questions 2 and 3 are proposed for this research.

Sub-question 2: How can the types of food fraud be used to assess Food Fraud Vulnerability factors?

Sub-question 3: Which of the variables, known to influence the vulnerability to food fraud, are most important?

In order to address these questions, potential variables that influence the level of vulnerability to food fraud from the literature (Bouzembrak & Marvin 2016; Marvin et al. 2016) and the source data (database) will be utilised using Barrier Analysis technique combined with the Routine Activity Theory to construct a Bayesian Network structure and from that develop a holistic model. The justification for this research will be presented next.

1.4 Justifications for the Research

As described in the previous sections, the main aim of this research is to develop a holistic model that can assess the level (degree) of vulnerability to food fraud for food products designed for human consumption. The academic literature investigating vulnerability prevention has to date, relied on the Routine Activity Theory (Spink et al. 2015; Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018) to provide a framework for categorising the FFV factors. These previous studies have organised the factors into three key groupings: opportunity; motivation; and countermeasures (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

In spite of the increased managerial interest in the issue of vulnerability to food fraud, particularly amongst those producing food for human consumption, the literature and empirical research addressing and assessing Food Fraud Vulnerability factors is only just emerging (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). This study contributes to this emerging field of scholarship by introducing an alternative method through the development of a holistic model that can assess the level of vulnerability to food fraud for food products targeted at human consumption. Table 1.2 presents a summary of the research objectives, research questions and research contribution for this study aligned to the research gaps in the literature.

Table 1.2: Research gaps and research contributions

Research Question	Research Gaps	Research Contribution
Main Research Question: How Can the vulnerability to food fraud for food products designed for human consumption be assessed?	Prior research has highlighted the need for a holistic approach to shifting from risk mitigation to vulnerability reduction (that is different from the common food safety management system strategies) to prevent food fraud (Spink & Moyer 2011; Spink et al. 2017; Lord, Flores Elizondo & Spencer 2017). Focus on FFV factors classification by the Routine Activity Theory is recommended (Spink, Moyer & Peru 2016; Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018)	This research will develop a holistic approach that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption
Sub-question 1: What are the factors that influence the vulnerability to food fraud food products designed for human consumption?	Need to understand the root causes of food fraud/or what motivates food fraudsters to commit fraud	New classifications of FFV factors will be developed and indexed using the Barrier Analysis method combined with the Routine Activity Theory categories of opportunity, motivation, and countermeasures
Sub-question 2: How can the types of food fraud be used to assess Fraud Vulnerability factors? Sub-question 3: Which of the known food fraud variables are most relevant when assessing vulnerability to food fraud?	Need to identify variables that influence vulnerability to food fraud and analyse (or compare) these variables through the application of Bayesian Modeling approach based on real data (from food fraud database) for different food fraud types (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). Focus on the food fraud incident type as a possible dynamic variable that influences FFV factors (Marvin et al. 2016), and other factors addressed by the source data (Bouzembrak & Marvin 2016; Marvin et al. 2016)	In order to address the Sub-question 2 and Sub-question 3 of the study, a Bayesian Network model will be constructed and tested against the theoretical assumptions (the Routine Activity Theory). The research will analyse different potential influencing variables of FFV factors and determine the most important one.

This proposed study is justified according to the three significant needs for vulnerability reduction strategies: (1) a need for a holistic approach to shifting from risk mitigation to vulnerability reduction; (2) gaps in food fraud research; (3) and benefits for food production companies, border protection authorities, governments and quality assurance agencies aiming to reduce food fraud (Spink & Moyer 2011; Spink, Moyer & Peru 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

The first justification for this study relates to the call from the literature to undertake a more innovative approach to combat the problem of food fraud (Silvis et al. 2017; Spink & Moyer 2011; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). The new approach for food fraud prevention requires the shift from risk mitigation (e.g. when using detection technologies), to strategies designed to reduce or remove areas of vulnerability with more valid tools for assessment (Lord, Flores Elizondo & Spencer 2017; Spink & Moyer 2011; Spink et al. 2017). Shifting the approach from risk mitigation to vulnerability reduction also requires changes in practice in relation to responses to the problem of food fraud.

Vulnerability reduction requires a proactive approach to the management of food fraud, relying on identifying the root causes of the problem before the fraud occurs (Spink & Moyer 2011). Risk mitigation, by contrast, is a reactive approach that identifies strategies for action once the fraud has occurred (Spink & Moyer 2011). This change in approach is especially important when dealing with fraudulent incidents that have the potential to threaten public health (Everstine, Spink & Kennedy 2013). If it is possible to prevent the vulnerability to food fraud and isolate the main areas of risk prior to fraud occurring, then it should be possible to also reduce the incidences of fraud, increase confidence for public safety and reduce the economic impact of food fraud for businesses.

To achieve this outcome in a way that is reliable and robust, researchers have supported the practice of using historical data of food fraud incidents, recorded in global databases (Everstine, Spink & Kennedy 2013), to test and confirm proposed models (Bouzembrak & Marvin 2016; Marvin et al. 2016; Tahkapaa et al. 2015). Databases such as Europe (RASFF), or US (EMA) have been used in the study by Marvin et al. (2016) combining these to attempt to ensure a global approach. However, the study by Bouzembrak et al. (2018) have criticised this method stating that the use of these two food fraud databases could lead to the overlap of incidents because of duplication that may exist as EMA also ‘collect[s] food fraud reports from the RASFF’ database (Bouzembrak et al. 2018, p.289). Therefore, a more robust analysis of food fraud incidents, using a comprehensive (global) database is needed.

This proposed study will take up the call from researchers to use a more comprehensive database, such as the USP FFD, for development of a holistic model (e.g. Bouzembrak et al. 2018; Bouzembrak & Marvin 2016). This database is relatively new and as such, its use in this study will contribute to the literature and research in this area of vulnerability to food fraud.

The food fraud literature has highlighted the need to be more proactive in the fight against food fraud by changing the focus from reaction to prevention of fraud. To do this it is important to first identify the root causes of food fraud to be able to then prevent the vulnerability to these factors (Spink & Moyer 2011; Van Ruth et al. 2018). This requires a multi-disciplinary approach to research as the root causes of food fraud can be diverse (Spink & Moyer 2013). This research takes up this call and will consider the insights from literature related to the Routine Activity Theory; and Signalling Theory.

The review of this literature has led to the identification of three gaps that this research will address, thus providing a second justification for this research. The first research gap relates to factors affecting vulnerability to food fraud (Spink, Moyer & Peru 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). The literature is in agreement that there is a lack of insight into these factors and that more research is needed (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). In particular whilst there has been some attempt to identify FFV factors using the SSAFE self-assessment tool and insights from the Routine Activity Theory approach, empirical analysis of these factors and their influencing variables based on real data (e.g. recorded by FFD) is still unexplored in the literature (Van Ruth et al. 2018).

The second and third research gaps are related to variables that influence FFV factors. Although the emerging food fraud literature emphasises the need to shift from thinking about intervention (or risk mitigation) strategies to that of vulnerability reduction (i.e. Spink et al. 2015), there is lack of comprehensive research that provides evidence about how variables that influence FFV factors behave. Specifically, food fraud scholars have called for an approach that allows for the modelling of the dynamic and possibly reciprocal interrelationship between the food fraud incident types and drivers of food fraud (or FFV factors) (Marvin et al. 2016; Bouzembrak & Marvin 2016). In addition, these researchers have called for such a model to be rigorously tested through the use of real data from a comprehensive food fraud database like USP FFD in order to develop an accurate holistic model (Bouzembrak et al. 2018). This study fills this gap by undertaking the development and testing of such a model.

The third justification of this study relates to the benefits for food production companies, border protection authorities, governments and quality assurance agencies who work to detect and reduce vulnerability to food fraud. A significant outcome for these groups would be the ability to identify and the root causes and the likelihood of food fraud vulnerability for different types of product (dairy versus meat for example). Furthermore, the development of a holistic model will help these groups reduce the costs of deploying countermeasures by facilitating the use of targeted countermeasures that will best combat the area of vulnerability instead of the more traditional scattergun approach. Finally, those in positions to create policies for the protection of food integrity within the supply chains will be able to use the outputs from the model developed by this research to more accurately target areas for focus and regulation.

1.5 Overview of Research Methods

This thesis has adopted a pragmatism paradigm according to which the researcher employs both qualitative and quantitative approaches to understand and acquire knowledge about the problem (Creswell 2014)– in this case, vulnerability to food fraud. Adopting this paradigm requires the researcher to use qualitative data analysis (Williams 2018) (in this case identification of relevant themes or factors that impact vulnerability to food fraud through Barrier Analysis method) to build a training model which is then tested against known data using quantitative methods to adjust and then validate the final holistic model.

Therefore, a mixed methods strategy is selected to address the research questions (Johnson & Onwuegbuzie 2004) for this study. The type of mixed methods research strategy that is chosen for this study will be sequential exploratory where qualitative data is conducted first, followed by the analysis of quantitative data (Venkatesh, Brown & Sullivan 2016). This mixed methods strategy is ideal for understanding complex research problem (Creswell 2014) such as vulnerability to food fraud, which is the focus of this study.

The first phase of the research is qualitative building on previous studies suggest that the identification of the key FFV factors (based on Routine Activity Theory) is yet to be completed (sub-question 1) (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). In addition, the identification of these factors requires initial exploratory screening of actual food fraud cases (Spink, Moyer & Peru 2016; Van Ruth et al. 2018). The purpose of this qualitative approach is to identify the root causes of vulnerability to food fraud based on reviewing food fraud history.

The Barrier Analysis method (Blomkvist et al. 2010) will be selected as a qualitative approach to understand and identify the root causes of incidents (Mahto & Kumar 2008) of food fraud and to extrapolate the factors most likely to indicate vulnerability to food fraud. The use of the Barrier Analysis technique is supported in the literature specifically related to incidents of security (and/or safety) violations (see Blomkvist et al. 2010; Dong et al. 2016; Johnson 2006). Four categories of food will be used for this analysis as these make up more than fifty percent of all food fraud incidents in the database. These are: seafood and seafood products; meat and poultry; alcoholic beverages; and dairy.

The second phase of the research will be quantitative in nature and will adopt a Bayesian Network analysis approach. There are two main reasons for the adoption of the approach. First, large data sets (580 cases of food fraud, one target variable with 128 input/independent variables) will be used in this study to acquire an accurate holistic model using statistical software of SPSS

Modeler 18.2. The Bayesian Network analysis approach has been shown to be most effective in building a probability model based on prior probability incidents identified (within a database) (IBM Nd (b)).

Second, the Bayesian Network modelling approach has precedence in the extant literature and has been shown to be an appropriate and robust method for the purpose of understanding the patterns of occurrences and interrelationships of variables related to food fraud (see Marvin et al. 2016; Bouzembrak & Marvin 2016). Given the nature of this study's main research question which requires an assessment of the level of inputs and pattern determination, the quantitative technique would be most appropriate for the second phase.

A secondary data analysis approach will be selected for this research because this thesis plans to test FFV factors against real data or food fraud incidents to address research gaps. The use of secondary data analysis is most suited to this research as this method includes the examination and assessment of recorded data (Jenkin 1985). The USP FFD will be selected as a secondary database for a 'greater knowledge of food fraud '(Bouzembrak et al. 2018; Bouzembrak & Marvin 2016, p. 185). From all 8,721 cases of food fraud reported in the USP FFD, this thesis will use four product types of seafood, meat and poultry, alcoholic beverages, and dairy products as the sample for data analysis as they cover more than 50% of the database records.

1.6 **Outline of the Study**

This thesis will develop a holistic model for determination of vulnerability to food fraud for food products designed for human consumption. The structure of the thesis is illustrated in the chapters describes next.

Chapter One – introduction describes an overview of this research by emphasising the theoretical background and illustrating its key components related to the research problem, research, objectives, research questions, research significance, and the research methodology.

Chapter Two – Literature review will analyse the academic literature in multi-disciplinary areas of food fraud, criminology, and business on relevant concepts and theories. Discussions illustrated in this chapter will focus on the definition of food fraud and the important differences between food fraud and food safety in order to highlight the importance of theoretical framing. The discussion will then move to an investigation of the concepts related to the vulnerability to food fraud. The chapter then will analyse the FFV concept based on the Routine Activity Theory and a preliminary Bayesian Network will be proposed.

Chapter Three – Research methodology will explain the justifications of selecting a pragmatist paradigm and mixed methods approach. The study then will illustrate the selection of the secondary data analysis approach to address the research problem, research questions, and data collection. A detailed description of the qualitative (Barrier Analysis technique) and quantitative (Bayesian Network modelling) approaches are then provided.

Chapter Four – Results will provide a discussion of the findings that emerge from the research questions composing this research. The discussion will present descriptive analysis of variables that influence FFV factors related to all four products categories, describing FFV factors identified from Barrier Analysis technique (sub-question 1), Building and constructing Bayesian Network structure to understand important influencing variables using SPSS Modeler 18.2 (sub-question 2 and sub-question 3), and finally, validating the holistic model (main research question).

Chapter Five – Contributions will summarise and integrate the result findings described in chapter four with the literature presented in chapter two. The results relating to the research question will be discussed and theoretical and practical contributions to the research questions will be described in this chapter.

1.7 **Conclusion**

Recent incidents of food fraud have stimulated academics to study this complex phenomenon. A need to develop a holistic approach to identify and assess vulnerability to food fraud for food products has been emphasized in the literature. In particular, previous studies suggest focusing on the Routine Activity Theory and real cases of food fraud recorded in the USP FFD for the assessment of FFV factors. This thesis focuses on this need and addresses the gaps in the extant literature through the development of a holistic model that can assess the level of vulnerability to food fraud for food products targeted at human consumption. The main research question was formulated about the assessment of the FFV factors, with three sub-questions that explore the main factors affecting vulnerability to food fraud (sub-question 1), and variables that influence FFV factors (sub-question 2, sub-question 3). A mixed methods research will be adopted in order to answer the research questions. Barrier Analysis Technique and Bayesian Network modelling approach will then be selected for data analysis methods.

The following chapter reviews the relevant literature and discusses in detail the key concepts formulated by the research questions. In particular, the Routine Activity Theory and the Routine Activity Theory will be explored.

2 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter 1 illustrated the growing seriousness of food fraud incidents for companies that produce and manufacture food for human consumption. In spite of the increased interest in the issue of vulnerability to food fraud, particularly amongst those producing food for human consumption, the literature and empirical research addressing Food Fraud Vulnerability (FFV) factors and its influencing variables is only just emerging (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). This research will contribute to this emerging field of scholarship through the development of a holistic model that can assess the level of vulnerability to food fraud for food products targeted at human consumption. Table 2.1 provides an overview of the structure and outline of this chapter.

The chapter commences with the review of the literature relating to food fraud, and a discussion of the issues of theoretical framing before moving to an investigation of the concepts related to the vulnerability to food fraud. Section 2.2 includes definitions of food fraud, its types and important differences between food fraud and food safety. Section 2.3 presents the theoretical frameworks from criminology literature providing insight into the food fraud problem through the area of vulnerability.

The theoretical frameworks presented in section 2.3 lead to a determination of factors that impact vulnerability to food fraud. These theoretical frameworks referred to in this section are: the Routine Activity Theory; and Signalling Theory. Section 2.4 presents the FFV concept and factors affecting vulnerability to food fraud. The chapter concludes with a preliminary theoretical framework that proposes inter-relationships between FFV factors and its influencing variables. The theory relevant to food fraud will now be presented.

Table 2.1: Chapter two structure

Section	Purpose
2.1 Introduction	Introduction
2.2 Food fraud	Definition of food fraud and its different types Describing the differences by Food Risk Matrix and Food Protection Plan
2.3 Criminology Literature	Justification of selecting the Routine Activity Theory to understand root causes of vulnerability to food fraud (including the area of vulnerability)
2.4 Food Fraud Vulnerability	Describing FFV factors
2.5 Conceptual Framework of the study	Conceptual model
2.6 Conclusion	Summary

2.2 Food Fraud

Although food fraud is not a new problem (Tahkapaa et al. 2015), academic and industry interest in this phenomenon is relatively recent, stimulated by two specific incidents of food fraud; (1) the melamine in the baby formula incident in China in 2008 (Lotta & Bogue 2015), and (2) the horsemeat scandal in the UK in 2012-2013 (Moore, Spink & Lipp 2012; Spink & Moyer 2011). The question over the effectiveness of food safety control system on handling these cases of intentional adulteration has highlighted the importance of the need for developing more specific definition on food fraud different to food safety (Spink & Moyer 2011). In the case of China, the melamine was not detected in time (before the death of several infants) by food safety officers due to the fact that melamine was not defined as food adulterants in the food safety management system. Food safety incident was historically defined as an unintentional act (Spink & Moyer 2011; Spink et al. 2017) that 'will not cause harm to the consumer' (Manning & Soon 2016, p. R823). The (intentional) motivation and root causes of these two incidents have enforced global food protection organisations and academics to set a new definition for food fraud (Curll 2015; Lotta & Bogue 2015; Spink & Moyer 2011).

Table 2.2 shows common food fraud definitions by organisations and academics with the key food fraud type in their definition. The US Food and Drug Administration (FDA) defined food fraud as Economically Motivated Adulteration (EMA) that is ‘ Fraudulent, intentional substitution or addition of a substance in a product for the purpose of increasing the apparent value of the product or reducing the cost of its production, i.e., for economic gain’ (Manning & Soon 2016, p. R824). EMA is one type of food fraud and thus this definition does not contain all other fraud types (Manning& Soon 2016; Spink & Moyer 2011). The UK’s FSA described food fraud based on two types of fraud: (1) unfit for consumption and (2) misdescription (Manning & Soon 2016). The term food fraud is broader than the only EMA type defined by FDA, GMA, NCFPD, Elliott Review (2014) and is more specific than ‘general concept of food counterfeiting’ (Spink & Moyer 2011, p. R158) that is covered in the USP FFD.

Table 2.2: Common definitions of food fraud by food organisations and academics

Organisation/Academics	Definition	Food fraud type inclusions
Food and Drug Administration (FDA) (2009)	'Fraudulent, intentional substitution or addition of a substance in a product for the purpose of increasing the apparent value of the product or reducing the cost of its production, i.e., for economic gain'	Economically Motivated Adulteration (EMA)
Food Standard Agency (FSA)	'The deliberate placement on the market, for financial gain, with the intention of deceiving the consumer, covering two main types of fraud. These include the sale of food which is unfit and potentially harmful as well as the deliberate misdescription of food, such as products substituted with a cheaper alternative'	Unfit/Harmful and Misdescription
United States Pharmacopeia (USP)	'Food fraud in the context of food ingredients refers to the fraudulent addition of non-authentic substances or removal or replacement of authentic substances without the purchaser's knowledge for economic gain of the seller. It is also referred to as economic adulteration, economically motivated adulteration, intentional adulteration, or food counterfeiting'	EMA, Food Counterfeiting
	'Economic adulteration is defined as the intentional fraudulent modification of a finished product or ingredient for economic gain through the following methods: unapproved enhancements, dilution with a lesser-value ingredient, concealment	EMA that include Enhancement, Dilution, Mislabelling, mislabeling,

Grocery Manufacturers Associations (GMA) (2010)	of damage or contamination, mislabelling of a product or ingredient, substitution of a lesser-value ingredient or failing to disclose required product information'	Substitution, Conceal damage/product information
National Centre for Food Protection and Defence (NCFPD) (Researchers from University of Minnesota)	'Economically motivated adulteration (EMA) is the intentional sale of substandard food or food products for the purpose of economic gain. Common types of EMA include intentional substitution of an authentic ingredient with a cheaper product, dilution with water or other substances, flavor or color enhancement using illicit or unapproved substances, and substitution of one species with another'	EMA which includes substitution, dilution, and enhancement
Spink and Moyer (2011)	the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients, or food packaging, or false or misleading statement about a product, for economic gain	Includes all types of food fraud
Elliott (2014)	food fraud becomes food crime when it no longer involves random acts by 'rogues' within the food industry but becomes an organized activity by groups which knowingly set out to deceive, and or injure, those purchasing food	Based on/Similar to FSA definition, EMA/Misrepresentation (Manning & Soon 2016)

Source: Elliott Review (2014); Johnson (2014, p. 5-6); Manning and Soon (2016); Moore, Spink and Lipp (2012); Spink and Moyer (2011)

In an attempt to provide consistency for academic researchers and those policing food fraud, Spink and Moyer (2011) synthesised these various perspectives to propose a standard definition of 'food fraud' for the first time in the Journal of Food Science (Spink & Moyer, 2011). Their definition provided a broader conceptualisation of the phenomenon of food fraud than had previously been considered by these other standard setting organisations (Curll 2015) and was proposed as:

'…*the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients, or food packaging, or false or misleading statement about a product, for economic gain.'* (Spink & Moyer 2011, p. R158)

This definition has been generally accepted in the theoretical discourse (e.g. Manning & Soon 2016; Lotta & Bogue 2015; Marvin et al. 2016; Silvis et al. 2017; Spink, Moyer & Peru 2016) and Spink and Moyer continue to lead the research in this field. This definitional consensus has allowed other researchers to be more focused in their investigations into aspects of food fraud which in turn has extended the impact of their work.

In developing their definition, Spink and Moyer (2011) sought to more clearly differentiate actions that would be defined as fraudulent in nature from those that related to food safety. Drawing from the criminology literature, they identified that the main difference in these incidents resided in the motivations of those involved. They determined that fraudsters were not generally motivated to seek harm to individuals through their acts of food tampering or adulteration. Rather, they were motivated to seek economic gain as a result of their actions and that these actions were purposeful in nature. Thus their definition proposed two key principles that are required for a food tampering/adulteration incident to be classified as food fraud. These are: the act needs to be intentional; and it needs to be motivated by the desire for economic gain. Further, it is the intentional nature of food fraud acts that result in them being considered criminal in nature and prosecutable by law (Spink et al. 2017).

According to this definition accidental, unintentional, serendipitous damage or contamination to food products would not be classified as food fraud (Spink & Moyer, 2011). Similarly, food safety incidents are not always motivated by the desire for economic gain and thus would also not be defined as food fraud using this approach. This approach works both ways with not all food fraud incidents also being classified as food safety. For example, the substitution of highly valuable food source (Beef) for a similar cheaper one (Horse meat) would be classified as food fraud but would not be classified as a food safety incident due to the clear intent for economic gain and the lack of harm to those who consumed the product (Huck, Pezzei & Huck- Pezzei 2016, p. 33).

To facilitate investigation and analysis of food fraud, researchers interrogate known cases of fraud and food safety that have been collected in three main commercial databases. These databases regularly collect and classify information on global food fraud incidents (Zhang & Xue 2016) and researchers have variously used any one or a combination of these to facilitate their study of food fraud (e.g. Bouzembrak et al. 2016; Marvin et al. 2016; Moore, Spink & Lipp 2012; Tahkapaa et al. 2015).

Within these databases, the broad category of food fraud has been further sub-divided into different types or categories with the exact number and definition generally established by the databases that hold the information. These categories are important as they control the scope of any research investigation. These databases are: the RASFF database (Rapid Alert System for Food and Feed); the EMA database (Economically Motivated Adulteration); and the USP database (US Pharmaceutical). Each will now be briefly described commencing with the RASFF database. Table 2.3 shows the comparison of these databases.

Table 2.3: Main food fraud database features and limitations

Database Name	Feature	Limitations
RASFF	• Food fraud classifications: improper, fraudulent, missing or absent health certificates; illegal importation; tampering; improper, expired, fraudulent or missing common entry documents or import declarations; false expiration date; and mislabelling	• Geographic limitation: only includes incidents in the EU • Includes both intentional and unintentional food safety incidents
EMA	Food fraud classifications: Intentional distribution of contaminated products; artificial enhancement; counterfeiting; substitution; mislabelling; dilution; transhipment; and theft and resale.	• Geographic limitation- Only incidents in the USA • Unavailable at the time of data collection for this research
USP	• Includes comprehensive incidents from all around the world • Food fraud classifications: Replacement, Addition, Removal	• Not publicly available (only through a paid subscription)

Source: Bouzembrak and Marvin (2016); Manning and Soon (2016); Moore, Spink and Lipp (2012); Zhang and Xue (2016)

The RASFF database is publicly available (since 2014) and releases and exchanges information in relation to food fraud incidents in the EU (only Europe) (Marvin et al. 2016). The RASFF uses six food fraud types or categories. These are: (1) improper, fraudulent, missing or absent health certificates; (2) illegal importation; (3) tampering; (4) improper, expired, fraudulent or missing common entry documents or import declarations; (5) false expiration date; and (6) mislabelling (Bouzembrak & Marvin 2016).

The main issue with this database is that it confines its listing to incidents that have occurred in the EU and thus, non-EU incidents of food fraud are not captured (Tahkapaa et al. 2015, p. 181). To account for this deficiency, most researchers who use this information supplement it with another database such as the EMA database. Moreover, the RASFF database includes both intentional and unintentional incidents (Marvin et al. 2016), means that it include food safety incidents which is out of scope of this research.

The EMA (Economically Motivated Adulteration) incident database publishes cases (or incidents) of food fraud from the United States (Marvin et al. 2016). This database was available upon request up until 2017-2018 and is now not accessible. This database classified eight types of food fraud: (1) intentional distribution of contaminated products; (2) artificial enhancement; (3) counterfeiting; (4) substitution; (5) mislabelling; (6) dilution; (7) transhipment; and (8) theft and resale.

In the literature, EMA and its classifications have been used to analyse food fraud types, food products likely to be targeted for food fraud, and food source/locations (Zhang & Xue 2016). Whilst this database provided a comprehensive inclusion of food fraud types and was particularly useful in conjunction with the RASFF database to provide global coverage, its discontinuation makes it redundant for the purposes of research post-2017. Moreover, the geographical limitation related to both EMA and RASFF is that they confined to incidents occurs in the EU only (for RASFF database) and/or the USA only (for EMA database) and therefore they do not include comprehensive incidents around the world when applying separately (Marvin et al. 2016).

The USP database, established in 2012, is new and provides comprehensive documentation of global food fraud incidents. The USP database classifies food fraud types into three categories that reference all types of food fraud defined by food organisations (e.g. GMA, FDA, etc. see Table 2.2) and scholars (Spink & Moyer 2011; Johnson 2014). The categories of food fraud used in the USP database are: (1) replacement; (2) addition; and (3) removal (Moore, Spink & Lipp 2012; Zhang & Xue 2016).

The USP food fraud database is regularly updated and currently lists thousands of publicly available cases sourced from published literature, media reports and regulatory reports (www.foodfraud.org). The recommendation by the USP expert panel from industry and academic also addresses ‘ food ingredient adulterant substances including vulnerability assessment’ (Spink, Moyer & Peru 2016, p. 309). As this study plans to develop a holistic model that can assess the level (degree) of vulnerability to food fraud for different food fraud incident types, this USP database will provide the best source of data. For this reason, each classification of food fraud adopted in this database and its theoretical source will now be briefly described, commencing with replacement.

2.2.1 Food Fraud Types in the USP Database

The idea of developing the USP Food Fraud Database came from the research gap existed in the literature related to systematic efforts needed towards collecting and analysing previous cases of food fraud (Moore, Spink & Lipp 2012). Collecting and analysing cases of food fraud is a fundamental step towards developing novel response strategies (Spink, Moyer & Peru 2016) to ‘ prevent future food fraud’ (Moore, Spink & Lipp 2012, p. R119). The need to collect and analyse cases of food fraud was first noticed after the case of melamine in the baby formula in 2008 in China. The case was not detected in time to save the life of several infants due to the fact that the melamine was not considered as contaminants or adulterants by traditional food safety/protection systems (Moore, Spink & Lipp 2012; Spink & Moyer 2011). Development of a new database that gathers specific cases of food fraud to determine ‘an infinite number of potential adulterants’ and identify future incidents are deemed essential (Moore, Spink & Lipp 2012; p. R119).

Moore, Spink and Lipp (2012) started collecting the case of food fraud based on a comprehensive literature review (peer-reviewed journals) and media reports. They analysed and coded the data into the database named the USP Food Fraud Database (FFD) which is available at www.foodfraud.org from 2012. Moreover, an expert panel from industry and academics has reviewed the data published in the USP FFD (Spink, Moyer & Peru 2016). The USP FFD described specific types of food fraud into three broad categories of Replacement, Addition, and Removal as they coded in the USP FFD. Table 2.4 shows these three categories, their definition and examples.

Table 2.4: Food fraud subtypes with examples

USP Food Fraud Types	Subtypes	Example
Replacement	Adulteration	- Addition of melamine to milk to artificially increase apparent protein contents measured by total nitrogen methods. - Addition of water and citric acid to lemon juice to fraudulently increase the titratable acidity of the final juice product. - Overtreating frozen fish with extra water (ice)
	Misrepresentation	- Substitution of cow's milk for sheep or goat's milk. - Substitution of common wheat for durum wheat - Substitution of Greek olive oil for Italian olive oil. - Substitution of synthetically produced vanillin for botanically derived (natural) vanillin
Addition	Colour enhancement	- Addition of Sudan Red dyes to enhance to the color of poor-quality paprika
	Taste enhancement	- Addition of sugar to mask the astringent taste of poor-quality pomegranate juice
Removal	NA	- Removal of nonpolar constituents from paprika (for example, lipids and flavor compounds) to produce paprika-derived flavoring extracts. The sale of the resulting defatted paprika, which lacks valuable flavoring compounds, as normal paprika is a fraudulent practice

Source: FDA (2009); Lotta & Bogue 2015; Moore, Spink & Lipp (2012), p. R121

Moore, Spink and Lipp (2012) defined subtype of Replacement as (1)‘addition, dilution, or .extension of an authentic ingredient with an adulterant or mixture of adulterants’, and (2) false declaration of geographic, species, botanical, or varietal origin, the raw material origin or production process used to manufacture an ingredient, and origin to evade taxes or tariffs’ (p. R121). The first subtype of replacement was defined as EMA (or intentional adulteration) as described in Table 2.2. The second subtype of replacement was further defined by Lotta and Bogue (2015) as Misrepresentation that encompasses both Falsification and Food counterfeiting. Table 2.4 shows the classification of food fraud subtypes based on the definitions by Moore, Spink and Lipp (2012), Lotta and Bogue (2015), and FDA (2009).

2.2.1.1 Replacement

Types of fraud that are listed under the classification of replacement are those where there is, ‘…complete or partial replacement of a food ingredient or valuable authentic constituent with a less expensive substitute’ (Johnson 2014, p. 8). Replacement types of food fraud have been further categorised in Table 2.4 having two sub-types: adulteration; and misrepresentation.

Food fraud incidents that are classified as Adulteration are those where there has been; ‘…a change of identity/or purity of the original and purported ingredient by substituting, diluting or modifying it by physical and/or chemical means’ (Lotta & Bogue 2015. p. 117). Adulteration can happen in different ways and the degree of dilution or sophistication of the change can also vary. A recent study by Zhang and Xue (2016) identified that this was the major food fraud concern from many Chinese consumers and that this type of food fraud has shown to have a higher number of cases in ‘regions with higher level of industrialization and urbanization’ than ‘less developed areas’ (p. 193)

This form of food fraud can be quite dangerous due to accidental serious health consequences for consumers. Addition of melamine to baby formula (milk) that increases the ‘protein contents measured by total nitrogen methods’ (Moore, Spink & Lipp 2012, p. R121) is an example of this dangerous form of food fraud. In addition, consumers with allergies, or those sensitive to particular substances could be negatively affected through the addition of a substance or through increased ‘quantities of an already present substance’ (Spink & Moyer 2013, p. 32).

Food fraud incidents that are classified as misrepresentation occur through falsification and/or counterfeiting activity. Whilst this is often a less dangerous form of food fraud for consumers it can still have health consequences if the falsification is also accompanied by mislabelling of ingredients (Huck, Pezzei & Huck- Pezzei 2016 ; Lotta & Bogue 2015). Falsification occurs when there is a false ‘declaration of geographic species’ (e.g. substitution of sheep or goat milk as cow’s milk), or ‘false declaration of raw material origin (e.g. substitution of synthetic vanillin for natural vanillin) (Moore, Spink & Lipp 2012).

Falsification has been reported in the academic literature mostly in relation to meat and fish products (Charlebois et al. 2016; Lotta & Bogue 2015) and can also include incidents where ‘false declaration of origin’ is made to evade taxes/tariffs (Johnson 2014, p. 8). An example of this type is the ‘importation of catfish from Vietnam labelled as grouper’ to avoid taxes and anti-dumping duties (Johnson 2014, p. 8). Other examples are ‘substitution of cow’s milk for sheep or goat’s milk’, and ‘substitution of Greek olive oil for Italian olive oil’ (Moore, Spink & Lipp 2012, p. R121).

Food counterfeiting is another sub-set of misrepresentation (Spink & Moyer 2013). In most food counterfeiting incidents, the country of origin is changed in order to gain more profit (Huck, Pezzei & Huck- Pezzei 2016). Other than the country of origin, food authentication certificates can also be counterfeited by fraudsters (Johnson 2014) such as in the cases of halal food products or organic food products. According to Lotta and Bogue (2015) label counterfeiting is related to misleading information about ‘certification or any registered trademarks’ (p. 118).

Counterfeiting organic certifications means that the seller did not obtain the required certificate from associated authorities and so the product is not compliant with regulations. Examples of this type can be selling ‘high stocking density’ eggs as ‘free range’ (Lotta & Bogue 2015, p. 118) and counterfeiting labels where unfit rotten meat was inserted into the product (Bosley 2007) with counterfeit halal certificates in France in 2006 (Tahkapaa et al. 2015).

2.2.1.2 Addition

Food fraud incidents that would be classified as addition would be those where there has been: '…the addition of nonauthentic substances to mask inferior quality ingredients without the purchasers' knowledge' (Moore, Spink & Lipp 2012, p. R121; Zhang and Xue 2016). Subtypes of addition in food fraud incidents as defined by Moore, Spink and Lipp (2012) include: colour enhancement using Sudan red dyes to enhance the colour of poor-quality paprika'; and taste enhancement like '[the] addition of sugar to mask the astringent taste of poor-quality pomegranate juice' (Moore, Spink & Lipp 2012, p. R121).

Colour enhancement actions are most commonly found in food spices (Everstine 2013; Galvin-King et al. 2018; Silvis et al. 2017) where the addition of dyes to spices is done to improve the value of the product (Galvin-King et al. 2018) or to make it look fresher (Everstine 2013). For example, 'older spices may be mixed with freshly ground ones', or 'non-spice material may be added as an extender' to enhance the colour (Everstine 2013, p. 16).

Synthetic dyes that are illegally added to food (i.e. by azo dyes or triphenylmethanes) can lead to allergic reactions or can even cause damage to the DNA (Galvin-King et al. 2018). Taste enhancement fraudulent practices are mostly related to fruit juices according to the literature (Hong et al. 2017). Examples are the addition of 'water, sugars, and other 'cheap alternatives' to the fruit juice (Hong et al. 2017, p. 3885). Based on the FDA report, 'addition of sugar and water, the addition of pulpwash solids, the substitution of a less expensive juice' are most popular fraudulent practices in fruit juices (Everstine 2013, p. 11).

2.2.1.3 Removal

Food fraud incidents that are classified as removal refer to, '…removal of an authentic and valuable constituent without the purchasers' knowledge' as defined by Moore, Spink and Lipp (2012, p. 121). The example of this type of food fraud can be the 'removal of nonpolar constituents from paprika (for example, lipids and flavor compounds) to produce paprika-derived flavoring extracts' (Moore, Spink & Lipp 2012, p. R121). Other examples include the removal of valuable components from 'spent' spices and selling these as whole spices (Everestine 2013, p. 16) and 'removal of essential oils from nutmeg' (Silvis et al. 2017, p. 83).

There is limited information about this type of food fraud. According to the study by Moore, Spink and Lipp (2012), based on their analysis of food fraud incidents published in the database, cases of removal represented less than one percent (Moore, Spink & Lipp 2012, p. R123).

2.2.2 Difference Between Food Fraud and Food Safety

The previous section presented a definition of food fraud and discussed the different types as well as outlining the differences between food fraud and food safety. Food fraud and food safety are not the only considerations when examining food contamination and adulteration risks. The Food Risk Matrix (Figure 2.1) is a useful way to identify differences between different types of food risk and categorises four types of risk related to food products. These four risks are: food safety; food fraud; food quality; and food defence (Spink & Moyer 2011).

Using this matrix, the risk of food fraud is shown where there is intentional action (cause) and motivation for economic gain. In contrast, the risks relating to food safety incidents occur when there is unintentional harm to individuals consuming the product (Spink & Moyer 2011). Food quality risks are shown where there are unintentional actions that result in economic gain and finally, the risks associated with food defence incidents are the most serious as these are (malicious) tampering cases with the intention and desire to do harm (Spink & Moyer 2011).

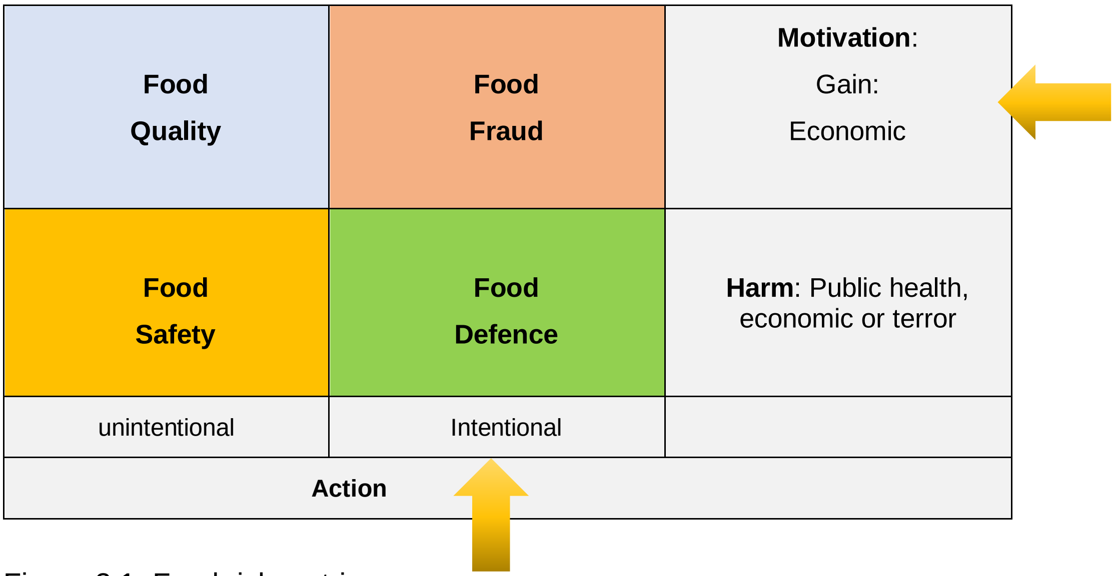


Figure 2.1: Food risk matrix
Source: Adapted Spink and Moyer (2011, p. R160)

The difference between the root causes of risks related to food fraud and those related to food safety risk explain why traditional food safety countermeasures, often used to detect contamination hazards (Bosona & Gebresenbet 2013), are not sufficient to detect and combat food fraud (Azuara et al. 2012; Curll 2014; Spink & Moyer 2011; Spink et al. 2017;). Food safety risk mitigation refers to, '…protecting the food supply from unintentional contamination' (Manning & Soon 2016,p. R823). In contrast, food fraud prevention refers to protecting the food supply from intentional adulteration with a motive to gain profit. In addition, food safety management systems deal with known hazards such as conventional toxic chemicals, however, 'fraudsters may use adulterants that are not listed among those conventional food safety contaminants' (Spink & Moyer 2011, p. R158).

In the food safety management systems, intervention countermeasures (see A in Figure 2.2) are deployed in order to decrease the negative consequences of the risk. Therefore, most food safety countermeasures are related to authentication technologies where the focus is on detection rather than deterrence (Azuara et al. 2012; Curll 2014; Spink & Moyer 2011). The authentication technologies deployed by food safety management systems are most often referred to as reactive measures, meaning that they are effective only once the adulteration is identified and thus, do not serve to prevent food fraud (Spink & Moyer 2011).

New ways of thinking about prevention of food fraud suggest focusing on the determination of the root causes of food fraud or Food Fraud Vulnerability (FFV) factors (see B in Figure 2.3) prior to implementing any intervention countermeasures (Van Ruth, Huisman & Luning 2017). According to a study by Spink, Moyer and Peru (2016), ‘ vulnerability is the potential exposure to a risk that may or may not have occurred’ (p. 307). The purpose of vulnerability reduction is to eliminate those root causes that create opportunity and motivation for fraudsters to commit the crime (Van Ruth, Huisman & Lunning 2017). The goal of this shift in thinking is to identify and then prevent those FFV factors (or root causes) to ultimately prevent future food fraud incidences that may threaten public health.

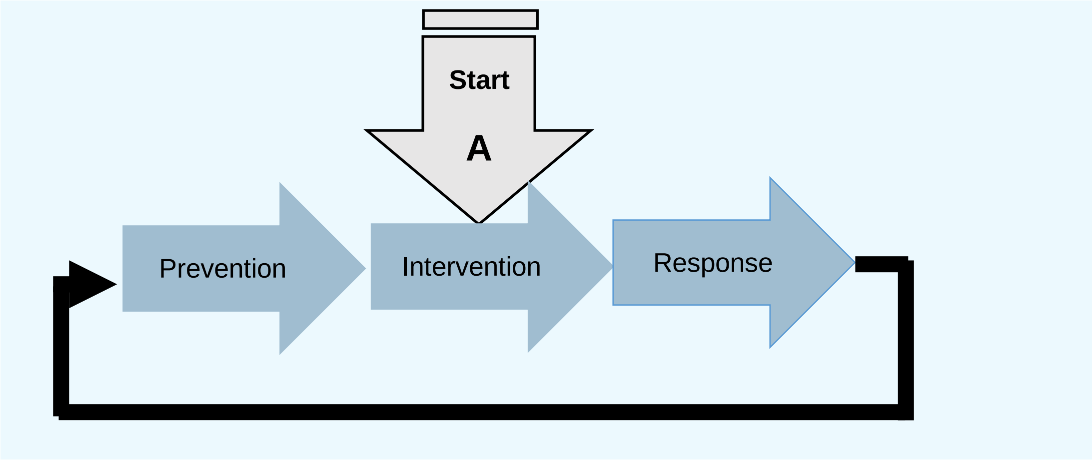


Figure 2.2: FDA Food protection plan progression
Source: Spink and Moyer (2011, p. R158)

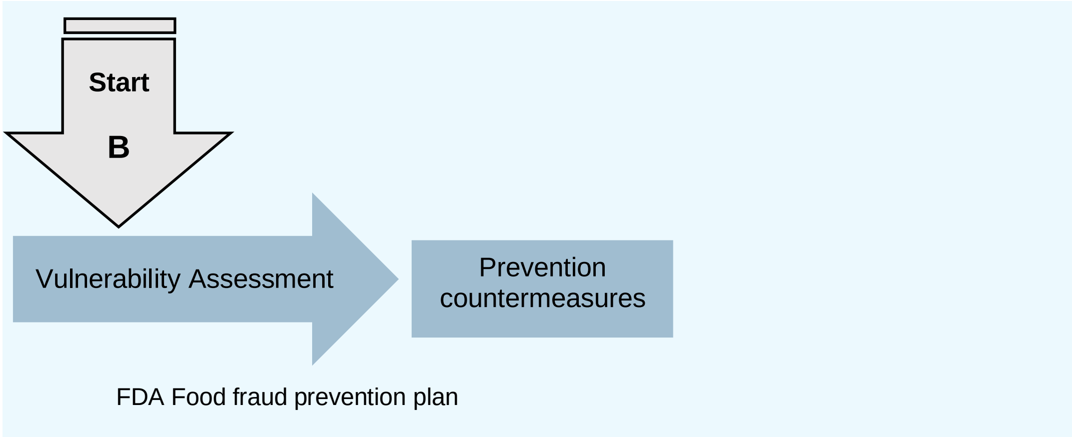


Figure 2.3: Shift from detection to prevention

Source: Spink and Moyer (2011) Spink et al. (2017, p. R159)

Studies by Bouzembrak and Marvin (2016) and Marvin et al. (2016) have tried to find ways to predict food fraud incident (types) in an attempt to mitigate or prevent fraudulent activity. Bouzembrak and Marvin (2016) employed Bayesian Network (BN) modelling to develop a model to predict the types of food fraud most likely to occur when some of the antecedent factors such as country of origin, food product type, year that incident occurred, and country of detection are known. They have found that the BN model can predict future food fraud types with an accuracy of 80% when food fraud type, food product type, and country of origin were reported before in the database. Their BN model predicts food fraud types based on the cases of food fraud published in the RASFF database (EU environment) (Bouzembrak & Marvin 2016) and this is one of the main limitations of this model. It is for this reason that food fraud researchers have called for more comprehensive consideration be given to additional data from other databases like EMA (which is not accessible now) or USP (Bouzembrak & Marvin 2016).

Marvin et al. (2016) developed a Bayesian Network (BN) modelling approach for the food production chain that used the RASFF and EMA databases together that links all available drivers related to food safety risks, focusing on incidents of food fraud. Their model is based on four steps: (1) collection of food fraud incidents (based on RASFF and EMA databases); (2) identification of drivers affecting fraud cases; (3) constructing BN model; and

(4) validation of the BN model. They have found that the BN model can predict future food fraud types with an accuracy of 91% when influencing drivers such as country of origin, food product type, country of detection, and the year (that incidents occurred) were reported before in the database. The limitation of their model is that the linking drivers (influencing drivers, root causes or what motivates fraudsters) relied on supply chain variables (based on the National Sanitation Foundation (NSF 2014)) report and food safety variables (unintentional adulteration published in RASFF which are not cases of food fraud) (Marvin et al. 2016, p. 468). This work continues to reinforce the gap in the extant literature providing cues to the prevention of food fraud based on an understanding of the motivation to commit the fraudulent action (Tahkapaa et al. 2015; Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

If food fraud is viewed as a crime, then criminology theories provide useful insights for researchers exploring issues of prevention (Spink and Moyer 2011; Silvis et al. 2017; Spink and Moyer 2013; Lord, Flores Elizondo & Spencer 2017). Criminology literature provides a framework to analyse situations where food fraud may occur (Smith, Manning & McElwee 2017). These theories are addressed next.

2.3 Criminology Literature

Criminology theories have aided food fraud researchers to better understand the motivations of potential fraudsters and to develop strategies to address issues of vulnerability and fraud prevention (Lord, Flores Elizondo & Spencer 2017; Manning & Soon 2016). There are several criminology theories discussed in the literature related to food fraud problem that include: Common Sense Theory, Game Theoretical approach Theory, Rational Choice Theory, Relative Depreciation Theory, Routine Activity Theory, and Social Control Theory. Table 2.5 shows the application of these criminology theories.

Table 2.5: Common theories related to food fraud

Theory	Application	Theory reference
Common-Sense Theory	*Understanding Fraudsters motivation*- Fraudsters commit fraud for economic gain	Walklate (2007); Manning & Soon (2016)
Game-Theoretic approach Theory	*Understanding Fraudsters motivation*- Fraudsters' economic motivation increases if they know there is a low likelihood risk of detection	Hirschauer & Zwoll (2008); Manning & Soon (2016); Vatsa, Sural & Majumdar (2007)
Rational Choice Theory	*Understanding Fraudsters motivation*- Offenders (fraudsters) evaluate the benefit and consequences of committing fraud and make a rational choice based on their evaluation	Pease (2006); Manning & Soon (2016); McMurtry & Curling (2008)
Relative Deprivation	*Understanding Fraudsters motivation*- when fraudsters perceived themselves as being deprived, they will feel injured and frustrated and may attempt to commit fraud	Walklate (2007); Manning & Soon (2016); Itashiki (2011)
Social Control Theory (Hisrchi 1969)	*Understanding Fraudsters motivation*- Fraudsters motivation to commit fraud increases when there are (1) low level of attachment (social relationships), (2) low level of commitments, (3)less involvement (time in conventional behaviour), and (4) low level of beliefs.	Manning & Soon (2016)
Routine Activity Approach (Cohen & Felson 1979)	***Understanding the root cause of Food Fraud Vulnerability***- Food fraud occurs when there is motivated offender, suitable victim and absence of guardian (or control measures)	Spink & Moyer (2013); 2017Lord, Flores Elizondo & Spencer (2017)Manning and Soon 2016; Van Ruth et al. (2017); Van Ruth, Huisman & Luning (2017)

This study will use the Routine Activity Theory for two main reasons. The first reason is that all of the other theories are related to the understanding motivation of fraudsters while the Routine Activity Theory is focusing on deterrence and understanding how to reduce food fraud vulnerability (Spink & Moyer 2013; Van Ruth, Huisman & Luning 2017). The second reason is related to its popularity in both criminology literature (Van Ruth, Huisman & Luning 2017) and the support from the food fraud literature as mentioned in several papers (see Moyer, DeVries & Spink 2017; Silvis et al. 2017; Spink & Moyer 2013; Van Ruth, Huisman & Luning 2017). The next section will describe the Routine Activity theory in detail.

2.3.1 The Routine Activity Theory

The Routine Activity Theory emerged in the 1970s (Cohen & Felson, 1979) and was developed to explain how crime rates are impacted by the routine activities of individuals in a society (Cohen & Felson 1979). The Routine Activity Theory allows criminal researchers to investigate how generalised patterns of social activity such as spatial and temporal patterns in the family, work and leisure, combine with situational factors to impact the likelihood of a crime occurring. The Routine Activity Theory suggests that criminal acts occur as a result of the convergence of a motivated offender, a suitable target and a lack of guardianship or control or supervision. The Routine Activity theory has shifted the focus of criminology theories from addressing fraudsters' motivation to ' a detailed analysis of criminal events and criminal activities' (Kleemans, Soudijn & Weenink 2012).

When applied to a food fraud context, the Routine Activity Theory assists organisations to identify potential situations where food fraud events are more likely to occur. The Routine Activity Theory is presented through the Crime Triangle tool (see Figure 2.4) (Hennessey, Busta & Cunningham 2011). The Crime Triangle shows that how fraud opportunity occurs based on three main characteristics that are : (1) the existence of potential fraudsters; (2) a potential victim or 'suitable target'; and (3) the absence of a capable guardian or countermeasures (Manning & Soon 2016; Spink & Moyer 2011; Ellis et al. 2016; Van Ruth, Huisman & Luning 2017). Based on the Crime Triangle (Figure 2.4), guardians (also known as capable guardians in the literature) can be investigators who monitor the food fraud system, managers, authorities, governments, law enforcement agencies and food producer/manufacturers. Guardian and Hurdle gaps (also shown in the model) are countermeasures that hinder and/or inhibit fraudulent activity (Spink & Moyer 2013). As these factors (Guardian and Hurdle gap) are both considered to be important countermeasures for food fraud incidents they are often grouped together, as shown in figure 2.4. Guardians and hurdle gaps can be proactive when considered for deterrence purposes or reactive when considered for detection purposes (Spink & Moyer 2011).

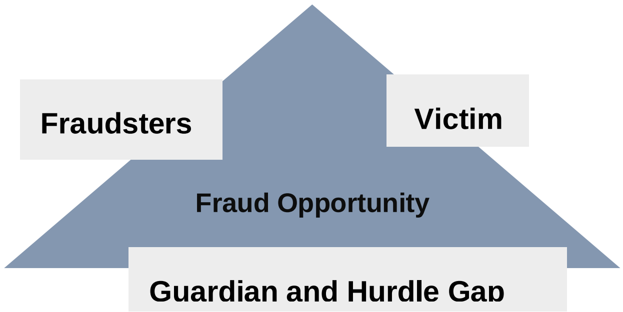


Figure 2.4: Crime Triangle

Source: Adapted from Spink and Moyer (2013, p. 34)

The Routine Activity Theory also focuses on crime prevention (Kleemans, Soudijn & Weenink 2012) through employing preventative strategies rather than focusing on the potential fraudsters and reactive strategies. According to the Crime Triangle, the area inside the triangle shows the magnitude of the food fraud opportunity. This area can grow or shrink depending on how an organisation manages the other three elements. The presence of capable guardians who are able to exert appropriate levels of oversight or vigilance have the greatest potential to reduce the vulnerability of organisations to food fraud (Kleerman, Soudijn & Weenink 2012, p. 87). Figure 2.5 shows this process. Capable guardians can decrease vulnerability (overlaps) to food fraud by increasing the risk of detection, decreasing the opportunities for environmental manipulation by fraudsters and intervening between potential fraudsters and likely victims (Ellis et al. 2016; Spink et al. 2015).

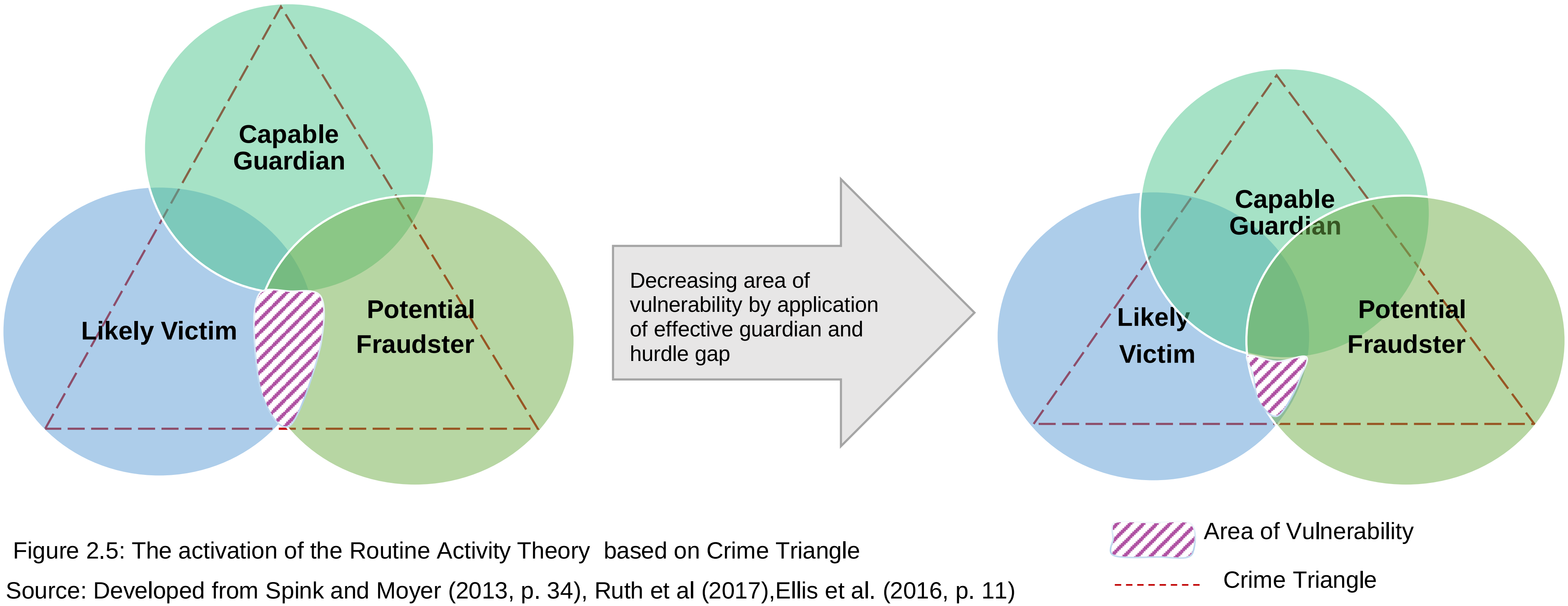


Figure 2.5: The activation of the Routine Activity Theory based on Crime Triangle

Source: Developed from Spink and Moyer (2013, p. 34), Ruth et al (2017),Ellis et al. (2016, p. 11)

Although the Routine Activity Theory principles have been adopted in the literature to investigate food fraud events and prevention methods, they do not focus on the root causes of food fraud (Lord, Flores Elizondo & Spencer 2017). Understanding the root causes of food fraud can also help to identify appropriate prevention methods. The root causes of a (food fraud) crime can be found by examining both the victims and the fraudster's routine activities (Senge 1990) and these are discussed next.

2.3.2 Root Causes of Food Fraud

Understanding the root causes of a complex phenomenon 'lie in a way of thinking' (Senge 1990, p. 55) that both victims (in this research food production companies) and food fraudsters have shared. In this section, the victim and food fraudster's routines and viewpoints are examined to highlight areas that may contribute to the root causes of food fraud. The Routine Activity Theory principles are used to provide a framework to understand the root causes of food fraud and describe how fraud opportunity occurs. Victims' routines are discussed first.

Victim routines:

When food production companies' routine (or viewpoint) is to react the impact of food fraud risk, they deploy authentication or reactive countermeasures. Such an example of this reactive strategies is the melamine in the baby formula in 2008 in China. The melamine was identified through the authentication analysis after several infant have been died due to the intentional adulteration by fraudsters. From the food production companies' viewpoint, reactive strategies are a defensive response to the threat of food fraud and are generally focused on minimising any reputational or financial damage (Hoecht & Trott 2014; Petrie 2016). Whilst reacting to food fraud incidents is important, understanding the organisation's vulnerability to food fraud is a more proactive way for companies to reduce their risk of financial or reputational damage. Figure 2.6 shows the viewpoint of food companies:

Food Fraud → **Threat to companies' finance and reputation** → **Need to deploy reactive strategies in the supply chain**

Figure 2.6: Companies' viewpoint
Source: Hoecht and Trott (2014); Senge (1990)

According to the Routine Activity Theory principles, if capable guardians and proactive countermeasures are absent in the victims' routine (see in Figure 2.5), the area of vulnerability to food fraud will increase both the motivation of fraudsters and subsequent opportunities to commit food fraud

(Ellis et al. 2016). Absence of capable guardians can be any reactive measure like using authentication countermeasures 'whenever public health is threatened'(Spink & Moyer 2011, p. R159). In cases of food fraud when the incident does not harm consumers (e.g. horsemeat scandal), the use of reactive measures are become somewhat redundant (Spink & Moyer 2011). Furthermore, reactive countermeasures are those that fraudsters can easily imitate or counterfeit (like holograms) (Ting & Tsang 2014). This, in turn, motivates food fraudsters to use their strategies to manipulate the opportunities for fraudulent activity that exist in the victim's routine.

Fraudster's routine:

Unfortunately, fraudsters can be large in number, with multiple identities using multi-sheltered companies (Spink & Moyer 2013) that can manipulate many areas of vulnerability to commit fraud (e.g. lack of proactive countermeasure) (see Figure 2.6) (Ellis et al. 2016; Stevenson & Busby 2015). Fraudsters are proficient at exploiting vulnerability factors in both micro and macro systems and they can obscure most of the known ways of detection such as: price; purchase location; and packaging through distribution and infiltration strategies (Chaudhry & Zimmerman 2013; Johnson 2014; Spink & Moyer 2013; Stevenson & Busby 2015).

According to Stevenson and Busby (2015), distribution and infiltration strategies are among the most common for fraudsters. These actions occur where inferior signallers (fraudsters) send false signals to the companies and legal supply chains, which in turn deceive consumers intentionally (Stevenson & Busby 2015). Signalling theory that examines the flow of communication between signallers (corporations) and receivers (consumers) assists in understanding this process (Connelly, Certo, Ireland & Reutzel 2014; Stevenson & Busby 2015).

False signals sent by fraudsters can be any attempt to make fake food products look authentic with a range of tactics such as: using credible locations (e.g. an authorised retailer/importer, restaurants, high-end supermarkets, hotels, and online markets); copying safety certificates (through duplication and reverse engineering); and/or using the same labour pool and authentication technologies for bundling fake and original food products (Stevenson & Busby 2015). In sum, the overall viewpoint of food fraudsters is generally to create fake reactive strategies as shown in Figure 2.7.

Create fake reactive strategy → **Exploit information asymmetric** → **Food fraud**

Figure 2.7: Fraudsters' viewpoint

Source: Stevenson and Busby (2015); Chaudhry and Zimmerman (2013)

These strategies by fraudsters will exploit the information asymmetric or situations where the buyer (legal supply chain, distributor, wholesaler, and consumers) knows far less than the seller (counterfeiter) (Hobbs 2004) about authentication information. The two straight lines (viewpoints of food companies and food fraudsters) form a cycle or framework that shows how food fraud occurs and can be undetected (Senge 1990) that is shown in Figure 2.8.

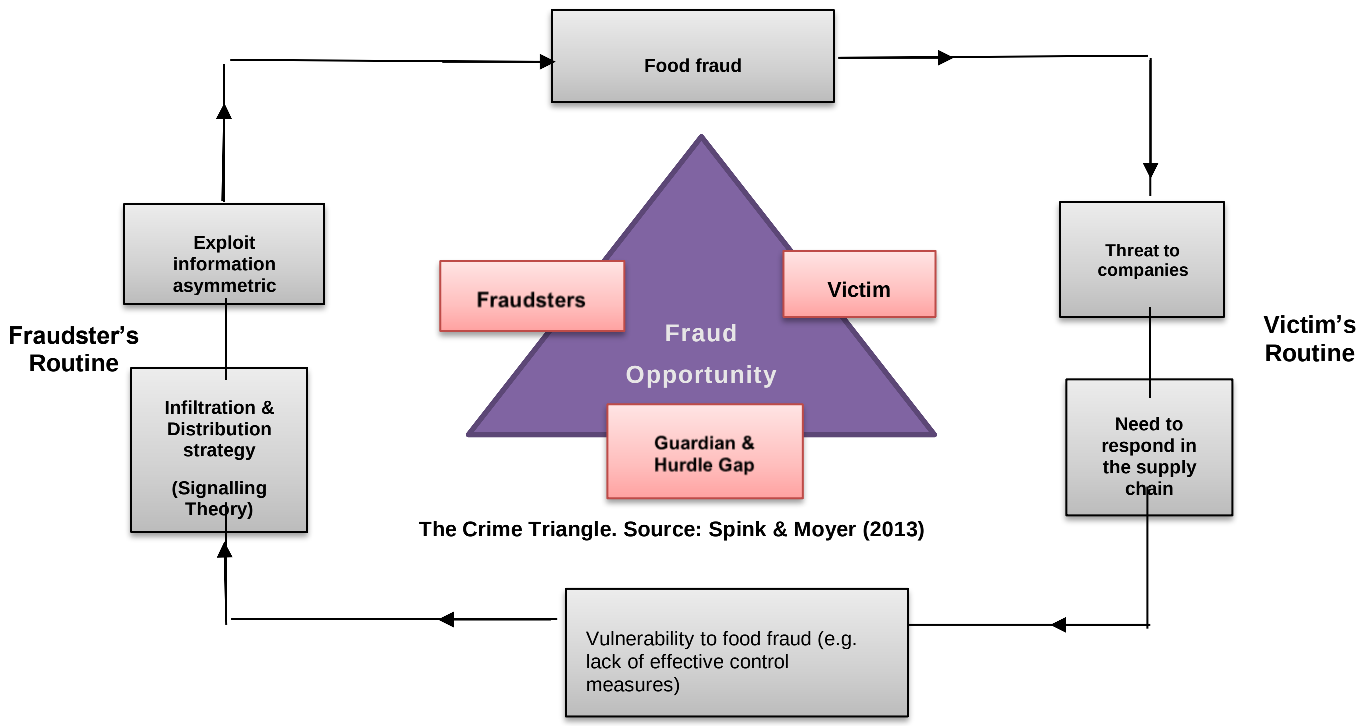


Figure 2.8: Integrating model

Source: Adapted from PwC (2015); Spink, Moyer and Peru (2016); Stevenson and Busby (2015)

Examination of the routine activities (strategies) of both victims and fraudsters allows identification of the degree of vulnerability to food fraud. Vulnerability to food fraud is generally the root cause of motivation for food fraudsters to engage in some form of fraudulent activity (Van Ruth, Huisman & Luning 2017) and provides opportunities for more fraud to take place until companies find ways to reduce this vulnerability. Therefore, prevention of the area of vulnerability can be the solution for treating the cause of food fraud problem.

Vulnerability is an emerging area of research for those investigating food fraud (e.g. Moyer, Silvis et al. 2017; Spink & Peru 2016; Van Ruth, Huisman & Luning 2017) with researchers suggesting that analysis of Food Fraud Vulnerability factors should precede the identification of any preventive food fraud countermeasures (Van Ruth, Huisman & Luning 2017) (e.g.

guardian or hurdle gaps). Thus, we need to better understand the concept of vulnerability to food fraud (Van Ruth, Huisman & Luning 2017) and the next section addresses this.

2.4 Food Fraud Vulnerability

According to the principle of vulnerability assessment proposed by the British Retail Consortium (BRC) (2015), vulnerability to food fraud can be assessed by the following formula (see also Silvis et al. 2017, p. 81).

Vulnerability to food fraud = Opportunities x Motivation x Control Measures

These three elements are known as FFV factors and they provide researchers with a framework by which to study this phenomenon (e.g. Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). Each of these elements has been shown to comprise different dimensions or factors that have been shown to variously impact vulnerability to food fraud in different contexts (Van Ruth, Huisman & Luning 2017). Table 2.6 provides a summary of these elements and their dimensions and the next section describes these factors in detail beginning with the Opportunity element.

Table 2.6: FFV factors and their detailed subfactors

Elements	Factors
Opportunity	***Technical opportunity***: simplicity/complexity of adulteration, simplicity/complexity of counterfeiting, availability of technology and knowledge of adulterate, availability of detection technology ***In time and space:*** accessibility to materials production/processing, transparency supply chain network, historical evidence
Motivation	***Economic drivers:*** supply and pricing of materials, special product attributes or value determining components of materials, price differences in countries, economic health business, level of competition, financial strains imposed on suppliers ***Culture and behaviour:*** business strategy, ethical business culture, previous criminal offences, (inter)national corruption level, victimisation
Countermeasures	***Technical measures:*** specificity and accuracy of the fraud monitoring system, systematics and autonomy of verification of fraud monitoring system, accuracy information system for mass balance control, extensiveness tracking and tracing system, fraud contingency plan ***Managerial measures:*** strictness ethical code of conduct, application integrity screening, support whistleblowing system, contractual requirements suppliers, social control and transparency across the supply chain, established guidance for fraud prevention across the supply chain, specificity national food policy, strictness enforcement for fraud prevention regulation/law

Source: Adapted from Van Ruth, Huisman & Luning (2017, p. 72)

2.4.1 Opportunity

The opportunity element of the vulnerability to food fraud formula (Van Ruth, Huisman & Luning 2017) describes the suitability of potential targets (or victims) (Hollis & Wilson 2014). This means that potential targets' characteristics shape the opportunity structure for fraudsters to commit a crime (Pratt et al. 2010). According to Cohen and Felson (1979), a suitable target needs to have four characteristics: visibility; accessibility; value; and inertia (Leukfeldt & Yar 2016). The first two characteristics are related to the availability of target products to fraudsters while the last two dimensions are related to the monetary value of target products and the ease or difficulty of counterfeiting products (Hollis et al. 2015). Van Ruth, Huisman and Luning (2017) expanded these characteristics specifically for food fraud victims into two main dimensions of technical opportunities and time and space (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017). Each will now be discussed in turn.

2.4.1.1 Technical Opportunities

Vulnerability to food fraud is often seen to increase when technical opportunities for fraud exist. This refers to factors such as: where the product composition is complex (and thus easy to obfuscate); and where the knowledge and technology to adulterate (or counterfeit/mislabel/etc.) food products (or raw materials) is easily available to fraudsters (SSAFE 2016; Silvis et al. 2016). In addition, this element of vulnerability is also increasing where the fraud is difficult to detect, and advanced technologies are required to identify the fraudulent products (Silvis et al. 2017).

Examples of this type of vulnerability have been noted in ground spices and beef mince due to their complex nature (BRC 2015; Van Ruth, Huisman & Luning 2017). In the case of mince, fraudulently substituted horsemeat is only able to be detected through DNA analysis. In summary, technical opportunities increase when the nature of food products are complex, the adulteration (or counterfeiting, mislabelling, etc.) technologies are available, and detection of the fraudulent practice requires a complex and advanced detection technology (SSAFE 2016; Van Ruth, Huisman & Luning 2017).

2.4.1.2 Opportunities in Time and Space

Opportunities in time and space refer to opportunities or vulnerability to food fraud as a result of fraudsters ‘having legitimate accesses to a place where fraud can be committed (Van Ruth, Huisman & Luning 2017, p. 71). One such example of this factor is when fraudsters use the same personnel who are employed in the legitimate production (e.g. in the processing lines) to access technologies to allow fraudulent intervention to occur (Stevenson & Busby 2015).

Opportunities in time and space also exist when there is a lack of transparency or high levels of complexity in the supply chain (Silvis et al. 2017) for the food product. These factors increase the opportunities for fraud to occur without easy detection. The complexity of the supply chain structure creates barriers to supply chain integration (Wagner & Neshat 2010) and can also increase vulnerability due to a lack of observability, and lack of effective control in the export channel (Hoecht & Trott 2014; PwC 2015; Stevenson & Busby 2015).

2.4.2 Motivation

The motivation element of the vulnerability to food fraud formula explains why food fraudsters 'would want to commit fraud' (Van Ruth, Huisman & Luning 2017, p. 71). This element includes those root causes that increase the susceptibility to food fraud and subsequently increase fraud commitment by food fraudsters. The overall motivation for fraud is generally when there is likely financial gain (Johnson 2014). Unlike other food crimes (such as food safety incidents), food fraudsters do not generally intend to harm consumers. Instead they seek to gain profit from their fraudulent activities (Spink & Moyer 2011). There are several environmental factors that will increase the susceptibility to food fraud used by fraudsters to commit the fraud for economic gain. These factors exist in both the macro and micro environmental levels of the supply chain.

Macro factors (e.g. global pricing) are those related to the broad food fraud threat assessment while micro factors (e.g. business relationships) are those that help understand how and why a 'specific fraudster is motivated to act' (Moyer, DeVries & Spink 2017, p. 359). The concept of macro and micro motivation factors are key vulnerability drivers for food fraudsters' decision making (Moyer, DeVries & Spink 2017). Van Ruth, Huisman and Luning (2017) explains these micro and macro factors as economic drivers and cultural and behavioural drivers that will lead to economic motivation of food fraudsters and these will be discussed next.

2.4.2.1 Economic Drivers

Economic drivers of vulnerability to food fraud can be found in various business and market conditions that can increase the potential return of the fraudulent activity to fraudsters. Specifically, it has been noted in: the supply and pricing of materials; value adding product attributes; associated price differences; the economic health of businesses; different levels of competition; and where financial strain exists (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017).

Vulnerability to food fraud as a result of the supply and pricing of materials occurs when there is economic pressure on raw materials and/or food products (SSAFE 2016). These economic pressures can be situations where there are export bans on raw materials and food products (SSAFE 2016) or there is a gap between 'physical availability of' the food product and market demand (Manning & Soon 2014, p.23; Van Ruth, Huisman & Luning 2017). These pressures result in a shift in prices due to global or national shortages (Moyer, DeVries & Spink 2017 which consequently increase the potential for economic returns to fraudsters and thus increase the vulnerability to food fraud.

Vulnerability to food fraud increases when a product has a higher risk of being counterfeited /adulterated (or mislabelled, etc.). One such example of this factor is products with value adding attributes (Van Ruth, Huisman & Lunning 2017). Attributes adding value include 'composition of raw materials (e.g. protein content), production methods (organic)' (SSAFE 2016), or 'particular processing' (e.g. artisanal products) (Van Ruth, Huisman & Luning 2017, p. 71). Since these products (like organic and artisanal products) have higher value and price, they may more likely be misrepresented and counterfeited (Silvis et al. 2917; Van Ruth, Huisman & Luning 2017).

Vulnerability to food fraud increases when there is poor economic health and a high level of competition and price differences in countries, resulting in financial strain. Vulnerability to food fraud, as a result of poor economic conditions, occurs when there is fear of losing profit, and there is a 'gap between financial targets and actual performance' (SSAFE 2016; Van Ruth, Huisman & Luning 2017). In addition, when there is a high level of competition among food industries (Silvis et al. 2017), achieving financial targets can be difficult (SSAFE 2016) which can cause companies to cut their costs (Van Ruth, Huisman & Luning 2017). One such example of this sort of cost reduction is the elimination of traceability systems or any advanced technologies (i.e. GS1 standards) that are helpful in deterring food fraud (Van Ruth, Huisman & Luning 2017).

Moreover, vulnerability to food fraud increases when there is price asymmetric in countries due to ‘regulatory diversity’ and high level of competition in the market. This, in turn, will increase the vulnerability to food fraud (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017, p. 71). Vulnerability to food fraud as a result of financial strains will also increase when there is financial pressure on a supplier to meet the exceeded demand from customers. In the case that the supplier is highly dependent on the specific customer (Waters 2011), they may choose fraudulent activities to meet the exceeded demand (in Van Ruth, Huisman & Luning 2017, p. 72).

2.4.2.2 Culture and Behaviours

Cultural and behavioural elements are also known to play a role in increasing the motivation of fraudsters (Silvis et al. 2017). One example of these elements can be suppliers who are accustomed to buying counterfeit products. The root motivation of their behaviours is because they do not want to pay full price for the authentic goods as a result of their cultural heritage (Hoecht & Trott 2014).

Vulnerability to food fraud as a result of cultural behaviours is related to: the business strategy and ethical practices of businesses; previous criminal offences; and victimisation or even international corruption (Van Ruth, Huisman & Luning 2017). For example, employees may be influenced by their company’s (business) strategy, having pressure to meet short term financial goals. This pressure may motivate them to engage in unethical behaviour ‘for the sake of saving themselves from being fired’ (SSAFE 2016; Van Ruth, Huisman & Luning 2017, p.72; Van Ruth et al. 2018). So, vulnerability to food fraud increases when there is no clear statement in the business strategy (or even implicit contacts) (Nyaga, Whipple & Lynch 2010) regarding how these financial goals can be achieved (Van Ruth, Huisman & Luning 2017, p. 72).

Vulnerability to food fraud as a result of unethical behaviour increases when there is a weak ethical business environment (or culture) (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). Examples of such factors are lack of mutual trust, ignoring reports on unethical conduct, (SSAFE 2016) and employee dissatisfaction (Kaptein 2011) The motivation of fraudsters is not only impacted by the strategies and policies within food production companies, but it is also impacted by these issues across national borders (Van Ruth, Huisman & Luning 2017).

One such example is the corruption level in detecting country (Spink & Moyer 2011) that is caused by 'the geopolitical situation' (Van Ruth, Huisman & Luning 2017, p. 72) or the lack of 'food safety regulatory/enforcement' system (USP Nd, p. 1603) . This means that businesses in countries with a higher corruption rate (e.g. based on the Corruption Perception Index) (Silvis et al. 2017) run a greater risk of being vulnerable to illegal or immoral activities (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018) that can result in food fraud.

Vulnerability to food fraud as a result of victimisation occurs when those who are victims of a food fraud activity then commit fraudulent actions on others in the future (Van Ruth, Huisman & Luning 2017). In cases of unfair competition, where competitors are choosing illegal actions, it is difficult for a company to make decisions to either withdraw from the market, choose legal actions or 'swim with the tide' (Hoecht & Trott 2014; Van Ruth, Huisman & Luning 2017, p. 73). In addition, once criminal activity like food fraud has occurred in the past, it is more likely to re-occur in the future. This consequence is well known in the literature to increase vulnerability to food fraud (Van Ruth, Huisman & Luning 2017).

2.4.3 Countermeasures

Appropriate countermeasures and capable guardians are necessary to combat food fraud (Hoecht & Trott 2014; Spink & Moyer 2011; Ting & Tsang 2014). Implementing these, however, remains problematic. Although high technology and the infrastructure to store food products in warehouses are now available (Marvin et al. 2016), easy imitation of some of these technologies like machine readable technologies (Ting & Tsang, 2014) increases the vulnerability to food fraud in the supply chain where visibility is low (Stevenson & Busby 2015). Such examples of these technologies for food packaging products are holograms, and Radio Frequency Identification (RFID) tag colour shifting ink that can be reverse engineered by fraudsters to deceive consumers (Stevenson & Busby 2015; Ting & Tsang 2014).

Two effective countermeasures recommended in the literature to reduce vulnerability to food fraud (Silvis et al. 2017; SSAFE 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018) are: technical measures and management measures. The technical measures (or hard control measures) are related to the detection of food fraud incidents while management measures (or soft measures) are related to preventive (or proactive) countermeasures (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017). Both technical and management measures are discussed next.

2.4.3.1 Technical Measures

Technical measures (hard controls) are those that can effectively detect fraud by collecting, documenting and analysing information related to the raw materials and final products (Van Ruth, Huisman & Luning 2017). Vulnerability to food fraud can be decreased through the adoption of various technical measures such as fraud monitoring systems, information systems, and traceability systems (Van Ruth, Huisman & Luning 2017).

A fraud monitoring system is designed to discover fraudulent incoming raw material and to ultimately product the integrity of final products (SSAFE 2016). This type of monitoring system can take the form of a sampling plan to detect fraud, advanced fraud detection methods (e.g. DNA analysis), and/or systematic verification of incoming raw materials based on documentation (SSAFE 2016; Van Ruth, Huisman & Luning 2017). In addition, mystery shoppers or private detectives can help to monitor and detect fake products (Berman 2008). Applying this principle to the context of food fraud can be training supply chain parties and employees to detect fake food products (and their packaging) and to notify the manufacturer upon identification (Chaudhry & Zimmerman 2009).

Vulnerability to food fraud can be decreased when companies use appropriate information systems and traceability technologies. Appropriate information systems can systematically collect and analyse information such as the mass balance control of incoming raw materials and final products (Everstine, Spink & Kennedy 2013; SSAFE 2016; Van Ruth, Huisman & Luning 2017). Through the information systems, data about the product location will be shared using a traceability system like Global Solution One (GS1). The GS1 traceability system includes three steps of identification, capturing and sharing information between the supply chains (GS1 US 2011). In this system, producers add a GS1 data metrics code (e.g. GS1 128 barcode, RFID tag, EPC, QR barcode) while labelling packages for identification to easily follow the product, the transaction and the supply chain and share captured information through an information system (Nason 2015).

2.4.3.2 Managerial Measures

Soft controls or managerial measures are those that can reduce opportunities and motivation of fraudsters (Van Ruth, Huisman & Luning 2017). Vulnerability to food fraud can be decreased through managerial measures like integrity screening, ethical codes of conduct, whistleblowing systems, fraud contingency plans, contractual requirements, social control, establishment of fraud prevention across supply chain, national food policy, and strict law enforcement (SSAFE 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

Integrity (honesty) screening methods are necessary when recruiting prospective employees (Van Ruth, Huisman & Luning 2017). An integrity screening test can help to prevent future fraudulent activities by employees. Companies need to be strict with zero tolerance in relation to food fraud and develop a strict ethical code of conduct (Silvis et al. 2017).

Companies can also provide a safe environment and a well-designed whistleblowing system for their own employees to report fraudulent activities anonymously (SSAFE 2016; Van Ruth, Huisman & Luning 2017). In the case of emergency and unexpected food fraud incidents, a contingency plan plays an important role in dealing with the incidents through the development of policies and procurements (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017). The fraud contingency plan is a plan for both food safety and food fraud issues that is ‘science based’ and is updated to reduce the risk of food fraud (SSAFE 2016).

Building strong relationships within the supply chain network can also reduce opportunities to commit fraud (Manning & Soon 2016; Spink 2016) and decrease the vulnerability to food fraud for food producers. Research has shown that strong relationships and information sharing (Juan Ding et al. 2014; Jie et al. 2013) between stakeholders in the supply chain will further result in supply chain integration, competitiveness (Knoll et al. 2017) and supply chain transparency.

An example of this occurring is the concept of the One such an example is Guanxi system in China, a system in China that helps to strengthen relationships between supply chain parties (Hoecht & Trott 2014). This system describes It is the use of personal networks that that ensure that indicates channel members have strong emotional ties, and thus they are less likely to engage in fraudulent activities (Hoecht & Trott 2014). The relationship between supply chain networks can also be strengthened through signing legal agreements. These legal agreements can clearly state contract conditions and can also act as a strong social control.

In some countries, low law enforcement and unclear laws (and regulations) at the (inter) national level can also increase the opportunities for fraudsters to commit the crime (Hoecht & Trott; Van Ruth, Huisman & Luning 2017). For example, low law enforcement for fraud in China enables fraudsters to be “symbolically” penalised which ultimately allows them to continue their fraudulent activities after a period of time (Hoecht & Trott 2014). Another example is the ‘first to file law’ in Chinese legislation. The first-to-file law means that until the company registers a trademark/brand, it has no rights to that trademark/brand (Harris 2011). This means that a fraudster can get profits from the Chinese market by registering the brand earlier than the original companies (intending to enter the Chinese market).

There are some strategies available for companies to pre-empt fraudsters’ motivation as a result of low law enforcement. One such strategy can be branding strategy, which helps integrate all parties in the supply chain and creates shared vision by having clear communication, knowledge sharing and a trusting relationship (Walters & Glaser 2008; Lewis et al. 2014).

For example, in China, registering a brand/trademark globally can pre-empt fraudsters' motivation at the point of entering the Chinese market (as China has 'first to file' law) (Chaudhry & Zimmerman 2009). Another strategy can be registering the brand, trademark, security features, and transfer certificates (e.g. traceability certificate) (Bai, Zhang & Jiang 2013) with customs authorities in the host country (e.g. China). This registration helps (online) buyers and government authorities to detect counterfeited goods and government agencies to seize them; and government (or brand owner) to take legal action.

2.5 Additional variables

Two influencing variables of FFV factors were added as illustrated in the USP FFD. These variables are (1) weight of evidence and (2) types of adulterants. The incident records were' evaluated with respect to the weight of evidence of the references that support them' (USP FF). For an example, incidents such as horsemeat scandals in the UK or melamine in the baby formula in China were evaluated as high weight of evidence due to the existence of supporting scientific/legal documentation. Accordingly, incidents that were not supported by regulatory authorities or legal authorities were evaluated as medium or low weight of evidence.

The USP FFD also identifies adulterants related to each incidents. These adulterants could be chemicals, additives, counterfeits, species, or expired types. The chemicals could be formaldehyde, methanol, Chloramphenicol, melamine etc. that are not declared in the food product ingredients. For an example, the formaldehyde is used as preservatives to extend the shelf life food products (e.g. seafood). Chemicals such as methanol that are added to the alcoholic beverages are more serious and could lead to the death/blindness of consumers. Additives were related to add of colour, water, oils, sugar, gelatin, etc. that will enhance the appearance of food products. For an example, add of water in India is related to add weight to the milk product to get more profit. Counterfeit type of adulterants are related to false declaration of organic/halal food product, certificates, false declaration of types of food (e.g. camel meat as lamb meat). The species type of adulterants are related to those of declaring false species of food products. For an example, declaring non-locally sourced Crab (seafood) as locally sourced Crab or Sutchi Catfish as Grouper. Finally, the expired types of adulterants are related to those food products that the expiration date of production are altered and are resell as fresh food products.

Although there is a growing awareness acceptance amongst researchers that there needs to be of the shift in focus from risk mitigation to vulnerability reduction and prevention for of food fraud (Spink, Moyer & Peru 2016; Spink et al. 2017; Van Ruth, Huisman & Luning 2017; Silvis et al. 2017), few studies to date have addressed this issue. with the first reported studies only appearing in 2017. This is mainly because the concept of Food Fraud Vulnerability concept is relatively new and there is limited knowledge of how the factors that affect vulnerability interact and impact vulnerability to food fraud (Van Ruth, Huisman & Lunning 2017; Van Ruth et al. 2018). The SSAFE Food Fraud Vulnerability assessment tool proposed by Van Ruth et al. (2018), and Silvis et al. (2017) is a notable exception to this. This tool was designed for self-assessment of vulnerability to food fraud based on a managers' perspective.

2.6 Conceptual Framework of the Study

This chapter described the key concepts in the relevant literature through three main theoretical domains of: 1) food fraud and its threat to food safety; 2) criminology theories; and 3) the concept of Food Fraud Vulnerability. From these three multi-disciplinary bodies of literature, the theoretical foundation of this study has been constructed. Table 2.7 provides a summary of key themes in the literature and relevant research gaps identified in each section.

Table 2.7: Summary of food fraud key themes in the literature and research gaps

Key themes	Key elements	Application to this study	Research Gaps	Authors	Contribution
Food fraud	Definition and types	Focus on the comprehensive food fraud types	Need to have a clear classification of food fraud types	(Charlebois et al. 2017; Zhang & Xue 2016 p. 193)	A new classification of food fraud types based on USP FFD will be provided
	Difference between food fraud and other food safety management system	Focus on prevention of food fraud (focusing on vulnerability reduction instead of risk mitigation)	Need for a holistic approach to shift from risk mitigation to vulnerability reduction (that is different from the common food safety management system strategies) to prevent food fraud	(Bouzembrak & Marvin 2016; Lord, Flores Elizondo & Spencer 2017; Spink & Moyer 2011; Spink et al. 2017; Tahkapaa et al. 2015; Van Ruth, Huisman & Luning 2017; Silvis et al. 2017;)	The study will develop a holistic approach that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption
Criminology theories	Integrated model on the root causes of the food fraud problem	Determining the root causes of the food fraud problem	Need to understand the root causes of food fraud/or what motivates food fraudsters to commit fraud	(Silvis et al. 2017; Spink & Moyer 2011; Van Ruth, Huisman & Luning 2017; Tahkapaa et al. 2015)	An integrated model based on Routine Activity Theory, Crime Triangle and Signalling theory were created to present how food fraud incident occurs when there is an area of vulnerability.
Food Fraud Vulnerability concept	Factors affecting Food Fraud Vulnerability	Focus on determining different categories of Food Fraud Vulnerability	Need to identify factors affecting Food Fraud Vulnerability concept (through the Routine Activity Theory) and analyse (or compare) vulnerability to food fraud through the application of real data (from food fraud database) for different food fraud types.	(Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018)	The study will identify FFV factors through the Barrier Analysis technique and will assess the FFV factors through the application of Bayesian Network (BN) modelling approach based on real data recorded in the USP FFD

This study formulated research questions in order to address the research gaps identified from the review of the literature conducted in this chapter as follows:

Main research question: How can the vulnerability to food fraud for food products designed for human consumption be assessed?

As discussed in the literature review, those who research and work in the area of food fraud have called for a more innovative and holistic approach that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption (Everstine, Spink & Kennedy 2013; Tahkapaa et al. 2015). This holistic approach needs to be differ from food safety management approaches, as efforts to combat food fraud require a preliminary focus on vulnerability reduction instead of intervention (or detection) (shift from risk mitigation to vulnerability reduction). Such an approach would be based on reviewing previous cases of food fraud incidents reported in the global online databases (e.g. RASFF and USP).

To answer the research question three sub-questions are proposed:

Sub-question 1: What are the factors that influence the vulnerability to food fraud food products designed for human consumption?

Sub-question 2: How can the types of food fraud be used to assess Fraud Vulnerability factors?

Sub-question 3: Which of the known food fraud variables are most relevant when assessing vulnerability to food fraud?

Whilst there are limited studies that have addressed food fraud prevention, one study by Bouzembrak and Marvin (2016) developed a Bayesian Model to predict food fraud incident types reported in the RASFF databases. Their BN model predicted food fraud incident types by knowing the country of origin and product category (types). However, their model did not consider other variables that have been shown to impact the vulnerability to food fraud for food items.

Another study by Marvin et al. (2016) built on this work by constructing a Predictive Bayesian Model (Bouzembrak & Marvin 2016) which included some of those the variables. Their BN model was able to predict which types of food fraud would be most likely when the country of origin, product category (types), country of detection, and year of the fraud occurring were known.

A criticism of this model was that it also included variables related to food safety and did not just focus on those (Tahkapaa et al. 2015) related to vulnerability to food fraud. Scholars in the emerging field of food fraud vulnerability have since called for approaches to extend the knowledge of the role and relationships of the factors that influence vulnerability to food fraud (Van Ruth, Huisman & Luning 2017). In particular, they seek models that allow for the consideration of the dynamic and potentially reciprocal interrelationships between food fraud incident types and root causes of food fraud (or FFV factors in this research) (Marvin et al. 2016). Further, scholars have also suggested that these relationships are best explored through analysis of real data from food fraud incidents (e.g. from the food fraud database) (Van Ruth et al. 2018).

This study will address the research gaps mentioned and will include all known factors that have been shown to influence the vulnerability to food fraud (sub- question 2 and 3). These factors (See Figure 2.9) will be investigated from a global database of food fraud incidents (USP database) that have been collected over an eighteen-year period (2000-2018). The results of this analysis will allow the researcher to assess the vulnerability to food fraud for a specified food product types (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018).

In addition, the analysis will investigate the patterns of relationships (see figure 2.9 for the proposed Bayesian Network Structure) between the variables known to influence food fraud vulnerability as suggested by the literature. The contribution of this work is to consider all of the known variables in one model which will ultimately provide a more rigorous and complete understanding of the factors that are involved in the assessment of vulnerability to food fraud (sub-question 3).

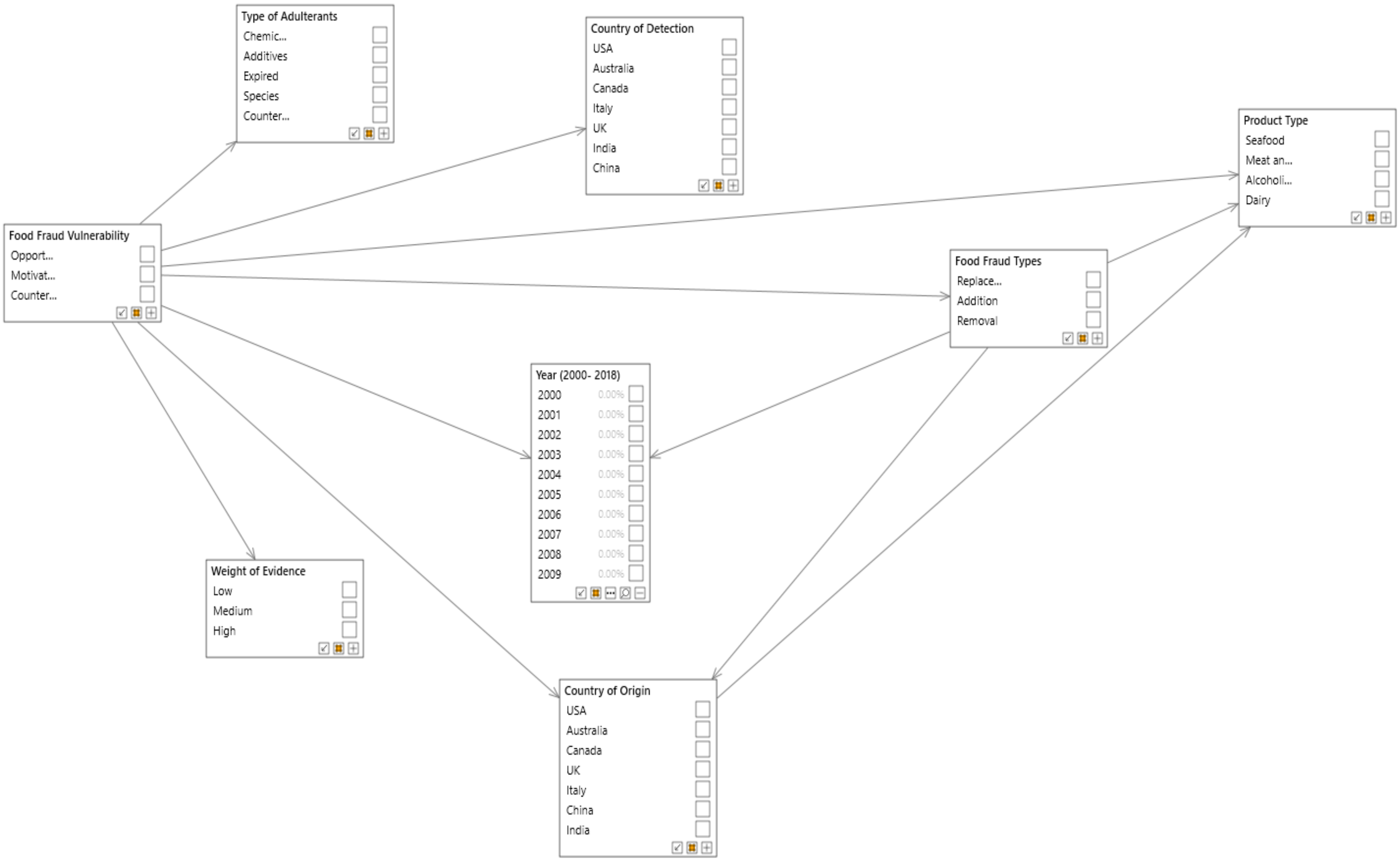


Figure 2.9: Bayesian Network Model

2.7 Conclusion

This chapter reviewed the relevant theories and concepts related to three main bodies of research relevant to food fraud. These are: fraud and its threat to food safety; criminology theories; and the Food Fraud Vulnerability (FFV) concept Definitions of food fraud, the different types of food fraud, and the differences between food fraud and food safety have been presented to highlight the rationale for the study and the importance of strategies for combating food fraud, strategies for the prevention of food fraud and strategies to assess the vulnerability to food fraud.

Criminology theories such as the Routine Activity Theory were reviewed to better understand the root cause of vulnerability to food fraud. The FFV concept was discussed from the perspective of the Routine Activity Theory to highlight the three main areas of vulnerability. These were: opportunity; motivation; and countermeasures. A detailed illustration of FFV factors was provided. Then the study proposed a BN model based on the literature for the development of a holistic model that can assess the level (degree) of vulnerability to food fraud for food products designed for human consumption. The next chapter, Research Methodology, presents and justifies the proposed research paradigm, research design, and research strategy adopted to answer the research questions for this study.

3 CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

In Chapter 2, the literature relating to food fraud, criminology theory (the Routine Activity Theory), and Food Fraud Vulnerability concept created the foundation for the research questions. This chapter presents the research design, data collection processes and data analysis methods employed to study the research questions. The research questions focus on the development of a holistic model that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption. For this purpose, 580 food fraud incident records in the USP Food Fraud Database (FFD) will be reviewed using the Barrier Analysis technique. A Bayesian Network (BN) model will be constructed based on the FFD to assess Food Fraud Vulnerability factors and their interrelationships.

Table 3.1 provides the structure and outline of this chapter. The chapter commences with a discussion about the selection of an appropriate research paradigm. The mixed methods approach that is used for this study is then illustrated, followed by a description of the selection of secondary data analysis methods. The next section describes the data analysis, using the Barrier Analysis technique and Bayesian Network modelling approach. The final section of this chapter discusses the evaluation of research quality and methodological limitations for this research.

Table 3.1: Chapter 3 structure

Section	Purpose
3.1 Introduction	Introduction
3.2 Pragmatism Research Paradigm	Selection of suitable research paradigm
3.3 Research Design: Mixed Methods	Describing the mixed methods approach
3.4 Research Strategy: Secondary Data Analysis	Secondary data analysis, identifying the suitable database to address research questions and evaluating the selected database, Justification of selecting Barrier Analysis method and Bayesian Modelling approach
3.5 Data analysis	Constructing a BN model for data analysis
3.6 Evaluation of the Research Design	Reliability and validity for mixed methods research
3.8. Methodological limitations	Limitations related to secondary data analysis methods and Sub-question 1
3.7 Conclusion	Summary

3.2 **Pragmatism Research Paradigm**

A research paradigm is a set of beliefs and concepts adopted by researchers to conduct a study (Mackenzie & Knipe 2006). In fact, research paradigms explain the worldview of the researcher (Denzin & Lincoln 2005) and provide a framework that leads to selection of a qualitative, quantitative, or mixed method approach (Creswell 2014) in the research. s. Table 3.2 clarifies four research paradigms (see Table 3.2) based on three basic assumptions of ontology ('the way in which the researcher sees the world'), epistemology ('the way in which the researcher believes knowledge can be shaped'), and methodology ('the way in which the researcher investigates reality') (Bongiovanni 2016 p. 114). The four research paradigms based on these assumptions are *Positivism*, *Critical Theory*, *Constructivism*, and *Realism/ Pragmatism* as described by Guba and Lincoln (1994) (Healy & Perry 2000)).

Table 3.2: Research paradigms

	Paradigm			
Element	***Positivism***	***Critical theory***	***Constructivism***	***Realism/Pragmatism***
Ontology	reality is real and apprehensible	'virtual' reality shaped by social, economic, ethnic, political, cultural, and gender values, crystallised over time	multiple local and specific 'constructed' realities	reality is 'real' but only imperfectly and probabilistically apprehensible.
Epistemology	objectivist: findings true	subjectivist: value mediated findings	subjectivist: created findings	modified objectivist: findings probably true
Common methodologies	experiments/ surveys: verification of hypotheses: chiefly quantitative methods	dialogic/dialectical: the researcher is a 'transformative intellectual' who changes the social world within which participants live	hermeneutical / dialectical: the researcher is a 'passionate participant' within the world being investigated	case studies/convergent interviewing: triangulation, interpretation of research issues by qualitative and by some quantitative methods such as structural equation modelling
Method	Quantitative	Ideological review, civil actions	Qualitative	Mixed methods

Adopted from: Healy and Perry (2000), p. 23; Guba and Lincoln (1994); Bongiovanni (2016)

This study adopts a pragmatism paradigm according to which the researcher employs available approaches to understand and acquire knowledge about the (food fraud) problem (Creswell 2003). The pragmatist worldview emphasises situational problems and consequences of actions (Creswell 2014). The underlying assumption of pragmatism is that the researcher should focus on the ‘research problem in social science research and then [use] pluralistic approaches to derive knowledge about the problem’ (Creswell 2009, p.11). Pragmatists believe that the research questions are the most important factor than ‘ the method of data collection’ (Andrew & Halcomb 2006, p.147) and the researcher have the freedom of choice in selecting the research design that ‘effectively answer their research questions’ (Andrew & Halcomb 2006, p. 148). The pragmatic researchers ‘look to the what and how to research based on the intended consequences’ (Creswell 2009, p.11).

The justifications for the study were presented in Section 1.4 with the main contribution addressing the call in the literature for an holistic approach to approach to assessment of vulnerability to food fraud that shifts the focus from risk mitigation to vulnerability reduction. In particular, there is a paucity of research related to the identification of the factors that impact Food Fraud Vulnerability (FFV). The development of an holistic model for FFV assessment requires an approach that includes both qualitative and quantitative inputs.

This study adheres to the pragmatism perspective as the focus of the study is related to the problem of food fraud and this research look at ways to assess the Food Fraud Vulnerability (FFV) factors. Multiple approaches (qualitative and quantitative) will be employed in order to assess the FFV factors. The first phase (qualitative) of this study is related to the identification of FFV factors using the Barrier Analysis technique based on the principles from the Routine Activity Theory. This information will be sourced from records of real food fraud incidents recorded in the USP Food Fraud Database (FFD). The second phase (quantitative) is related to the application of Bayesian Modelling analysis for assessment of the relationships between food fraud vulnerability factors and their impact on the vulnerability to food fraud. Thus, the philosophical paradigm for this research is based on a pragmatist view. Pragmatism offers a more flexible research approach in order to explain an event that ‘rises out of real-world practical problems (Creswell 2009, p.10).’ of food fraud.

3.3 Research Design: Mixed methods

The research design includes qualitative, quantitative, or mixed methods approach (Creswell 2009). Creswell (1994) defined a qualitative study as ‘an inquiry process of understanding a social or human problem, based on building a complex, holistic picture, formed with words, reporting detailed views of informants, and conducted in a natural setting’ (Isaacs 2014, p. 318) The qualitative approach focuses on exploring ‘the meaning individuals or groups ascribe to a social or human problem’ (Creswell 2014, p. 4). The quantitative approach is appropriate for testing theories (Creswell 2014) by assessing the existing relationships between variables using statistical procedures (Bongiovanni 2016;Denzin & Lincoln 2008).

A mixed methods research methodology provides the possibility of combining qualitative and quantitative data collection (Creswell 2014). It helps to use a ‘distinct design that may involve philosophical assumptions and theoretical frameworks’ (Creswell 2014, p. 4). It also helps to better understand the research problem (Creswell 2014, p. 4) by using qualitative data to be combined with quantitative analysis (Adams et al. 2014; Creswell 2014; Wisdom & Creswell 2013). Mixed methods is an ideal way to assess complex issues (Wisdom & Creswell 2013) like assessment of FFV factors.

The mixed methods methodology will be applied in this research for two reasons. First, the appropriate methodology for the pragmatism approach, the selected paradigm of this research is a mixed method (Creswell 2014, Hughes n.d.; Kawulich 2012). This is because, in the pragmatism paradigm, the aim of the research is to find solutions to problems and ‘instead of methods being important, the problem is most important’ (Creswell 2003, p. 11). Second, the literature review conducted in chapter Two (sub-section 2.3.2) propose the importance of assessing vulnerability to food fraud. Previous research focusing on the area of food fraud prevention has embraced the mixed methods as shown in their paper (see Marvin et al. 2016). For the above reasons, mixed methods research is the appropriate methodology for studies on assessing Food Fraud Vulnerability factors.

Adopting a sequential exploratory mixed methods approach provides a framework (Venkatesh, Brown & Sullivan 2016) for this research to find out a holistic approach for assessment of FFV factors from multiple approaches. The framework in this study will begin with qualitative exploration (phase one) using Barrier Analysis techniques in order to extract the appropriate Food Fraud Vulnerability factors. Then, a Bayesian Network Model (phase two) will be developed based on the information and factors explored in the first step and from the data source (USP FFD) (Wisdom & Creswell 2013). The overall phases of research methods for this research (phase one and Two) are demonstrated in Figure 3.1.

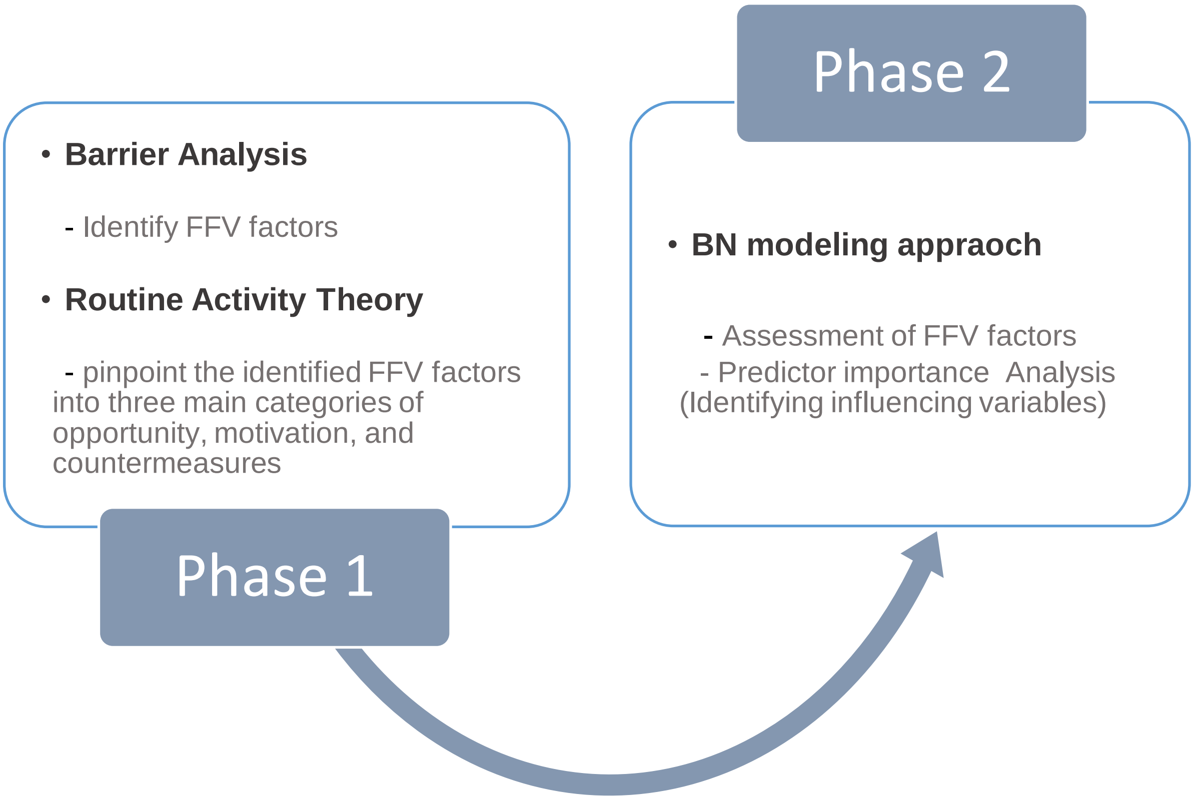


Figure 3.1: Overall research methods

3.4 Research Strategy: Secondary Data Analysis

Secondary data analysis or archival research is defined as a type of research strategy ‘where the research is conducted from existing materials’ (Ukessays 2013). When selecting a research strategy, Yin (2009) suggests that there are five types that can be selected: experiments, surveys, archival analysis, history and case studies . These five strategies are described in Table 3.3. These five options will be discussed next in order to justify why archival analysis is selected for this study.

Table 3.3: Research strategies

Strategy Form of	Form of RQ	Requires control of Behavioural Events?	Focuses on Contemporary Events
Experiment	how, why	Yes	Yes
Survey	who, what, where, how many, how much	No	Yes
Archival analysis	who, what, where, how many, how much	No	Yes/No
History	how, why	No	No
Case Study	how, why	No	Yes

Source: Paterson (2006, P. 76), Yin (2003, p. 5)

The research questions and objectives of the research are ‘fundamental components of determining which research method to utilise’ (Tushi 2015, p. 16). The experiment strategy is not suitable, as this research will not include experiments in the field or laboratory. To understand Food Fraud Vulnerability factors or root causes of food fraud, this research is required to obtain data by conducting reviews of incidents (see Spink, Moyer & Peru 2016). In addition, studies of food fraud are sensitive topics that may often identify and quantify problems with no real solutions for companies. A case study research is not considered suitable, as this research seeks to assess FFV factors against real data or food fraud incidents recorded in the USP FFD. Moreover, the secondary data analysis does not focus on ’contemporary phenomena’, but the case study does (Yin 2014, p. 2) .

The main research objective of this study is to develop a holistic model that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption. The overall objective is testing Food Fraud Vulnerability factors against real data or food fraud incidents. The use of archival analysis is most suited to this research as this method ‘encompasses the examination and analysis of recorded data’ (Jenkin 1985, cited in Tushi 2015, p. 16-17). In addition, research sub-questions of this study include ‘what’ question which is also supported by archival analysis research (Yin 2014). Moreover, the use of archival analysis or secondary data analysis strategy has also been employed in recent studies to identify research gaps in the area of food fraud (e.g. Bouzembrak & Marvin 2016; Marvin et al. 2016; Tahkapaa et al. 2015).

Having explained the justification for using the secondary data analysis or archival analysis research methodology, there is a need to describe the appropriate framework or processes to conduct secondary data analysis (Johnston 2014). This study will follow the secondary data analysis processes developed by Johnston (2014) that include: (1) developing the research questions; (2) identifying the dataset (or database); and (3) evaluating the database. The following sections will describe these processes in detail for this research.

3.4.1 Developing the Research Questions

The fundamental key to conducting secondary data analysis is to use theoretical knowledge ‘to utilize existing data to address the research questions’ (Johnston 2014, p. 620). The purpose of this research is to develop a holistic model that can assess the level (degree) of vulnerability to food fraud for food products targeted at human consumption. The main research question that guided this study is: How Can the vulnerability to food fraud for food products designed for human consumption be assessed? Sub-questions are: sub-question 1: What are the factors that influence the vulnerability to food fraud food products designed for human consumption? Sub-question 2: How can the types of food fraud be used to assess Fraud Vulnerability factors? and sub-question 3: Which of the variables, known to influence the vulnerability to food fraud, are most important? Identification of Database

This section addresses the need to consider 'previously collected data on the topic' of food fraud (Johnston 2014, p. 621). Recent studies urge the need for research on food fraud to shift from detection/ intervention to prevention and vulnerability reduction (e.g. Spink & Moyer 2011; Manning & Soon 2016; Ellis et al. 2016; Spink et al. 2017) The first step towards developing a measure to prevent food fraud is to review incidents of food fraud (Tahkapaa et al. 2015). From the three main databases of food fraud (RASFF, EMA, and USP FFD), recent studies only used RASFF and EMA (e.g. Marvin et al. 2016; Tahkapaa et al. 2015; Bouzembrak & Marvin 2016). Tahkapaa et al. (2015) used the RASFF database (along with two local Finnish local authority reports) to determine patterns of food fraud and adulteration. Bouzembrak and Marvin (2016) used the RASFF database to predict the type of food fraud for imported products to the EU. A study by Marvin et al. (2016) also used RASFF and EMA (together) to validate the application of Bayesian Modelling in the prediction of food safety risks.

There are three limitations in using the RASFF database alone or even along with the EMA. First, the RASFF database includes incidents of food fraud limited to the European Union. Second, the RASFF database includes incidents of food crime for both food safety and food fraud types. It means that the RASFF database provides cases of both intentional and unintentional adulteration (Marvin et al. 2016). Third, in the case of using the RASFF database along with the EMA, the overlap of incidents because of duplication may exist as EMA also 'collect[s] food fraud reports from the RASFF' database (Bouzembrak et al. 2018, p.289).

Although recent studies have suggested using the USP FFD to acquire 'greater knowledge of food fraud and to improve the prediction performance' (Bouzembrak & Marvin 2016, p. 185), the data in the USP FFD is not yet used and analysed in any studies. In addition, the USP Food Fraud Database (FFD) does not have the limitations that exist in other databases. The USP FFD includes intentional adulteration (and not unintentional adulteration related to food safety) which is not the case in the RASFF database (Marvin et al. 2016). Moreover, the USP FFD provides information and documents in order to 'identify trends and vulnerabilities' (USP 2018). Therefore, this study will use USP FFD as it will adequately address the research question by providing a comprehensive history of food fraud for FFV factors assessment. The USP FFD provides the publicly available data related to each case (incident) of food fraud that helps the researcher to easily review them for FFV factor identification (Sub-question 1). The USP FFD also provides data sources related to influencing variables of FFV factors (i.e. country of origin, country of detection, year, etc.) as previous literature stated (see Bouzembrak and Marvin 2016; Marvin et al. 2016).

3.4.2 Evaluating the FFD

In this research, The Food Fraud Database (FFD) in the United States Pharmacopeia Convention (USP) will be selected to review cases of food fraud and to address research questions. The USP FFD was established by USP in 2012, providing information about the patterns of food fraud (USP 2018). The food fraud database in the USP also 'supports compliance with FSMA and GFSI requirements' (USP 2018). FSMA (Food Safety Modernisation Act) and the GFSI (Global Food Safety Initiative) are 'a set of standards' (GFSI 2017). New GFSI compliance requires all companies in the USA to undertake Food Fraud Vulnerability Assessment (FFVA) (addressing all types of food fraud and all ingredients) along with a completed and documented Food Fraud Prevention Strategy (Spink 2017). The expert panel and academics have already reviewed and validated the data published in the USP and made recommendations to identify the vulnerability of food ingredients (Spink, Moyer & Peru 2016) to food fraud. It is important to know that the USP FFD is accessible only through subscription purchase options (e.g. annual, 30 days, academic annual, and enterprise annual subscriptions) (USP FFD 2018). Therefore, it is not publicly and freely available.

There are more than 8,700 records of food fraud related to four types in the USP FFD including incidents, inferences, surveillance, and methods that are publicly available (USP FFD 2018). The incident records are those reported in the media and include information about 'the perpetrator, motive, geographic location, and/or other characteristics' (USP FFD 2018). An inference record is provided by 'published research conducted to develop detection methods for adulterants in particular ingredients' (USP FFD 2018). A surveillance record is typically conducted by 'regulatory agencies, trade organizations, or other interest groups, and may also occur as part of published research regarding analytical detection methods' (USP FFD 2018). A method record provides extra information about technical countermeasures that have helped detect the method record. Definition of each record type, numbers of records and their features are illustrated in Table 3.4.

Table 3.4: The FFD record types and definitions

Record Type	Number of Records from 2000 to 2018	Definition	Features in FFD
Incident records	1,146	'a documented occurrence of food fraud in a food ingredient or product within a defined time frame'	Ingredient name, ingredient synonyms, adulterant name, hazard (yes, no, unknown), fraud type, year reported, produced location, distributed location, weight of evidence (low, medium, high), and references as supporting information
Inference records	2,897	'an indication of probable knowledge of food fraud adulteration without sufficient documentation to be classified as an incident'	Ingredient name, ingredient synonyms, adulterant name, fraud type, hazard, year published, and references as supporting information
Surveillance record	532	'a report of sampling and testing of foods or ingredients in specified geographic locations or at multiple points along the supply chain to gain knowledge about the scope or prevalence of fraud'	Ingredient name, ingredient synonyms, adulterant name, hazard, year reported, surveillance country (detected or distributed), and references as supporting information
Method records	4,146	provides information on an analytical method for detecting food adulteration or authenticating food ingredients that has been published in a scholarly report.	Ingredient name, ingredient synonyms, adulterant name, hazard, year published, detection methods, and references as supporting information
Total	8,721		

Source: USP FFD (2018), Accessed on July 2018

The USP FFD records are updated regularly, adding new cases of food fraud. Other than records of food fraud, the FFD provides five analytics features or options for their customers/subscribers. These five data analytical features are: (1) Adulteration Record Time Series for tracking number of food fraud cases over time); (2) Ingredient Comparison (based on the number of food fraud reports and adulterants); (3) Geographic Distribution of Incidents (discovering incident location); (4) Analytical Methods (to determine technical countermeasures); and (5) Ingredient Tabular Display (showing a ‘snapshot of the number of records and list of adulterants’) (USP FFD 2018). The USP FFD analytic features can be done for an ingredient, a set of ingredients or for all ingredients. Figure 3.2 shows a data analytics example of the geographical distribution of incidents in the USP FFD for alcoholic beverages. The USP FFD collects incidents that are only publicly available. Therefore, none reported (or validated) incidents are not included in this database. All analysis results will be fully described in Chapter Four.

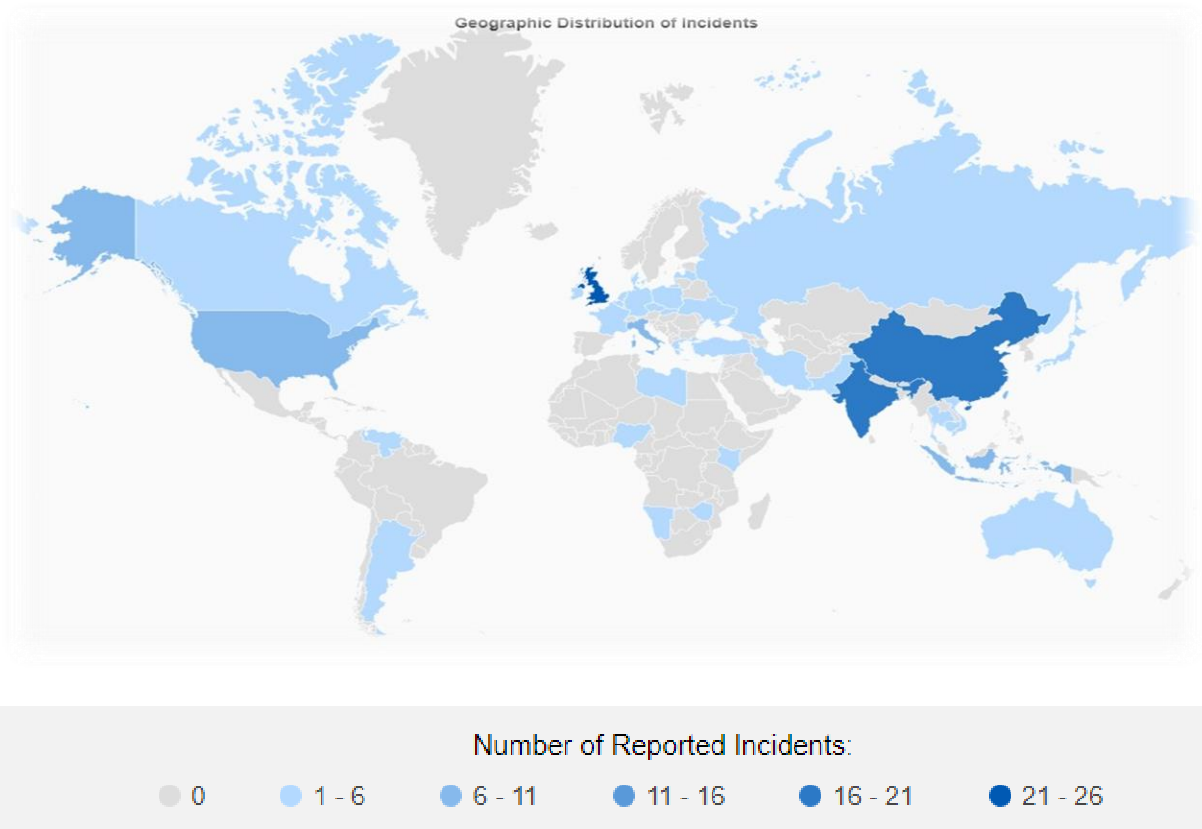


Figure 3.2: Geographic distributions of incidents (country of detection)

Source: USP FFD (2018)

3.5 **Data Analysis**

Data analysis is generally defined as the process of inspecting, transforming, and modelling data to determine useful information, suggest conclusions, and support decision-making (Ayele 2016, p. 13). Data analysis can be divided into three forms: descriptive, exploratory, and confirmatory data analysis (Ayele 2016). Exploratory data analysis focuses on ‘discovering new features in the data and confirmatory on confirming or falsifying existing hypotheses’ (Ayele 2016, p. 13). This research will employ both descriptive and confirmatory data analysis.

Descriptive data analysis is basic analysis including measures at the pre-test or post-test phase of data analysis (Creswell 2014). Examples of these statistics are mean, frequencies and standard deviations. Using descriptive data analysis, this study will present the basic analytical result of a number of food fraud reports per year, food ingredient types/ categories, country of origin, and types of food fraud reported in the USP FFD. These analyses will help to identify trends of food fraud based on time series, food categories that are more vulnerable and are at higher risk of being counterfeited, mislabelled, etc., countries where food fraud occurs more frequently, and important types of food fraud.

Confirmatory Analysis refers to inferential statistics used to examine the hypothesis (Creswell 2014) and research questions. For the purpose of this study, developing a holistic model that can assess the level (degree) of vulnerability to food fraud for food, a Bayesian Network (BN) model is used based on incidents reported in the USP FFD. Bayesian Modelling provides ‘a framework for plausible reasoning’ and has the ability toanalyse the causes of an outcome (Sharma 2017, p. 3). BNs are graphical models, showing relationships between variables (Margarities 2003). They are based on probability theory ‘originating from Bayesian statistics and decision theory combined with graph theory’ (Bouzembrak & Marvin 2016, p.181). BNs are also capable of other features: they can ‘[model] dependencies between variables, manage non-linear interaction and integrate different kinds of information about the system such as expert knowledge, measurement data, feedback experience and information regarding the system behaviour' (Marvin et al. 2016, p. 464). Bayesian Modelling was adopted in the food fraud literature for prediction of food fraud types (see Bouzembrak & Marvin 2016; Marvin et al. 2016).

For this study, Bayesian Modeling will be used to analyse incidents of food fraud in the USP FFD and to assess the Food Fraud Vulnerability factors based on food fraud types and other known influencing variables. The Bayesian modelling approach for this research will include three steps: (1) collection of food fraud incidents; (2) identification of Food Fraud Vulnerability factors associated to each food fraud incidents which will be derived from the literature (e.g. Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018), and reports linked to each food fraud incident in the FFD; (3) constructing BN models consisting of nodes, edges, and parameters related to each node within Conditional Probability Tables (CPT).

3.5.1 Collecting Cases of Reported Food Fraud

The USP FFD includes 8,721 records of food fraud from the year 1980 to 2018 (accessed on 10 July 2018) in the form of four recording types of incidents (1,146), inferences (2,897), methods (4146), and surveillance (532). From all these four types of food fraud records, only incident records have the complete information to determine vulnerability to food fraud, and other variables related to influencing variables (e.g. country of origin, country of distribution, weight of evidence, contextual and supporting information about the perpetrator, and motives) (FFD 2018). Other records like inferences are based on probable knowledge from published research. In addition, they do not include the variable 'country of origin' which is one of the important factors influencing food fraud cases (Bouzembrak & Marvin 2016). Methods and surveillance records are not selected for this study's analysis because the former does not have the information (or features) of the country of origin and distribution country and the latter lacks the information related to the types of food fraud for each case reported/published.

Table 3.5 shows the list of ingredient groups addressed within the incident recording type in the USP FFD from 2000 to 2018 (accessed 10 July 2018). The seafood, meat and poultry, alcoholic beverages, and dairy products cover more than 50% of the database related to incident records. Therefore, this study focuses on these top four product types as the sample for this research. From all the number of incidents related to these four products, 80% will be used to train the BN model and the rest to evaluate the performances and validity of the model according to the previous research (Marvin et al. 2016).

Table 3.5: List of ingredient groups and their percentage in the USP FFD from 2000 to 2018 (from incident type category)

Product Group	Percentage %
Meat and Poultry products	16.3
Dairy ingredients	16.1
Alcohol	15.8
Seafood and seafood products	12.4
Herbs, Spices, and Seasoning	7.4
Vegetable Oils	5.6
Grains	5.2
Olive oil	4.1
Beverages (Non-alcoholic)	3.2
Honey	2.4
Tea and Coffee	2.2
Fruits and Vegetable juices and concentrates	1.5
Eggs and egg products	1.8
Tree nuts and peanuts	1.8
Confectionary (Chocolate, cocoa, and candy)	1.8
Food additives and dietary supplements (Flavour, plant-based protein, whey products, sweeteners)	2.4
Total	100

Source: USP FFD (2018)

The incident records in the USP FFD are divided into three types: replacement, addition, and removal with 14 sub-types (10 for replacement, 3 for addition, and 1 for removal) based on the description provided in the database (for food fraud sub-type) and literature (for food fraud types, see Moore, Spink & Lipp 2012) (see Table 3.6).

Table 3.6: Types of food fraud and their sub-types

Food fraud type	Food fraud sub-type	Description
Replacement	Other dilution/substitution	Dilution or substitution with an alternate ingredient
	Geographic origin misrepresentation	Misrepresentation of geographic origin
	Unapproved biocides	Use of non-declared, unapproved or banned biocides (preservatives, antibiotics, anti-fungal agents, etc.)
	Animal Misrepresentation	Misrepresentation of animal origin
	Varietal origin misrepresentation	Misrepresentation of varietal origin
	Nutritional content fraud	Misrepresentation of nutritional content
	Botanical origin misrepresentation	Misrepresentation of botanical origin
	Fraudulent Labelling	Fraudulent labelling claims
	Addition of non-food substance	Dilution or substitution with an alternate substance (not food grade)
	Multiple adulterants	Formulation of an artificial product through the use of multiple adulterants and techniques
Addition	Addition of colourants	Artificial enhancement of perceived quality with colour additives
	Artificial enhancement (protein)	Artificial enhancement of apparent protein content
	Artificial enhancement (other)	Artificial enhancement of organoleptic qualities
Removal	Removal of authentic constituents	Removal of authentic constituents

Source: Moore, Spink and Lipp (2012); USP FFD (2018)

3.5.2 Identification of Food Fraud Vulnerability Factors (Sub-question 1)

The first step towards determining root causes of vulnerability to food fraud related to a product is to review the incident and its history (Spink & Moyer 2011). The Food Fraud Vulnerability factor for each incident can be determined by literature (Silvis et al. 2017; Van Ruth et al. 2018; see Table 2.3 in Chapter

Two) and the USP FFD. Examples of these factors are supply chain complexity, product price, and the legal system. For determining the vulnerability factors related to each food fraud incident in the USP FFD, this study will use a Barrier Analysis technique. Justification for the adoption of this technique is provided next.

3.5.2.1 Justification of the use of Barrier Analysis technique/method

The Barrier Analysis (BA) method, has been widely adopted as an assessment tool for the identification of barriers to behavioural change (Zafimanjaka 2010; Lewis 2016; Stacy 2016). In particular, it has been used in the critical incident analysis (Mahto & Kumar 2008) and identification of root causes of safety systems failure (Johnson 2006; Hollnagel & Speziali 2008). In these contexts, Barrier Analysis considers the range of potential hazards, risks and organisational factors that act as hurdles to inhibit (or facilitate) anti-social or dangerous behaviours in a given context (Huang 2015; Shah 2019). Barrier Analysis relies on the premise that as effective barriers decrease in number, then the likelihood of hazardous and/or unwanted behaviours increases (Johnson 2006; Shah 2019).

Over time, the Barrier Analysis method has been adapted to account for multiple such as food fraud as well. The BA theory was further developed to other methods such as Management Oversight and Risk Tree (MORT) and Bowtie methodology (Flynn 2013) which could be effective in food fraud related studies (Flynn 2013).

As Barrier Analysis methods have been shown to be effective at the identification of the root causes of critical incidents (Mahto & Kumar 2008) it was determined that this method would be appropriate in this analysis. The BA methods, in particular, ’focus on the barriers that should, but did not, prevent the occurrence of an adverse event and/or an unwanted outcome’ (Hollnagel & Speziali 2008, p.26; Shah 2019). These barriers are addressed in the literature as failed barriers (or effective countermeasures) ‘for identifying and resolving’ (or events/incidents (Mahto & Kumar 2008, p. 18). It is important to firstly identify the factors (root cause) related to an incident (Dew 1991) rather than simply applying reactive strategies (Huluka & Popov 2012) which could be ineffective.

In this research, the application of BA for the identification of vulnerability factors deemed appropriate as the research is dealing with the problem of food fraud hazard when food safety management systems failed to address the fraud case or were unsuccessful barriers (or failed safety barriers) as stated in related researches (see Figure 3.3). In addition, BA is more helpful when shifting from traditional risk analysis to vulnerability analysis. Figure 3.2 shows the ideas in the Barrier Analysis technique for food fraud events. As can be seen from Figure 3.3, food fraud hazards/events pass through a sequence of potential (safety) barriers before reaching their victims/targets. The weakness in these potentials (safety) barriers (that are unsuccessful) 'can be seen as the vulnerabilities' (Johnson 2006, p. 9). .

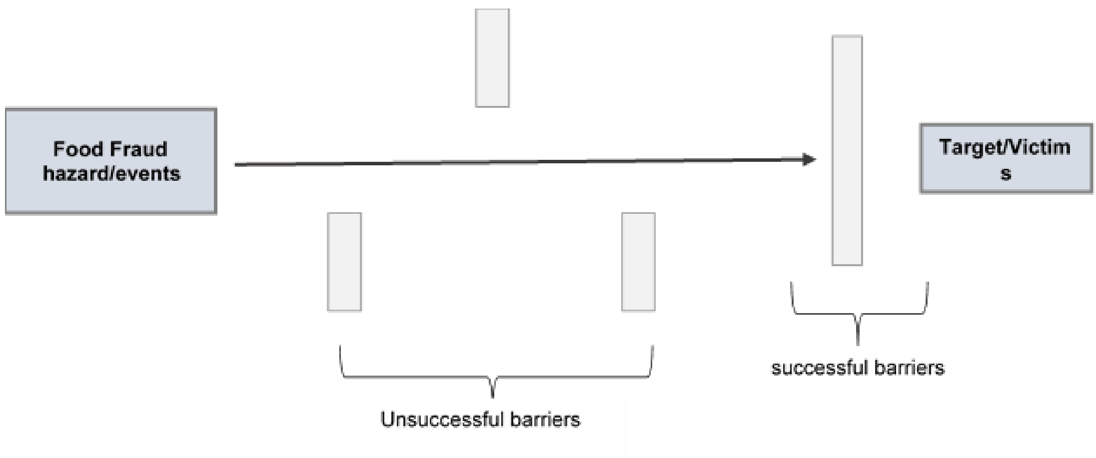


Figure 3.3: Barrier Analysis technique

Source: (Johnson 2006, p. 9)

The Barrier Analysis technique is combined with this study's framework provided in chapter Two based on the Routine Activity Theory. The research framework (Model) of this study explained that if capable guardians (or control measures or countermeasures) are absent to detect/seize food fraudsters and there is failed safety barriers (or ineffective food safety intervention measures), the area of vulnerability to food fraud will increase the motivation of fraudsters and the subsequent opportunities to commit food fraud (Ellis et al. 2016). Combining the Barrier Analysis technique and the Routine Activity Theory will strengthen the credibility of qualitative phase of this research by pinpointing the FFV factors into three categories of opportunity, motivation, and countermeasures according to the literature (Van Ruth, Huisman & Luning 2017).Table 3.7 shows the steps undertaken for the BA technique for this research. First, the researchers reviewed the cases of food fraud in the USP FF to be familiar with the database. Second, the researcher identified target (victim) and safety barriers or countermeasures that have used to detect food fraud. Third, the researcher identified the filed (safety) barrier that was unsuccessful in addressing and deterring case of food fraud. Finally, the researcher calibrated the identified factors/dimensions with the Routine Activity Theory categories and the literature.

Table 3.7: Steps undertaken for the BA

Task	Rationale
Initial reviewing the incidents of food fraud in the USP FFD	To be familiar with the database and review cases of food fraud
Identify Target, Victim and safety barriers	To understand how the safety barriers detected the food fraud incident
Identifying the failed safety barriers	Answering the question: Why the safety barrier system (e.g. safety officers) was failed to deter incident of food fraud in time? (before reaching to consumers and/or before the death of consumers when consumed fake alcoholic beverages)
Pinpointing the safety failed barriers (FFV factors) into three categories of opportunity, motivation, and countermeasures	Facilitating the assessment of vulnerability to food fraud in the Bayesian Network (BN) analysis model

Justification of Choosing Bayesian Network Modelling

The main research question, assessment of Food Fraud Vulnerability (FFV) factor, will be analysed using predictive analytics. Predictive analytics can be grouped into three main categories: regression, classification, and clustering (Lu 2017, p. 10). Regression analysis is a technique that 'focuses on understanding how dependent variable changes when an independent variable is changed' (Lu 2017, P.10) when the target variable is numerical (or continuous) (Lu 2017). Classification analysis is a technique that 'covers the problem of identifying which category a new observation belongs to base on information from a training data set' when the target variable is categorical. Clustering analysis is a technique that 'discovers the natural groupings of a data set with unknown class labels' (Lu 2017, p.10) when the target variable can be either numerical or categorical. The description of these three techniques is shown in Table 3.8.

Table 3.8: Types of predictive analytics and definitions

Techniques	Focus	Method types	Target variable
Regression	'understanding how a dependent variable changes when a predictor (or independent variable) is changed'	e.g. Linear and non-linear regression,	Numerical
Classification	'learn patterns using the data attribute features from the training set and these patterns can be applied to unknown instances to predict their categories'	e.g. Bayesian classification, logistic regression, decision trees, support vector machines (SVM), and artificial neural networks (ANN)	Categorical
Clustering	'categorize a new observation into a class membership'	e.g. gene sequence analysis, image segmentation, document summarization, and recommender systems	Categorical/Numerical

Source: Lu 2017

From the above definition of these three analysis techniques and based on the level of measurement of the target variable (FFV: opportunity, motivation, countermeasures) for this study, which is categorical, the appropriate analysis technique seems to be classification analysis. From common methods of classification analysis methods, this research will use the Bayesian approach for two reasons. The first reason is based on the number of the dependent variable (FFV factors) and independent variables, and their measurement levels of this research. Since this study has one target variable of FFV factors that is categorical (three categories of opportunity, motivation, countermeasures), with a large set of inputs (more than 100 influencing variables) that have different levels of measurements (e.g. ordinal, nominal, flags or binary value) the Bayesian approach seems to be appropriate for the analysis (IBM Nd (b)). Comparison between classification methods based on the target variable measurement level is shown in Table 3.9.

Table 3.9: Comparison between classification methods based on target variable measurement

	Logistic regression	**Bayesian approach**	**Decision Tree**	**Support vector machine**	**ANN**
Target Variable measurement	*Continuous* (target variable values between 0.0 to 1.0), or *categorical* with two categories (dichotomous or binary) (DTREG Nd)	Must be *categorical* with any measurement of Nominal, Ordinal, or Flag (IBM Nd (b))	Both *Categorical* and *Continuous*- However, the categorical target variable in the decision tree is binary (two values e.g. yes or no) (Ray 2015)	*Dichotomous or binary* (Dreiseitl and Ohno-Machado 2002)	*Discrete or real values* (Bain 2009)

Second, previous research focusing on the area of food fraud prevention has embraced the Bayesian approach as shown in their papers (see Marvin et al. 2016; Bouzembrak & Marvin 2016) as a suitable method for the purpose of assessment of FFV factors (main research question), understanding 'pattern of occurrences' (Marvin et al. 2016, p. 468) and determining the level of influencing variable importance (Sub-question 2 and 3). Given the nature of this study's research question (analysis of the level of inputs), the number of independent variables and dependent variable and their level of measurement, the Bayesian Network modelling approach seems to be an appropriate method for this research.

3.5.3 BN Model Building (Sub-question 2, Sub-question 3)

A Bayesian Network is a graphical model and consists of the following: (1) a set of random variables (or node) and a set of directed links (or edges) between variables; (2) a set of mutually exclusive states within each random variable which explain 'the condition of a variable' (Marvin et al. 2016, p. 465); (3) 'a directed acyclic graph' (DAG) formed from the variables and the directed links (or edges) (Jensen & Nielsen 2007; Marvin et al.2016, p. 465, Tien & Der Kiureghian 2016). A DAG is a directed graph with no directed path from A_i to A_j (e.g. $A_i \to \cdots \to Aj$) (Jensen & Nielsen 2007). If there is a link between A_i to A_j , then the random variable A_i is the parent of A_j and$A_j$is the child of A_i (Marvin et al. 2016; Jensen & Nielsen 2007). A Bayesian Network considers the joint probability distribution of all variables, $P(U) = P(A_1, \ldots\ldots, A_n)$ 'given by the product of all Conditional Probability Tables' (Jensen & Nielsen 2007, p. 36):

$$\text{P(U)}= \prod_{i=1}^{n} P(Ai|\ parents\ (Ai)) \qquad (1)$$

Bayesian Networks also have the ability to calculate new probabilities when new information about the state of a set of random variables are available (Jensen & Nielsen 2007; Hossain & Muromachi 2013). The new information provides the evidence, meaning that 'some of the variables are observed' taking values from their domains (Marvin et al. 2016, p. 466). For example, if the evidence (e) related to the state of m variables ($e_{1,\ldots\ldots,}$,e_m) becomes available, then inserting this new information to Eq. (1) we can get E.q (2):

$$\text{P(U, e)}= \prod_{i=1}^{n} P\big(A_i|parents\ (A_i)\big) \prod_{j=1}^{m} e_j \qquad (2)$$

And for A $\in$U we have

$$\text{P } (A|e) = \frac{\sum_{U\{A\}} P\ (U,e)}{P(e)} \qquad (3)$$

The BN model for this study will comprise (see Figure 3.3):

(1) A set of seven random variables (or nodes) of food fraud type, country of origin, country of distribution, Food Fraud Vulnerability factors, the weight of evidence, product, and year.

(2) A set of mutual states for each random variable (e.g. for the variable food fraud type the states are replacement, addition, and removal).
(3) A set of directed edges between the variables and an associated conditional probability for each of them. The links between the variables in the BN are based on family relationships. In this study, Food Fraud Vulnerability factor(s) is supposed to be the parent of food fraud type (and sub-type), year, country of origin, country of distribution, weight of evidence, and product. Relationships between food fraud type and other variables are drawn from the literature (see Marvin et al. 2016; Bouzembrak & Marvin 2016).

To construct the BN model for this study, we will use 80% of the incident records from the USP FFD, the machine learning technique ‘Expectation Maximisation Algorithm’ and the SPSS Modeler 18.2 software.

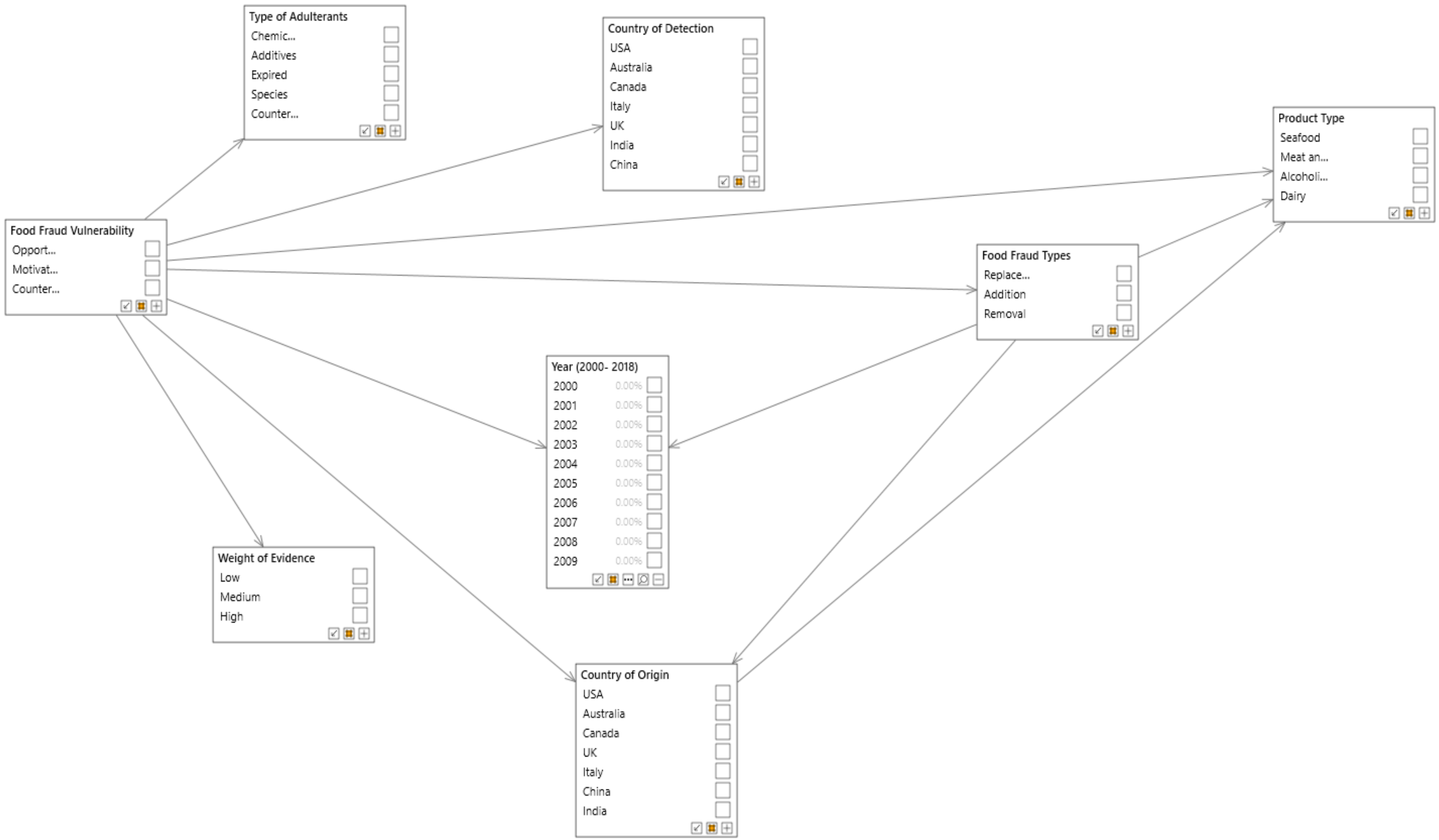


Figure 3.4: Proposed BN structure

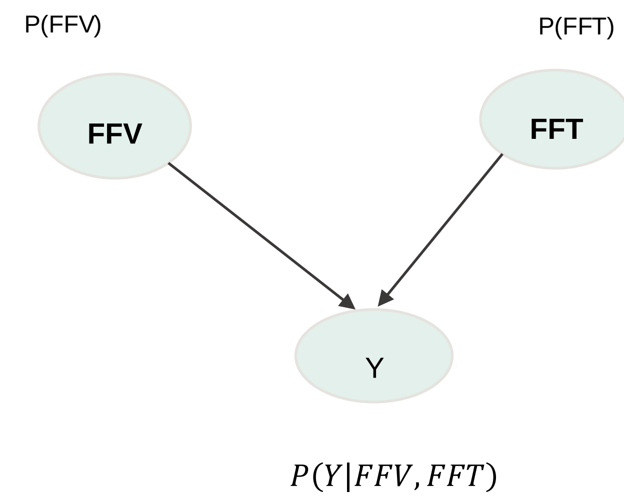
3.5.4 Example of Bayesian Network Calculations

Figure 3.5 shows an example of a BN with three nodes (random variables) of Food Fraud Vulnerability (FFV) factors, Food Fraud Type (FFT), and Year(Y). Variable FFV factors has three states of Opportunity (O), Motivation (M), and (Countermeasures), variable FFT has three states of Replacement (Rep), Addition (Add), and Removal (Rem), and finally variable Year has four states of Y1 (2002-2006), Y2 (2006-2010), Y3 (2010-2014), and Y4 (2014-2018). It can be seen from the edges between these three variables in Figure 3.3 and 3.4 that FFV and FFT are parents of Year. Variable Year (Y) with its parents FFV and FFT, form a conditional probability distribution, $P(Year|FFV, FFT)$ or Conditional Probability Table (CPT) (Jensen & Nielsen 2007). CPT and Unconditional Probability Tables (UPTs) are shown in Figure 3.5. The UPTs are given to a variable (e.g. FFV and FFT) when there is no parent for them (Jensen & Nielsen 2007). In this example, we supposed that FFV and FFT are independent. UPTs and CPT can be obtained through training the data (Li et al. 2014; Marvin et al. 2016, p. 469). In the case that there are no known UPTs, $\frac{1}{n}$ probability can be assigned, where n is 'the number of states of the parameters' (Marvin et al. 2016, p. 469).

Child variable (Y) is conditionally dependent on the sates of parent variables (FFV and FFT). In Figure 3.4, the CPT for the child variable (Y) is a table of all possible stated combinations of the parent variables. The first probability in the CPT in Figure 3.5 can be described as: given that FFV is (O), and FFT is (Rep), the probability that (Y1) will be equal to them is the conditional probability $\mathrm{P}(\mathrm{Y} = \mathrm{Y1} |\ \mathrm{FFV}\ = 0, \mathrm{FFT} = \mathrm{Rep})$.

FFV	Probability
O	P(FFV=O)
M	P(FFV=M)
C	P(FFV=C)

UPTs



FFT	Probability
Rep	P(FFT=Rep)
Add	P(FFT=Add)
Rem	P(FFT=Rem)

UPTs

YEAR	O (Opportunity)			M (Motivation)			C (Countermeasures)		
	Rep	Add	Rem	Rep	Add	Rem	Rep	Add	Rem
Y1	$P(Y = Y1\| FFV = 0, FFT = Rep)$	$P(Y = Y1\|FFV = O, FFT = Add)$	$P(Y = Y1\|FFV = O, FFT = Rem)$	$P(Y = Y1\|FFV = M, FFT = Rep)$	$P(Y = Y1\|FFV = M, FFT = Add)$	$P(Y = Y1\|FFV = M, FFT = Rem)$	$P(Y = Y1\|FFV = C, FFT = Rep)$	$P(Y = Y1\|FFV = C, FFT = Add)$	$P(Y = Y1\|FFV = C, FFT = Rem)$
Y2	$P(Y = Y2\|FFV = 0, FFT = Rep)$	$P(Y = Y2\|FFV = O, FFT = Add)$	$P(Y = Y2\|FFV = O, FFT = Rem)$	$P(Y = Y2\|FFV = M, FFT = Rep)$	$P(Y = Y2\|FFV = M, FFT = Add)$	$P(Y = Y2\|FFV = M, FFT = Rem)$	$P(Y = Y2\|FFV = C, FFT = Rep)$	$P(Y = Y2\|FFV = C, FFT = Add)$	$P(Y = Y2\|FFV = C, FFT = Rem)$
Y3	$P(Y = Y3\|FFV = O, FFT = Rep)$	$P(Y = Y3\|FFV = O, FFT = Add)$	$P(Y = Y3\|FFV = O, FFT = Rem)$	$P(Y = Y3\|FFV = M, FFT = Rep)$	$P(Y = Y3\|FFV = M, FFT = Add)$	$P(Y = Y3\|FFV = M, FFT = Rem)$	$P(Y = Y3\|FFV = C, FFT = Rep)$	$P(Y = Y3\|FFV = C, FFT = Add)$	$P(Y = Y3\|FFV = C, FFT = Rem)$
Y4	$P(Y = Y4\|FFV = O, FFT = Rep)$	$P(Y = Y4\|FFV = O, FFT = Add)$	$P(Y = Y4\|FFV = O, FFT = Rem)$	$P(Y = Y4\|FFV = M, FFT = Rep)$	$P(Y = Y4\|FFV = M, FFT = Add)$	$P(Y = Y4\|FFV = M, FFT = Rem)$	$P(Y = Y4\|FFV = C, FFT = Rep)$	$P(Y = Y4\|FFV = C, FFT = Add)$	$P(Y = Y4\|FFV = C, FFT = Rem)$

Figure 3.5: Examples of BN, UPTs, and CPT for three variables of FF, FFV and Year

3.6 Evaluation of the Research Design

In order to evaluate the rigour in mixed methods research, the literature suggested ‘assessing integration and the need to justify the use of mixed methods’ (Brown et al. 2015, p. 813) as well as assessing the rigour of qualitative and quantitative approach separately (Tashakkori and Teddlie 2010). This study integrated both qualitative and quantitative approach based on two main reasons. First, the researcher selected a pragmatism worldview in order to use pluralistic methods to address the problem of vulnerability to food fraud. The second reason is related to the research questions. The first sub-question of the research is exploratory in nature and according to the literature identification of key FFV factors is yet to be completed (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). Therefore, a qualitative approach is deemed to be appropriate. Other sub-questions, as well as the main research question, are related to the assessment of FFV factors and therefore quantitative approach was selected.

According to the literature, a qualitative approach can be assessed based on the following criteria of *credibility, transferability, dependability,* and *confirmability* (Lincoln & Guba 1985; Healy & Perry 2000). *Credibility* refers to the ‘assessment of the association between the actual investigation and its planned objectives’ (Bonjiovanni 2016, p. 149). To achieve the credibility, the research method selected in the qualitative approach (Barrier Analysis technique or Sub-question 1) is well established and is based on previous studies (Blomkvist et al. 2010; Dong et al. 2016; Johnson 2006). In addition, data analysis in the qualitative phase follows the Routine Activity Theory as has been approved in assessing and identifying key FFV factors according to the literature (Silvis et al. 2017; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). Moreover, the credibility of the research is ensured by the ‘development of familiarity’ with cases of food fraud reported in the USP FFD. The researcher will spend extensive time reviewing the incident recorded in the database during data collection for about 20 days. This allows the researcher to extensively understand the platform of the USP FFD and different sources of data presented in the USP FFD.

Transferability refers to the assessment of trustworthiness in qualitative approach in case of the generalisability factor (Bonjiovanni 2016). To achieve transferability, this study will select a large sample of data (580 cases of food fraud) from different product categories. Using different categories of food product type will help the generalisability of this research by providing differences and similarities related to FFV factors. In addition, the researcher provided the readers with specific information regarding the research design, the sampling strategy, etc. This can help the readers to ensure the trustworthiness of the research by providing relevant information on how the same results could be obtained (Bonjiovanni 2015) in all other food product types.

Dependability refers to 'obtaining the same results when the investigation is repeated under the same conditions by other researchers' (Bonjiovanni 2016, p. 150). To ensure the dependability of this investigation, the researcher carefully described the processes or framework to conduct secondary data analysis. The framework comprises developing the research question, identifying the database, and evaluating the database according to the literature (Johnston 2014). In addition, the study will clarify the processes of identifying FFV factors using Barrier Analysis technique and the Routine Activity Theory and the full data is available in Appendix A

Finally, confirmability refers to the degree to which the researcher's findings can be confirmed by others, 'rather than on the choices of the researcher' (Bonjiovanni 2016, p.151). Two steps will be undertaken to ensure the confirmability of the present research (specifically related to the Barrier Analysis technique results). First, a draft of Barrier Analysis result related to each product category as well as the process with all data related to it will be sent to two supervisors for verification. Second, the study also will use quantitative BN model in order to confirm or disconfirm the assessment of identified FFV factors based on predictors addressed in the literature and the data source (the USP FFD).

According to the literature, the quality of a quantitative approach can be assessed based on the criteria of validity and reliability (Brown et al. 2015). The validity of the quantitative approach refers to 'the extent to which a concept is accurately measured in a quantitative study' (Heale & Twycross 2015). There are two ways to validate the constructed BN for this study. First, the researcher will use approximately 20 % of the incident records (similar to the study by Marvin et al. 2016) in the USP FFD to assess FFV factors. For this purpose, these incidents will be retrieved from the USP FFD and will be stored in Excel. All variables (except FFV) will be used as input in the constructed BN model to assess Food Fraud Vulnerability factors as identified by the Barrier Analysis Technique. Second, the study will compare the result of the BN model to the results previously published by other studies. For example, the result of the BN analysis for products will be compared with the research by Tahkapaa et al. (2015), and Bouzembrak and Marvin (2016).

Reliability of quantitative approach refers to 'to the consistency of a measure' (Heale & Twycross 2015). This research will adopt two steps to ensure the reliability of the BN modelling approach. First, the research will provide the description of processes undertaken to construct the BN model using SPSS Modeler 18.2. The processes include clarification of step by step development of Stream by the SPSS Modeler. Furthermore, the study will test the reliability of the holistic model through the partition node which split the dataset into training (80%) and testing (20%) set according to previous research (Marvin et al. 2016). Second, data used to construct the BN model will be fully accessible (including each incident with a record ID, influencing variable and target variable of FFV) following USQ's protocols for data retrieval.

3.7 Methodological Limitations

One methodological limitation that this research had to face relates to the use of secondary data analysis. The secondary data analysis has two main limitations. First, the data in the secondary data analysis method is collected for some other reason/purposes (Johnston 2014). In this research obtaining primary data (through either interview or survey) is impossible for the researcher due to the sensitivity of addressing food fraud in companies. Studies of food fraud are sensitive topics that may often identify and quantify problems with no real solutions for companies. Moreover, identifying vulnerability to food fraud requires initial screening of cases of food fraud organised within a database (Spink et al. 2016). Therefore, secondary data analysis is selected for data collection and data analysis. In order to avoid this limitation, the researcher selected the secondary data that is best described in the literature for collecting incidents of food fraud (Bouzembrak et al. 2018).

A second limitation of using secondary data is that 'the secondary researcher did not participate in the data collection process and does not know exactly how it was conducted' (Johnston 2014, p. 625). In this research, incidents of food fraud will be carefully collected in the USP FFD from scientific literature, media publications, regulatory reports, judicial records, and trade association. Therefore, the source of data is available and reliable. In addition, the study addressed this limitation by describing a framework for undertaking secondary data analysis. This framework was described in section 3.4.

Another methodological limitation is linked to Sub-question 1, identifying FFV factors. The identification of FFV factor based on real data or reviewing cases of food fraud is absent in the literature (Van Ruth et al. 2018). Therefore, there are a lack of knowledge and/or techniques in order to extract the vulnerability factor from a database. The USP FFD addresses the possibility of identifying 'trends and vulnerabilities through a customizable dashboard, powerful search capabilities, and automated analytics' (USP FFD 2018). However, identification of FFV factors requires reviewing incidents of food fraud from their source. To avoid this limitation, the study will use Barrier Analysis technique based on similar studies (Blomkvist et al. 2010; Dong et al. 2016; Johnson 2006) combined with the Routine Activity Theory in order to pinpoint the identified FFV factors into three main categories of opportunity, motivation, and countermeasures.

3.8 **Conclusion**

This chapter outlined the research methodology selected in the present study. Originated from pragmatism paradigm, this exploratory sequential mixed methods investigation adopts a secondary data analysis research strategy. A detailed description of framework and processes to conduct secondary data analysis including development of research question, identifying the database, and evaluating the database is provided. Data analysis of this research revolves around the identification of FFV factors (Sub-question 1), the way these factors be assessed by fraud incident types (Sub-question 2), and other known influencing variables (Sub-question 3), and BN validation (main RQ). Methodological limitations of this study are outlined related to secondary data analysis research strategy and also Sub-question 1. Several steps will be undertaken to reduce the influence of these limitations. Chapter Four discusses the results that emerged from the above main research question and sub-questions.

4 CHAPTER 4: RESEARCH RESULTS

4.1 Introduction

As the previous chapters of this research highlighted, addressing, understanding, and answering the three research sub-questions of this document will enable assessment of Food Fraud Vulnerability (FFV) factors for food products targeted at human consumption. In particular, a better understanding of factors that can contribute to FFV factors(Sub-question 1), determining the level of influencing variable of food fraud type (Sub-question 2), and other known influencing variables (Sub-question 3) are considered essential in the assessment of FFV factors for food products designed for human consumption.

Chapter Two laid the conceptual foundation for the study of vulnerability to food fraud. By reviewing relevant literature in the field of food fraud, this study has cast light on the differences between food fraud and other food safety management categories (e.g. food quality) (Spink & Moyer 2011) that requires prevention strategies rather than intervention/detection responses. Chapter Two also introduced the Routine Activity Theory, a criminal theory that provides a framework for the identification of factors (root causes) impacting vulnerability to food fraud. Furthermore, chapter Two illustrated the Bayesian Network (BN) model to test the existing theoretical assumption provided by the Routine Activity Theory for the assessment of FFV factors. Chapter Three demonstrated the research design selected in this research, as well as its paradigm, strategy, methods, and justification of selecting Barrier Analysis technique and Bayesian Modeling analysis approach.

This Chapter provides an overview of the findings that emerged from the research questions comprising this research. This chapter starts with descriptive analysis results related to all influencing variables of FFV factors. Next, this chapter focuses on describing FFV factors identified from the Barrier Analysis technique (Sub-question 1), building and constructing a Bayesian Network structure to understand important influencing variables (Sub-question 2 and Sub-question 3), and finally validating the holistic model (main RQ). The structure of the present chapter is shown in Table 4.1.

Table 4.1: Chapter 4 structure

Section	Purpose
4.1 Introduction	Introduction
4.2 Descriptive Analysis	Descriptive statistics related to influencing variables of FFV factors
4.3 Barrier Analysis Results	FFV factors categories and sub-categories related to 580 cases of Food Fraud
4.4 Bayesian Network Modeling Approach	Building and testing the BN model based on food fraud incident types (Sub-question 2), and based on other known influencing variables (Sub-question 3)
4.5 Holistic TAN Model Validation	Holistic TAN model validation based on the testing sub-set and previous studies
4.6 Conclusion	Summary

4.2 Descriptive Analysis

From 2000 to 2018, a total sample of 580 incidents of food fraud reported by the USP Food Fraud Database (FFD) relating to four types of food products: seafood, meat and poultry, alcoholic beverages, and dairy were reviewed. This section summarises the information related to the sample of 580 cases of food fraud. The descriptive analysis was used to summarise information related to all influencing variables of FFV factors. These variables are product type, country of origin, detecting countries, year (reported and detected), type of adulterants, the weight of evidence, and food fraud incident types. The descriptive data for these factors is presented next commencing with Food Fraud Types.

4.2.1 Food Product Types

Table 4.2 shows the descriptive statistics related to seafood, meat and poultry, alcoholic beverages, and dairy reported by the USP FFD. The information related to each food product category, the geographical distribution of incidents for these products (based on both the produced country/country of origin and distributed country/detecting country), and analysis of time series for each of them are described next.

Table 4.2: Total number of Food Fraud incidents based on food product types (from 2000 to 2018)

Product	Number of incidents	Percent
Seafood	129	22.2
Meat	162	27.9
Alcoholic Beverages	161	27.8
Dairy	128	22.1
Total	580	100

4.2.1.1 Criteria's of Detecting Country, Country Of Origin, And Year for Seafood And Seafood Product Type

Fraud incidents related to seafood and seafood products contained 22.2 percent of all incidents studied in this research. The incidents were related to a broad range of fish products. Examples were shrimp, grouper, salmon, snapper, caviar, monkfish, haddock, catfish, cod and jellyfish. Figure 4.1 depicts the geographic distribution of seafood fraud incidents detected between 2000 to 2018 provided by the USP FFD automated analytics. A considerable number of incidents related to seafood fraud were detected in five countries: USA (%34.1), UK (%11.6), Taiwan (%10.9), China (%9,3), and Japan (%6.2).

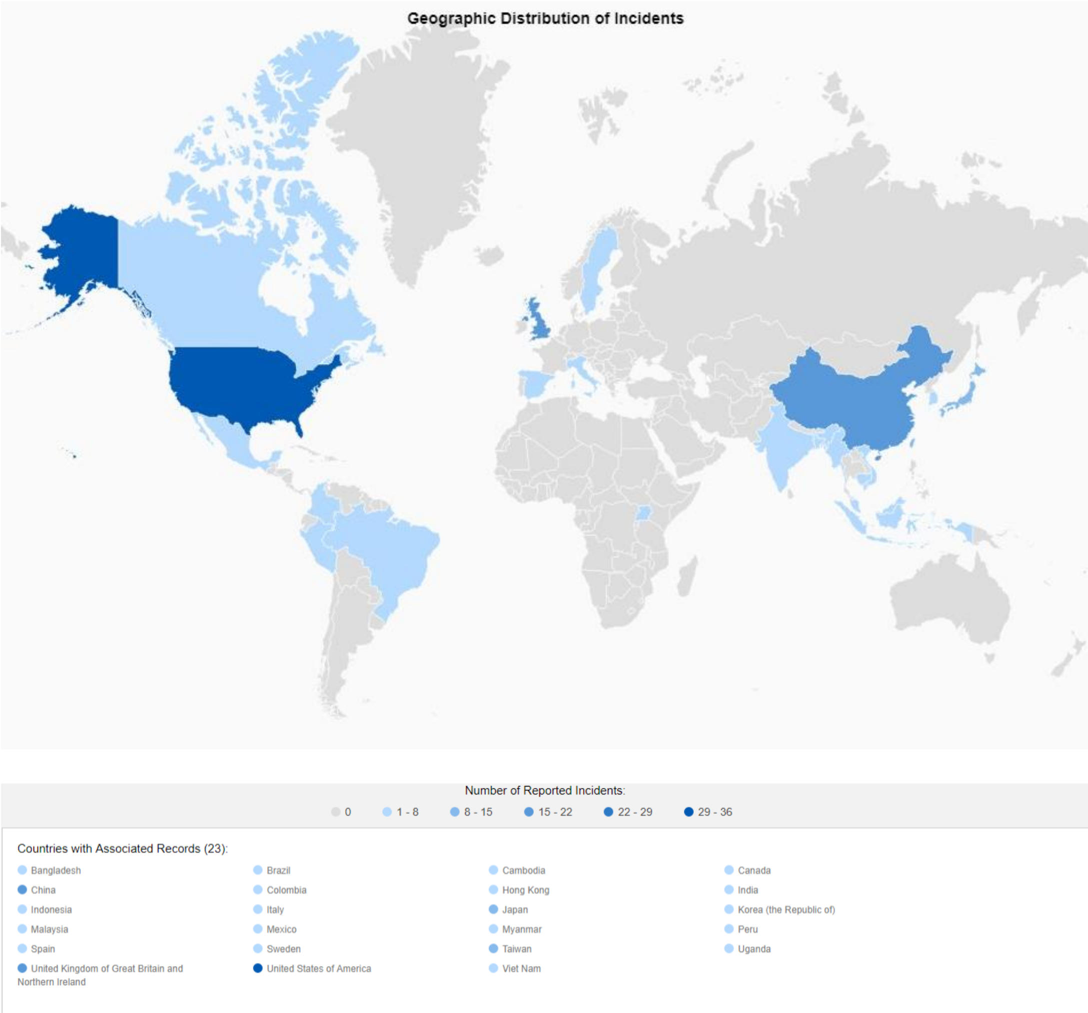


Figure 4.1: Geographical distribution of Seafood fraud (detecting country)

Source: USP FFD (www.foodfraud.org)

Figure 4.2 shows the country of origin of incidents of seafood fraud by the continents. As shown in Figure 4.2, most of the seafood fraud incidents originated from the Asia, Europe, and America continents. In Asia, most of the seafood incidents were originated from China (12.4%), Taiwan(10.08 %), and Japan (9.3 %). In America, most of the seafood incidents were originated from the USA (27.13 %) and in Europe, most of the seafood incidents were originated from the UK (12.4 %).

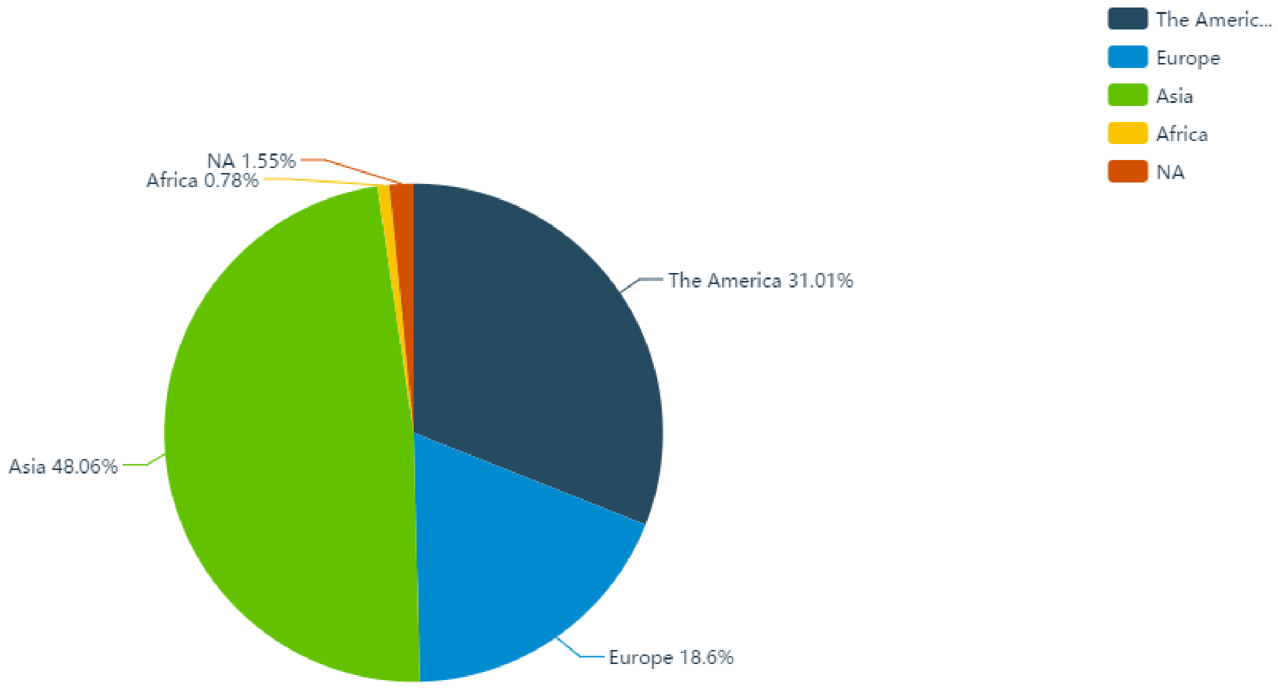


Figure 4.2: Seafood fraud incidents' country of origin by continents

Figure 4.3 depicts the overall increase in the number of seafood fraud incidents detected over an eighteen-year period from 2000 to 2018. The number of seafood fraud incidents has increased from 5 incidents in 2002 to approximately 13 incidents in 2018. At the beginning of this period, the number of incidents showed a slight decline until the year 2007 but was then followed by rapid changes from 2007 to 2015 following a dramatic increase in 2016. The number of incidents reached its highest level of about 35 incidents in 2016 before falling to about 13 incidents in 2018

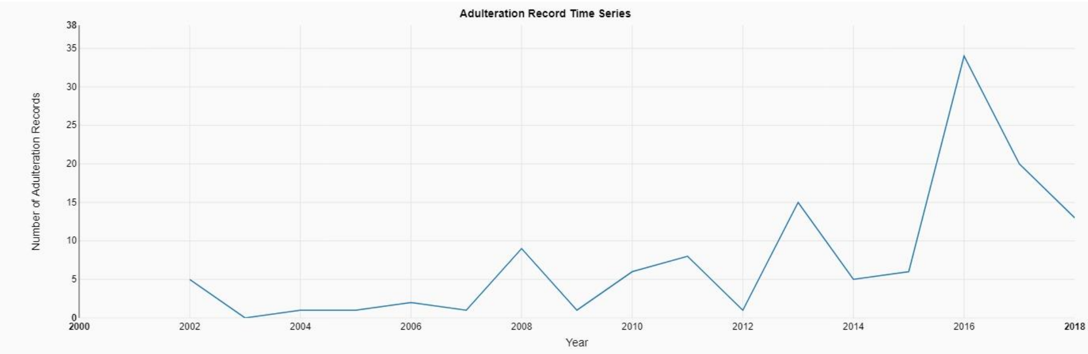


Figure 4.3: Seafood fraud time series
Source: USP FFD

4.2.1.2 Criteria's Of Detecting Country, Country Of Origin, And Year For Meat And Poultry Product Type

Fraud incidents related to meat and poultry products contained 29.7 percent of all incident's studied in this research as shown in Table 4.2. The incidents were related to a broad range of meat products available for human consumption. Examples were pork, sheep, beef and mutton. Figure 4.4 depicts the geographic distribution of meat and poultry fraud incidents detected between 2000 to 2018 provided by the USP FFD automated analytics. A considerable number of incidents related to meat and poultry were detected in four countries: China (%22.8), UK (%20.4), USA (%9.3), and South Africa (%6.8).

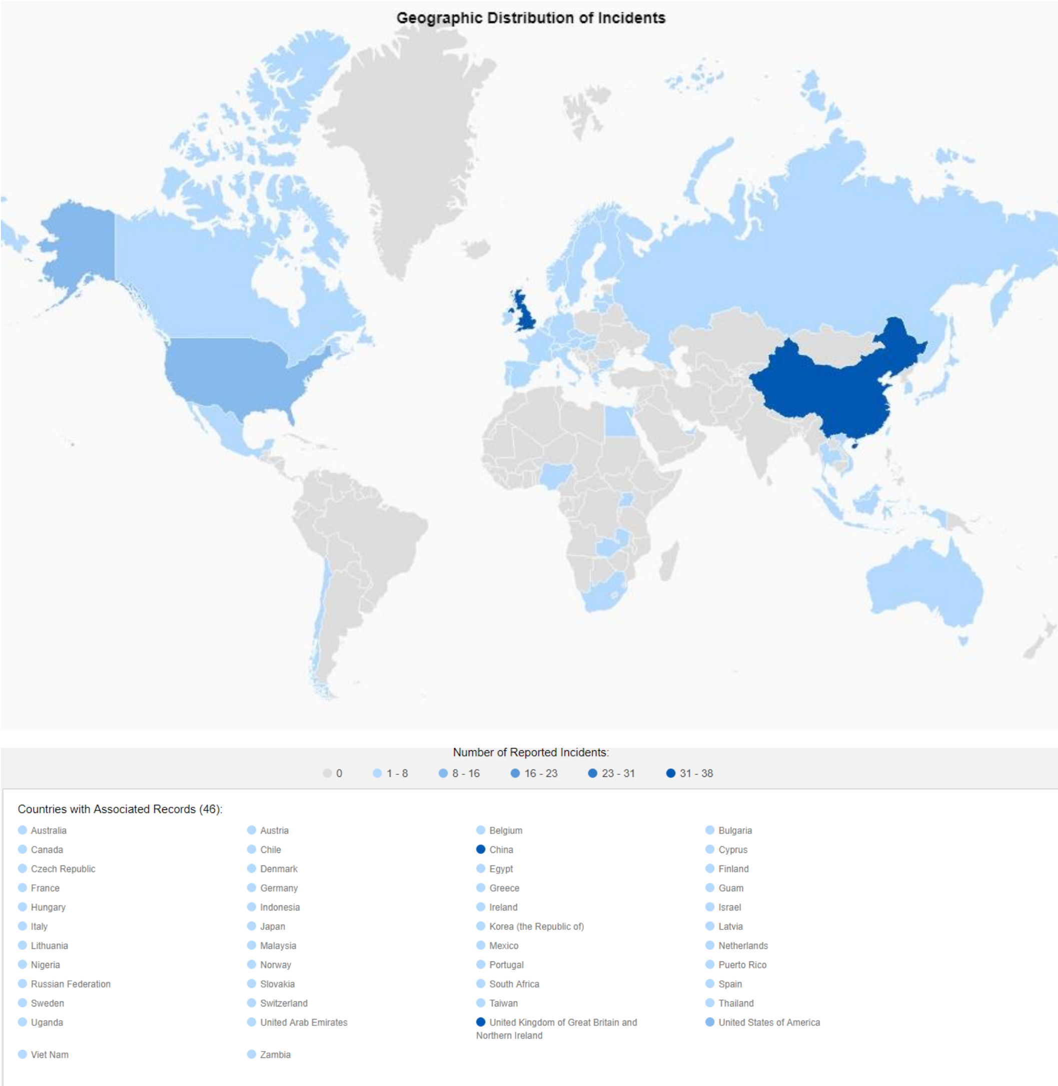


Figure 4.4: Geographical distribution of Meat and Poultry fraud (detecting country)
Source: USP FFD

Figure 4.5 shows the country of origin of incidents of meat and poultry fraud by continents. As shown in Figure 4.5, most of the Meat and Poultry fraud incidents originated from the Asia, Europe, America, and Africa continents. In Asia, most of the meat and poultry incidents were originated from China (21.6 %). In America, most of the meat and poultry incidents were originated from the USA (10.49 %). In Europe, most of the meat and poultry incidents were originated from the UK (19.13 %) and in Africa, most of meat and poultry incidents were originated from South Africa (6.79 %).   .

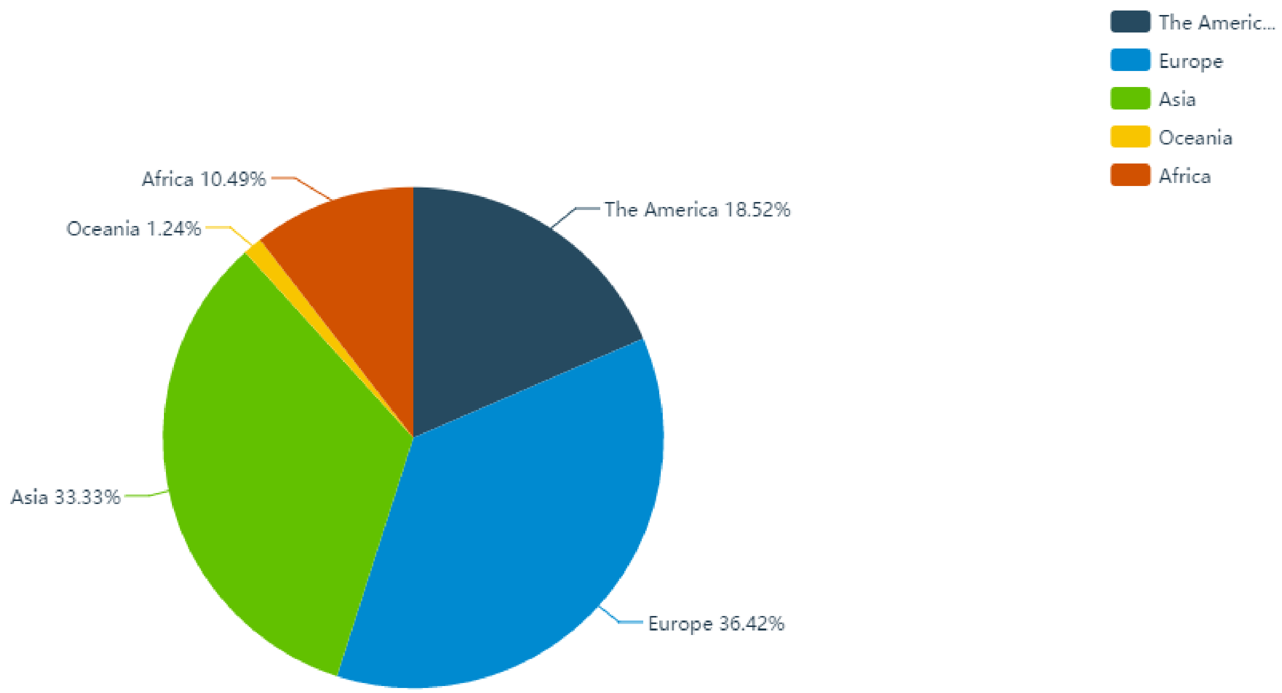


Figure 4.5: Meat and Poultry fraud incidents' country of origin by continents

Figure 4.6 depicts the overall increase in the number of meat and poultry fraud incidents detected over an eighteen-year period from 2000 to 2018. The number of fraud incidents in meat and poultry products has increased from 2 incidents in 2001 to approximately 23 incidents in 2018. At the beginning of this period, the number of incidents remained stable until the year 2009 but was then followed by rapid changes from 2009 to 2018. The number of incidents reached its highest level to 24 incidents in 2016.

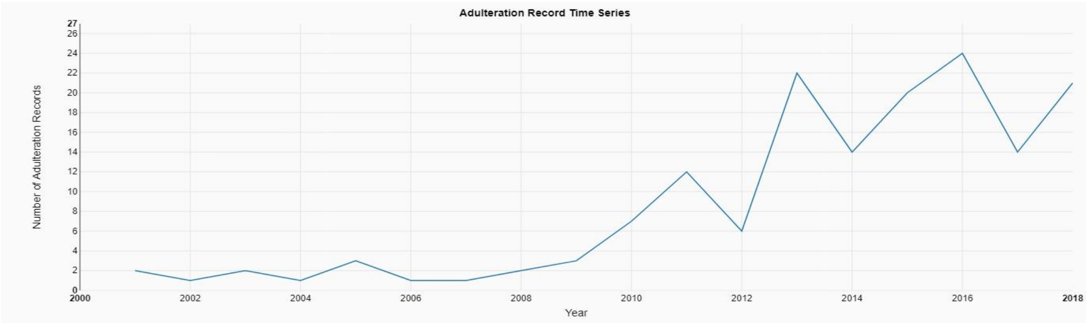


Figure 4.6: Meat and Poultry fraud time series
Source: USP FFD

4.2.1.3 Criteria's Of Detecting Country, Country Of Origin, And Year For Alcoholic Beverages Product Type

Incidents related to alcoholic beverages contained 27.8 percent of all incident's studied in this research as shown in Table 4.2. The alcoholic beverage category included Vodka, Wine, Gin, Beer and Tequila. Figure 4.7 depicts the geographic distribution of incidents of fraud related to alcoholic beverages between 2000 to 2018 provided by the USP FFD automated analytics. A considerable number of incidents relating to Alcoholic Beverages fraud were detected in four countries: the UK (%15.5). China (%13), India (%9.9), and Italy (%6.8).

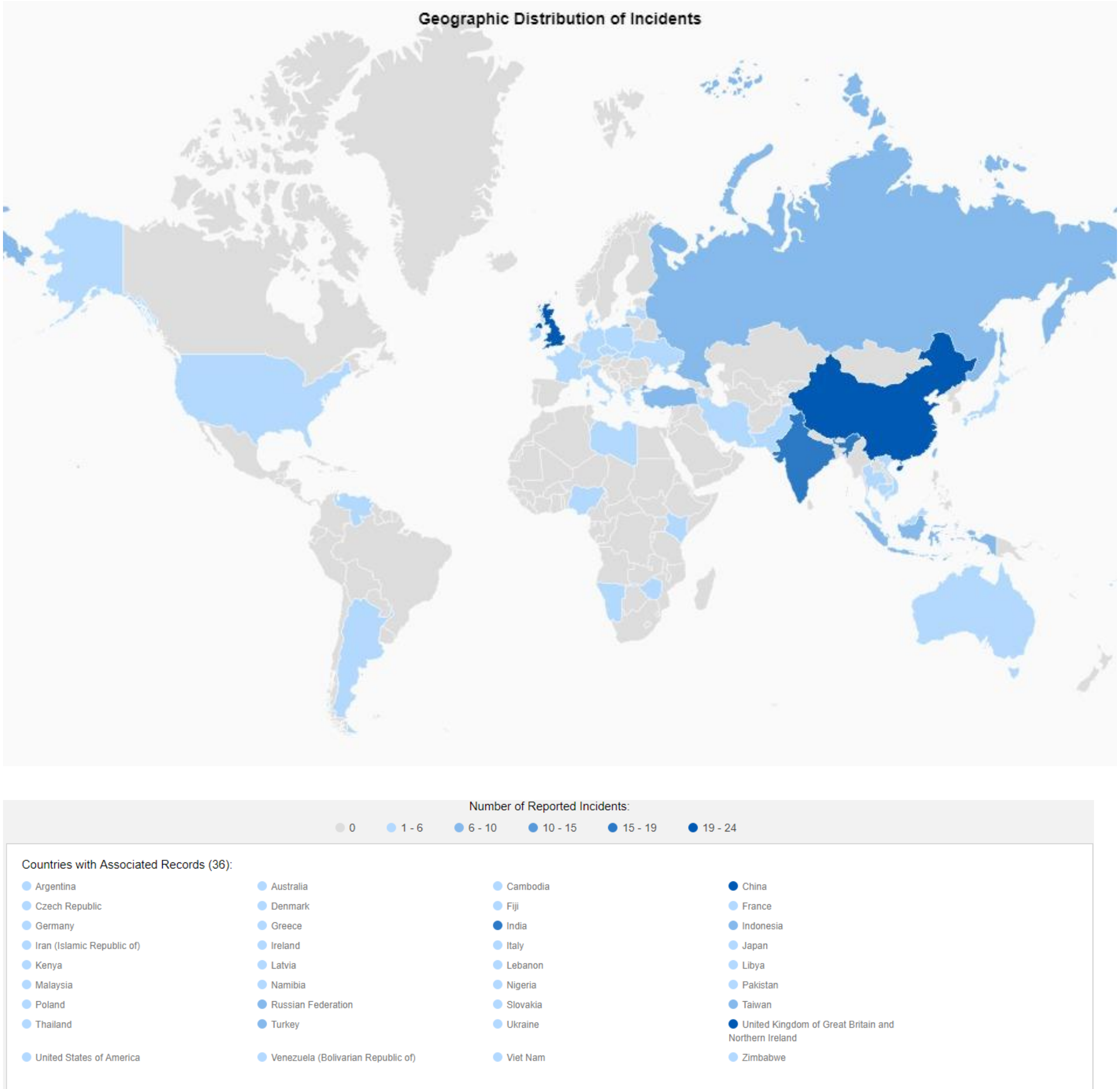


Figure 4.7: Geographical distribution of Alcoholic Beverages fraud (detecting country) Source: USP FFD

Figure 4.8 shows the country of origin of incidents of alcoholic Beverages fraud by continents. As shown in Figure 4.8, most of the alcoholic Beverages fraud incidents originated from the Asia and Europe continents In Asia, most of the alcoholic Beverage incidents were originated from China(13.67 %) and India (9.94 %). In Europe, most of the alcoholic Beverage incidents were originated from the UK (12.42 %) and Italy (9.32 %).

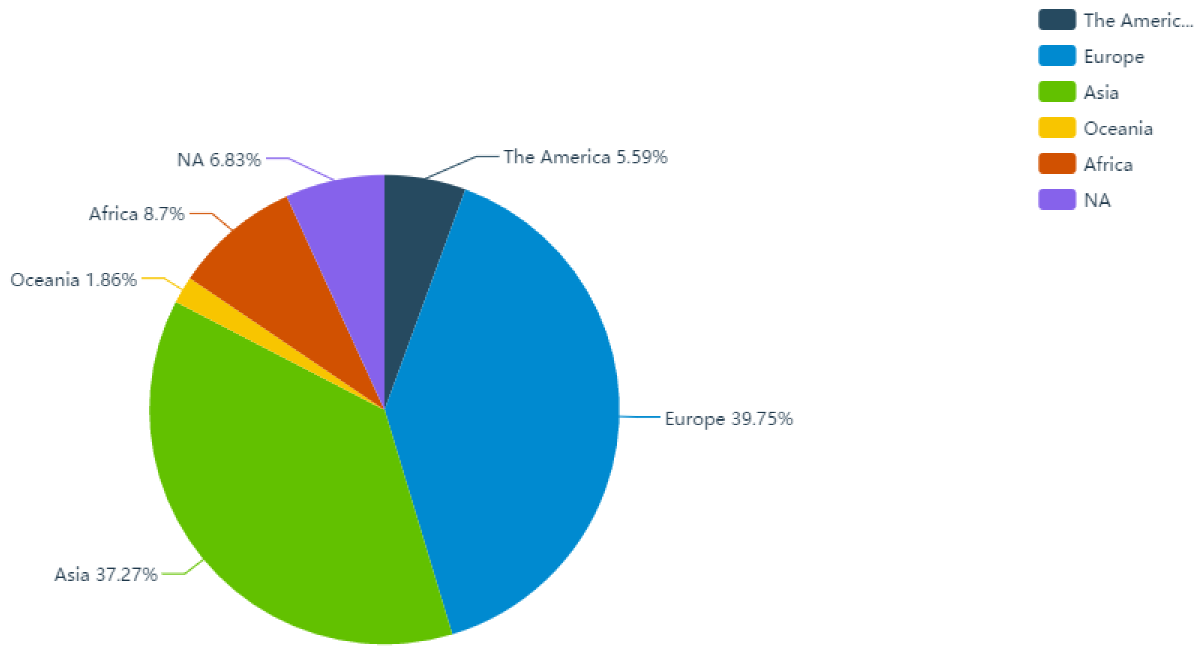


Figure 4.8: Alcoholic Beverages fraud incidents' country of origin by continents

Figure 4.9 depicts the overall increase in the number of fraud incidents related to alcoholic beverages over an eighteen-year period from 2000 to 2018. The number of fraud incidents has increased from about 3 incidents in 2002 to 20 incidents in 2018. At the beginning of this period, the number of incidents showed a slight decline until the year 2008 but was then followed by a gradual increase from 2008 to 2012. Then the number of incidents started to change rapidly from 2013 and reached the highest point of about 28 incidents in 2017.

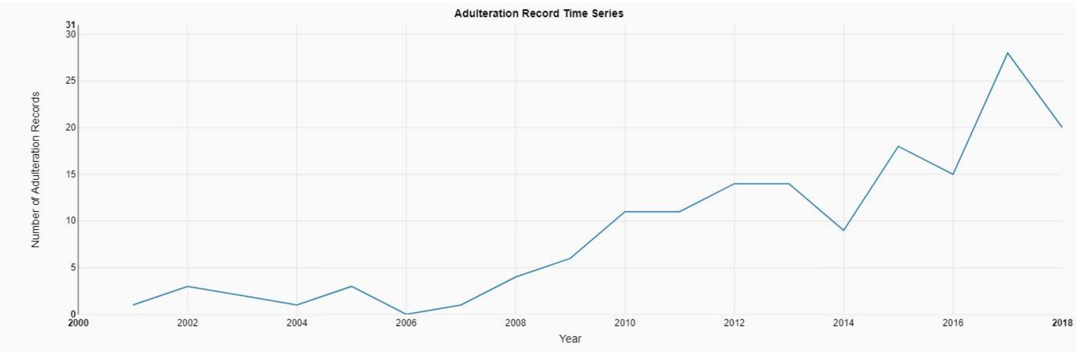


Figure 4.9: Alcoholic Beverages fraud time series
Source: USP FFD

4.2.1.4 Criteria's Of Detecting Country, Country Of Origin, And Year For Dairy Product Type

Incidents related to Dairy products contained 27.8 percent of all incident's studied in this research as shown in Table 4.2. The Dairy product category included milk, infant formula, cheese, butter, khoa, ice cream and ghee. Figure 4.10 depicts the geographic distribution of incidents of fraud related to Dairy products between 2000 to 2018 provided by the USP FFD automated analytics. As can be seen, A considerable number of incidents related to Dairy products were detected in five countries: India (%48.4), China (%14.8), USA (%7), and Pakistan (%6.3).

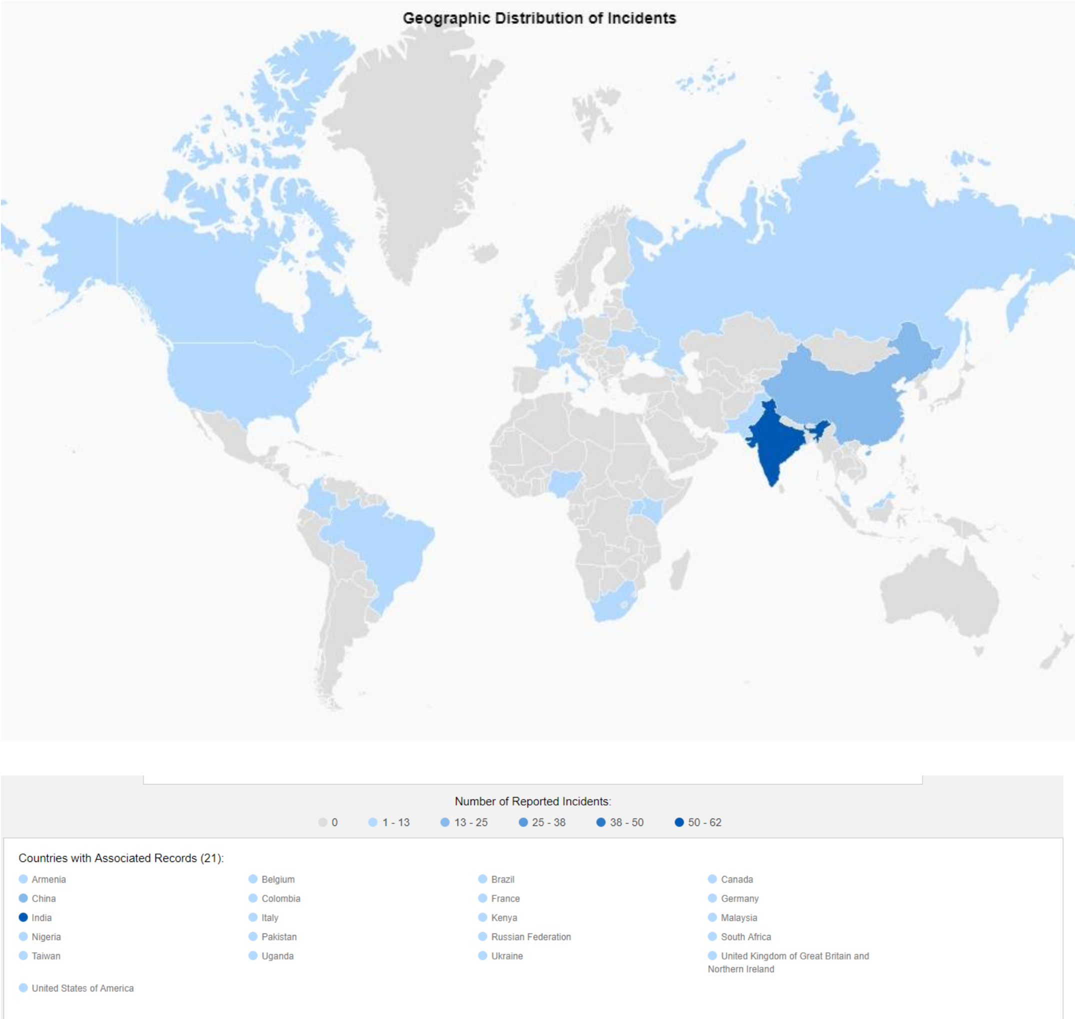


Figure 4.10: Geographical distribution of Dairy fraud (detecting country)
Source: USP FFD

The country of origin of incidents of Dairy fraud by continents is shown in Figure 4.11. As shown in Figure 4.11, most of the Dairy fraud originated from the Asia, and America continents. In Asia, most of dairy incidents were originated from India (48.44 %), China (12.5 %), and Pakistan (6.25 %). In America, most of the dairy incidents were originated from the USA (7.3%).

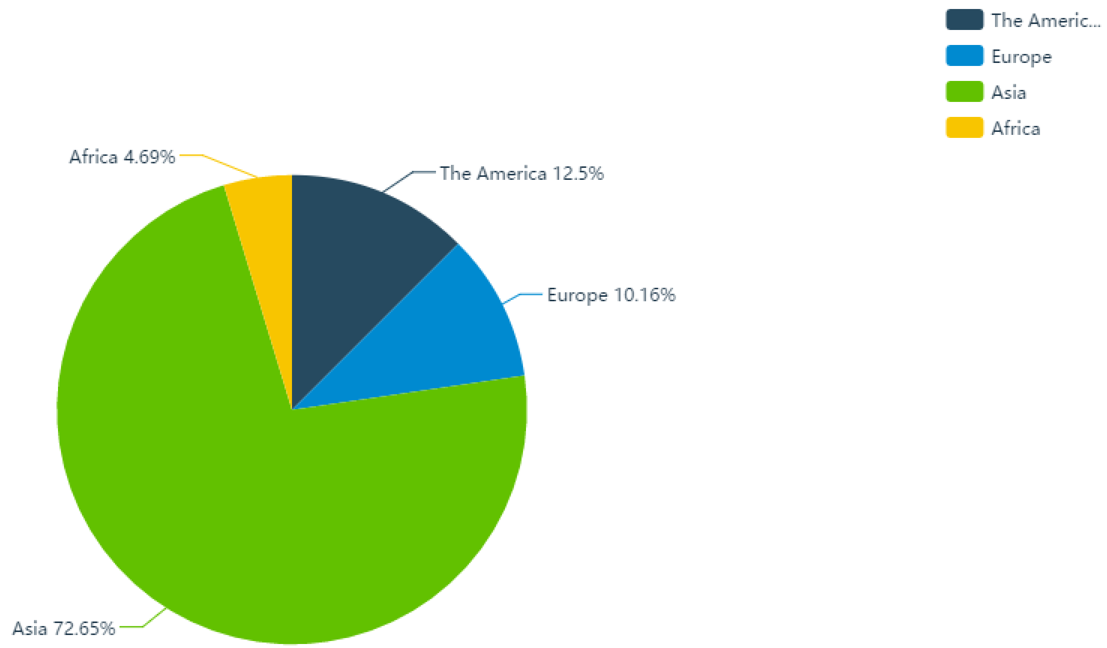


Figure 4.11: Dairy fraud incidents' country of origin by continents

Figure 4.12 depicts the overall increase in the number of fraud incidents related to Dairy products in an eighteen-year period from 2000 to 2018. The number of fraud incidents has been increased from about 2 incidents in 2004 to 19 incidents in 2018. At the beginning of this period, the number of incidents remained stable (with slight fluctuations) until the year 2008 but was then followed by a rapid increase from 2008 to 2012. Then the number of incidents started to fluctuate from 2012 to 2018 and reached the highest point of about 19 incidents in 2018.

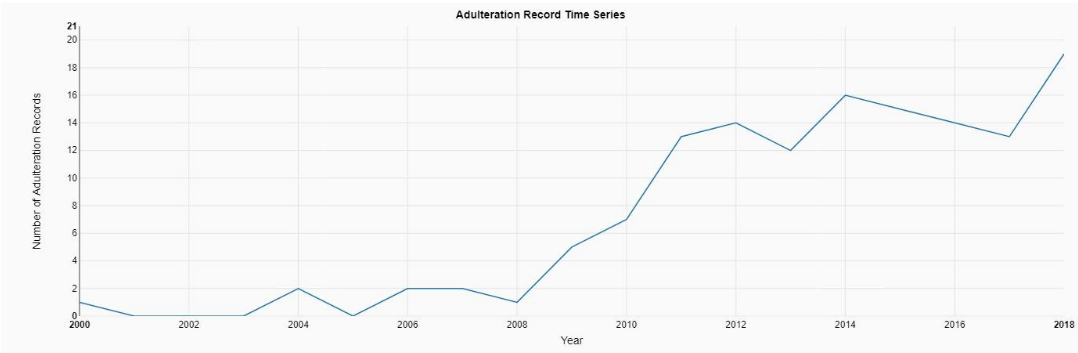


Figure 4.12: Dairy fraud time series

4.2.2 Criteria of Food Fraud (FF) Incident Types

As mentioned in chapter Two, this research characterised food fraud incident types according to the USP Food Fraud Database (FFD). These types were all categorised by USP FFD into 15 sub-categories listed in Table 4.3. Descriptive statistics for food fraud incident types as well as examples related to each incident type are shown in Table 4.3. The majority of food fraud incident types were included dilution/substitution with alternative ingredient (ODS) (23.8%), Dilution or substitution with an alternate substance (DSAS) (22.6%), Fraudulent labelling claims (FLC) (22.6%), Misrepresentation of animal origin (MAO) (16.6%), and Other (22.4%).

Table 4.3: Food Fraud Types (FFT) category and sub-category, code, frequencies, and examples (n= 580)

FFT Category	FFT sub-category	Code	Frequency		%	Example
			Yes	No		
	Fraudulent labelling claims	FLC	131	449	22.6	'The Canadian Food Inspection Agency has charged Creation Foods and its vice-president, Kefir Sadiklar, with sending cheddar cheese falsely described as 'kosher' to Jewish summer camps in June 2015 '(Incident ID: 279451)
	Dilution or substitution with an alternate substance (not food grade)	DSAS	131	449	22.6	'The authority disposed of milk over contamination with harmful chemicals, powder, urea and polluted water'
	Other/Dilution or substitution with an alternate ingredient	ODS	100	480	17.2	'In a popular barbecue restaurant in Changsha, central China's Hunan province, diners tuck into a self-service buffet of beef, mutton and veggies, but none of them know the beef they are eating is actually duck meat' (Incident ID: 116586)

Replacement	Misrepresentation of animal origin	MAO	96	484	16.6	'An Iceland company sold ling fish (also known as catfish) as Atlantic wolfish in 2011 and 2012 to foreign market '(incident ID: 1871079)
	Use of non-declared, unapproved or banned biocides (preservatives, antibiotics, anti-fungal agents, etc.)	UNB	47	533	8.1	'Police in China's southern province of Guangdong have seized $12.3 million of potentially hazardous frozen meat including some reportedly soaked in bleach'(Incident ID: 65650)
	Misrepresentation of geographic origin	MGO	29	551	5	'A Texas shrimping company pleaded guilty Thursday to relabelling 35,000 pounds of hard-to-sell Mexican shrimp as wild-caught American crustaceans' (Incident ID: 24799)
	Misrepresentation of varietal origin	MVO	16	564	2.8	'Italy's treasury department and the Italian agriculture ministry are investigating quantities of current-release wine that may have been made using blending wines of inferior quality not allowed by appellation regulations' (Incident ID: 13398)

	Formulation of an artificial product through the use of multiple adulterants and techniques	FAP	10	570	1.7	‘Dodgy drinks are being served as house spirits in bars and pubs and sold in independent liquor stores in the country's biggest markets, including Sydney, Melbourne and Brisbane’ (Incident ID: 1044355)
	Misrepresentation of nutritional content	MNC	3	577	0.5	‘The Ministry of Health (MOH) on Wednesday recalled a batch of baby formula, ‘Xiang Xue Hai’ with batch number 20050112, found to be of hazardously low nutritional value. Stores have been ordered to stop sales of the product immediately’ (Incident ID: 74149)
Addition	Artificial enhancement of apparent protein content	AEP	19	561	3.3	‘High levels of melamine found in two baby formula products recalled this week might be from animal feed, the KwaZulu-Natal health department said on Wednesday’ (Incident ID: 24574)
	Artificial enhancement of perceived quality with colour additives	AEC	11	569	1.9	‘The fake beef was found to be actually made from pork, which had been treated with chemicals such as paraffin wax and industrial salts to make it look like beef’ (Incident ID: 17392)

	Artificial enhancement of organoleptic qualities	AEO	9	571	1.6	‘In an ongoing debate over accepted winemaking practices in France, the Bordeaux court of appeals has fined four châteaus and a cooperage house more than $13,000 each for adulterating wines by adding wood chips for flavor’ (Incident ID: 1024237)
Removal	Removal of authentic constituents	RMVL	0	0	0	N/A
	Other	Other	130	450	22.4	N/A
	Unknown	Unknown	6	574	1	N/A

4.2.3 Criteria of Weight of Evidence

The weight of evidence related to each food fraud incident reported in the USP FFD was evaluated based on ‘scientific or legal documentation’ (USP FFD 2018). For example, a highly documented incident like melamine adulteration of milk in China was assigned as High weight of evidence by the USP FFD. Medium or Low weight of evidence was associated with ‘incidents with only media sources as references, unsupported by associated regulatory or other documentation’ (USP 2018). Figure 4.13 shows that 16.72% of the incidents were categorised into High weight of evidence, 50% into Medium weight of evidence, and 33.28% into Low weight of evidence.

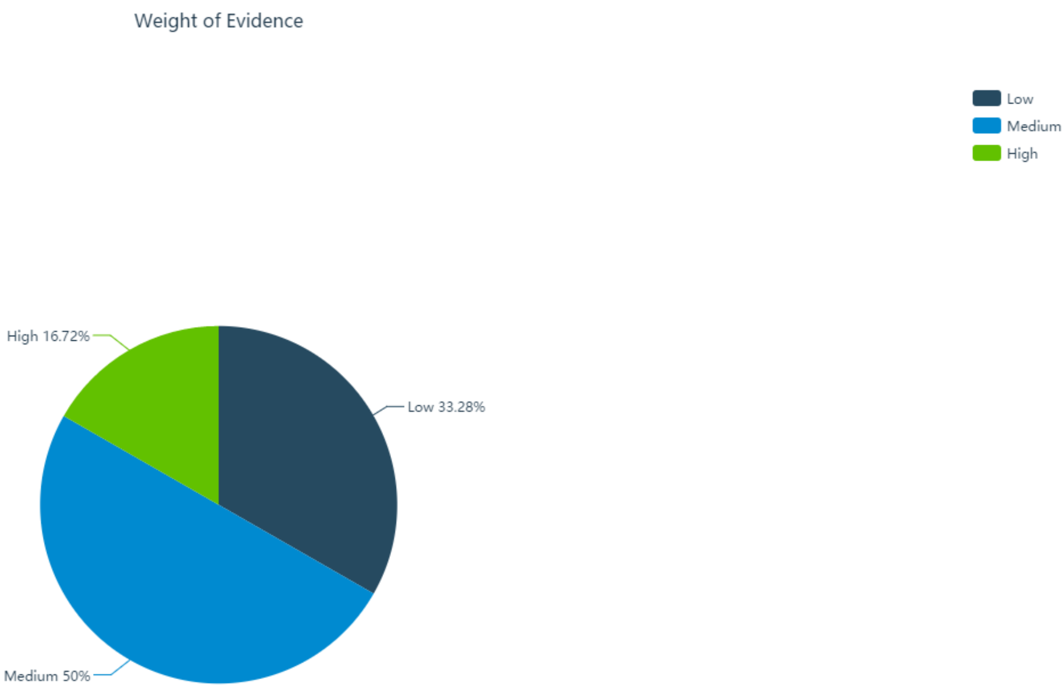


Figure 4.13: Weight of Evidence

4.2.4 Criteria of Type of Adulterants

Adulterants were those substances used to adulterate the food products. Adulterants related to these 580 cases of food fraud were related to the main 5 categories of additives, chemicals, counterfeit, species, and expired. Additives were those substances that were added to enhance the quality and/or weight of products. Examples were colour, water and oil. Chemical adulterants were those substances that were used to make the product look fresh and nutritious (i.e. formaldehyde, melamine, methanol, etc.). Counterfeit types were related to those products that were either fraudulently claimed as 'products from defined provenance or production system' (Van Ruth, Huisman & Luning 2017, p. 72) (i.e. organic) or their geographic origin were mislabelled. Adulterated species were related to products whose species were different from those they were supposed to be (i.e. Turkey meat as Ham). Finally, expired types were related to those products that were expired but were still in the human food chain. Table 4.4 shows the descriptive statistics for different types of adulterants.

Table 4.4: Frequencies of types of adulterants

	Frequency		
Types of Adulterants	Yes	No	Percent
Additives	77	503	13.3
Chemicals	193	387	33.3
Expired	56	524	9.7
Species	115	465	19.8
Counterfeit	187	393	32.2

The above sections showed the descriptive statistics for the main influencing variables of FFV factors. The following section will present the result of Barrier Analysis techniques to identify the most common FFV factors.

4.3 Barrier Analysis Results (Sub-question 1)

Chapter Two highlighted study by Van Ruth, Huisman and Luning (2017) that provides an overview of the most common and relevant factors that affect vulnerability to food fraud which was based on the Routine Activity Theory and within three classifications of opportunity, motivation, and countermeasure. These three categories and their sub-categories were described in detail in chapter Two. Chapter Two also described a lack of further studies analysing these factors based on real data to assess FFV factors. Therefore, in order to assess FFV factors, Sub-question 1 aimed to identify factors impacting vulnerability to food fraud. The first task the present research had to accomplish was to undertake the Barrier Analysis technique to identify FFV factors.

Sub-question 1: What are the factors that influence the vulnerability to food fraud for human food products?

Here, each incident reported in the USP FFD was carefully reviewed in order to find reasons why barriers or authorities (i.e. FDA, USDA, Federal Agencies, Trading standards, etc.) failed to detect food fraud events. The reasons/barriers were indexed into 13 dimensions (see Table 4.5). The data source related to each incident was based on more than 600 media reports documented in the USP FFD. All these factors were further grouped into the main Food Fraud Vulnerability factors (opportunity, motivation, countermeasures) according to the Routine Activity Theory and previous research (e.g. Van Ruth, Huisman & Luning 2017) (see Appendix A in the Appendices).

Table 4.5: Description of FFV factors

Food Fraud Vulnerability Factor (FFV)	FFV - Subcategory	Description
Opportunity	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	• Determining the identity of product species (e.g. cod from sutchi catfish) in restaurants, butcheries, etc., confirming the presence of chemicals like methanol or isopropanol in alcohol beverages. The advanced technologies can be an autopsy, DNA analysis, etc.
	The physical form of products: (1) Ease of alteration (SSAFE 2016) The physical form of products: (2) Nature of the product (BRC 2015)	• 'Composition of the raw materials can be modified by mixing with low-quality or foreign material (e.g. powders, ground meat, etc.) and by altering valuable food components (e.g. protein content)' • 'prepared ingredients such as beef mince or ground spices are likely to have a greater risk than the whole raw material '(BRC 2015)
	Availability of knowledge and technology to adulterate food products (SSAFE 2016)	• 'Simple/basic technologies and methods are available, and no specialist facilities are required, to adulterate the raw materials. The knowledge required for adulteration is generally available'
	Supply chain complexity/ Transparency supply chain (SSAFE 2016; Van Ruth, Huisman & Luning 2017	• The legitimate product, with the original packaging and labelling, are either stolen or bought (or even have been taken from garbage bin) and will be adulterated in the offender's house or facilities.
		• 'Fraud opportunities increase when potential fraudsters have legitimate access to the location in which the fraud can be committed, i.e. access

	Opportunity in Time and space (Van Ruth, Huisman & Luning 2017)	to the product, processing lines, etc.' (Van Ruth, Huisman & Luning 2017, p. 71).
Motivation	Corruption level of the country (Van Ruth, Huisman & Luning 2017)	• High levels of corruption in a country increase the risk of fraud (SSAFE 2016). Examples are bribery of authorities, and corrupted inspections.
	The economic health of the business (country), financial strains (Van Ruth, Huisman & Luning 2017), Culture, the price spike	• The economic condition of the country can motivate offenders to commit fraud (e.g. turning to homemade alcoholic beverages due to the nation's currency plummets against the dollar)
	Supply and Pricing	• Economic pressures on raw materials can motivate offenders to commit fraud or • 'When gaps exist between physical product availability and market demand (Manning & Soon, 2014) and prices shift due to regional or global supply shortages (Moyer, DeVries & Spink 2017) fraud vulnerability will also increase' (Van Ruth, Huisman & Luning 2017, p. 71-72)
	Requires coordination between law enforcement agencies (Reilly 2018)	• Detection and combating food fraud incidents require food control authorities and law enforcement agencies cooperate together. Examples of these cases are: (1) when combating fraud within international level (in all Europe for example), or (2) in case of tax evasion scheme that needs multi-agencies to coordinate, and/or (3) when there is a need in border regions to stop adulterated food reaching to customers.

Countermeasures	Extensiveness of Traceability	• 'traceability programmes relying on paper certificates and documents that can be easily falsified' (Reilly 2018, p. 13) • Track and tracing system used in companies are reactive countermeasures instead of being proactive countermeasures (Ting & Tang 2014), or traceability technologies can be easily imitated (Ting & Tang 2014) • lack of an effective traceability system to track and trace sources (SSAFE 2016), track and trace the source of suppliers (SSFE 2016) • Lack of packaging and labelling in commodity products.
	Lack of law enforcement	• No punishment although a violation of laws are apparent (Everstine, Spink & Kennedy 2013) • Limited law enforcement by authorities (Hoecht & Trott 2014)
	Food safety (Reilly 2018, SSAFE 2016)	• Detectability is based on food safety sampling and food quality not Food Fraud Vulnerability assessment (SSAFE 2016) • lack of definition of food fraud (Reilly 2018)
	Whistleblowing system (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	• Lack of a well-designed whistleblowing system (e.g. former employees that were sacked from companies are reporting fraudulent activities)

The results from the Barrier Analysis technique revealed that Opportunity factors account for 32.7 % of all incidents, Motivation factors account for 6.7 % of all incidents, and Countermeasure factors account for 46 % of all incidents. The Unknown FFV factor category was related to incidents where there was no information provided (either unavailable or in other languages). Figure 4.14 shows the frequency of FFV factors by food product types as indicated in 580 incidents. The result from the Barrier Analysis technique revealed that the majority of incidents in Dairy products were related to Opportunity factors, while in seafood, meat, and alcoholic beverages countermeasure factors were dominant.

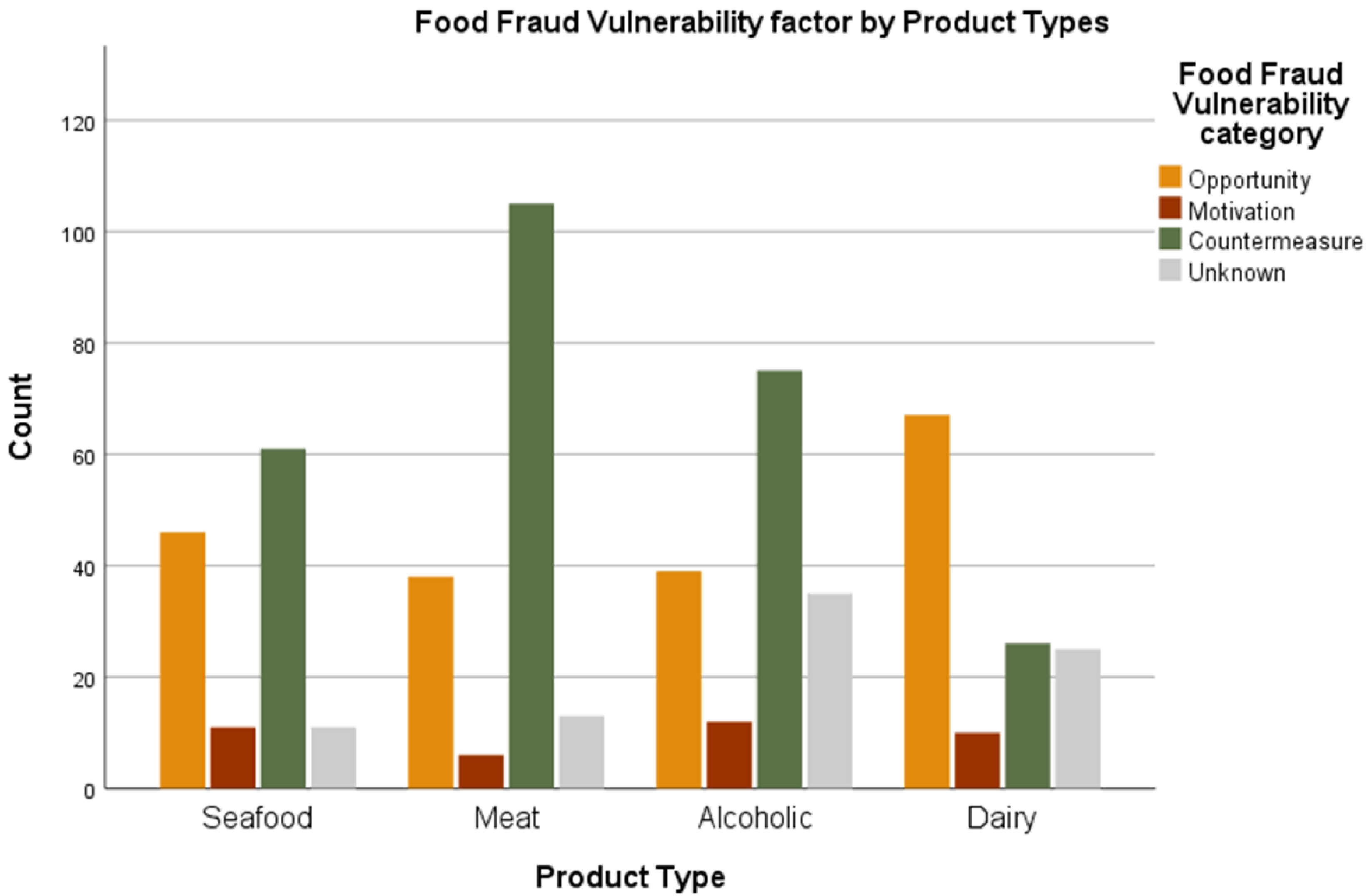


Figure 4.14: Frequency of FFV factors by food product types

From 580 cases of food fraud recorded in the USP FFD, 338 cases/incidents were originated from 5 countries of USA, China, UK, India, and Italy. Incidents originated from these countries cover more than 50% of all incidents recorded in the USP FFD. Table 4.6 shows the number of incidents in each country of origin based on different product types and categories of FFV factors (opportunity, motivation, and countermeasures). In the opportunity category of FFV, US, UK, and India have the dominant number of incidents orderly in seafood, meat and alcoholic beverages, and dairy food product types. In the motivation category of FFV, UK and India have the dominant number of incidents orderly in seafood and alcoholic beverages food product types. In the countermeasure category of FFV, China has the dominant number of incidents in all four food product types of seafood, meat, alcoholic beverages and dairy. Next sections will describe each of these FFV factors starting with the Opportunity category.

Table 4.6: Frequency of incidents based on country of origin and FFV factors.

FFV Factors	Product type	China	India	Italy	UK	US	Total
Opportunity	Seafood	1	3	0	10	23	37
	Meat	8	0	0	13	1	22
	Alcoholic Beverages	3	2	2	13	1	21
	Dairy	9	39	2	2	6	58
	Total	21	44	4	38	31	138
Motivation	Seafood	3	0	0	4	0	7
	Meat	0	0	0	1	1	2
	Alcoholic Beverages	0	7	0	0	1	8
	Dairy	0	8	0	0	0	8
	Total	3	15	0	5	2	25
Countermeasure	Seafood	11	1	1	2	10	25
	Meat	25	2	1	15	13	56
	Alcoholic Beverages	18	4	9	4	4	39
	Dairy	7	7	1	0	2	17
	Total	61	14	12	21	29	137

4.3.1 Opportunity (probability: 33%)

4.3.1.1 Detection of Adulterants Requires Advanced Laboratory Analysis

The need for advanced technologies to detect food fraud was identified as a potential Opportunity factor that increases vulnerability to food fraud. This is because ‘Fraud detection is impeded when analysis of raw materials requires advanced laboratory methods and facilities or if methods are lacking, which in turn provide opportunities for potential offenders to commit fraud’ (SSAFE 2016). This factor was identified in all four types of food product (seafood, meat, alcoholic beverages, and dairy).

In the seafood products, advanced technologies were needed to confirm or disconfirm the authenticity of the *seafood species* and presence of *preservatives* (e.g. formalin, ammonia, etc.). The challenge for authorities or even consumers was to identify seafood species mainly because ‘fish can be difficult to identify especially in fillet or other processed forms’ (Upton 2015, p. 8). Therefore, the mislabelled/substituted species were detected only when advanced laboratory analysis was available to confirm the adulteration and/or substitution.

‘…… DNA tests on several Casey's Seafood products purchased in Virginia, North Carolina and Delaware contained mixtures of Atlantic blue crab and some cheaper alternatives native to foreign waters’ (Incident ID:28451)

‘…. the Consumer and Environmental Protection Unit of the Office of the City Attorney purchased advertised ‘lobster rolls’ from various sushi restaurants throughout San Diego, then sent them to a laboratory where DNA testing confirmed that no lobster was in fact in any of the rolls’ (Incident ID: 52904)

‘…...sold him what he claimed was Russian sevruga caviar, but DNA testing proved it was not; the vast majority of the eggs came from American paddlefish, a protected species indigenous to the United States’ (Incident ID:36416)

As mentioned in the above examples, DNA analysis was the most common methods for the detection of species’ adulteration/substitution. Another application of advanced technologies in seafood fraud detection was to identify *preservatives*. Preservatives like formalin or ammonia are added to extend the shelf life of fish products or make them look fresh. Since these preservatives had no smell or colour, detecting the contaminated fish with formalin was difficult and often was undetected.

'……in absence of a proven testing methodology to detect the presence of formalin or ammonia several such cases went undetected' (Incident ID:1135452)

'……The squad confirmed the presence of the preservative using a testing strip developed by the Central Institute of Fisheries Technology (CIFT)' (Incident ID:1476705)

In meat and poultry product types, advanced technologies were needed to identify meat species, determine the authenticity of processed meat products, and test for dye or preservatives. Most incidents in this category were detected in the restaurant or takeaways where customers could not see the package or origin of the dishes. Similar to seafood products, the substituted meat and poultry species were detected only when advanced laboratory analysis was available to confirm the adulteration and/or substitution.

'…. Food tests discovered turkey DNA in dishes that were supposed to be lamb'

'…. tested 60 lamb takeaways from a selection of Birmingham and London restaurants and revealed that 40% of the meals were contaminated with other meats' (Incident ID:158917)

'……An investigator at the agency, Pontus Elvingson, told the BBC that tests were still being done to identify the dye.' (Incident ID:16467)

'…...The minced beef was found to contain DNA of pork, chicken, and lamb not listed on the label. The minced pork detected the DNA of beef, chicken, lamb, and a beef and lamb semi-kebab also found pork traces' (Incident ID:22166)

In alcoholic beverages, advanced technologies were mostly needed to detect excessive methanol in drinks. Excessive methanol in alcoholic beverages could lead to severe sicknesses, blindness or even death. Unlike other types of food products, excessive methanol in alcoholic beverages was detected only when consumers became sick (or died). Other applications of highly advanced technologies were to detect chemical additives (e.g.

isopropanol) or testing the level of purity of alcoholic drinks (for example measuring how much water was added to dilute alcoholic drinks).

'…. Laboratory tests found the deaths were caused by the high methanol level in the wine,' Ly Sovann, a spokesman for the health ministry, told AFP' (Incident ID:190178)

'…. Tests revealed they contained methanol, which is similar to but far more potent than ethanol, the alcohol commonly found in liquor' (Incident ID: 597655)

' …. Laboratory analyses detected deficiencies in following two cases: Hraběnka, dry white wine, lot No. 176, country of origin: Hungary and Hraběnka, dry red wine, lot No. 155, country of origin: Hungary. Presence of added water amounting to 66% was detected in white wine' (Incident ID:38085)

In Dairy products, advanced technologies were mostly needed to determine chemical adulterants. The adulterants in dairy products included unhealthy ingredients that were not for human consumption like formalin and urea, bacteria (food safety), gum, high alkalinity due to the presence of bacteria, melamine, detergent, ammonia, and listeria. Other applications of advanced technologies were to test the level of purity of milk products (confirm/disconfirm if they were diluted with water or not) or detect milk origin (e.g. from a dairy cow).

'….. PFA officials examined 40 containers of milk in Faisalabad today. They found it to be adulterated with formalin - a chemical used chiefly as a preservative for biological specimens - as well as urea, salt and water' (Incident ID:132152)

'…… The State Public Health Laboratory has found the presence of gum in this delicacy which is an act of adulteration as per the provisions of the Prevention of Food Adulteration (PFA) Act' (Incident ID: 29064)

'……. In 10 of the samples, high alkalinity was found, indicating the presence of chemical agents used to mask the addition of water and the deterioration of the product through the action of bacteria' (Incident ID: 23203)

4.3.1.2 The Physical Form of Product

The physical form of the product was identified as a potential Opportunity factor that increased vulnerability to food fraud. Fraud detection could be challenging for authorities based on how easy the alteration/adulteration of the food product or physical form of products was. 'Easy alteration of the composition of the raw materials provided opportunities for potential offenders to commit fraud' (SSAFE 2016). This could happen when the product was mixed (or minced) or processed (Donkey meat mixed with spices and sold as cow meat). This factor was detected mostly in the seafood and meat and poultry products.

'….. the production cost of the artificial jellyfish was less than half the cost of processing real jellyfish. In addition, less time is required to produce artificial jellyfish than is needed to process real ones'(Incident ID: 56929)

'……. The defendants had allegedly mixed their meat with spices to cover up the bad odour of the meat and sold it for 20 Egyptian pounds [about Dh13.6] per kg.... the vets says its kinda hard to know the different between the donkey's meat and the cow's meat' (Incident ID:118699)

'…. The duck meat is ground into small pieces and mixed with a special red-color sauce, which makes it looks and tastes like real beef' (Incident ID:116586)

4.3.1.3 Availability of Knowledge and Technology to Adulterate Food Products

The availability of knowledge and technology to adulterate food products was identified as a potential Opportunity factor that increases vulnerability to food fraud. Availability of 'technology, methods and knowledge to adulterate/modify a certain type of raw materials provided opportunities for potential offenders to commit fraud' (SSAFE 2016). This factor detected mostly in dairy products when either the adulterants were easily available with a low cost or simple methods with no specialist were required to adulterate the product.

'……used to buy empty packets of branded milk companies……They would then fill in adulterated milk in these packets and sell them (Incident ID:22960)

'……Further elaborating on the modus operandi, cops informed that the accused had devised two methods to adulterate milk packets. In the first method, they would tear open branded milk packets, and mix dirty water in them before sealing them with a stapling machine' (Incident ID:16052)

4.3.1.4 Supply Chain Complexity/ Transparency Supply Chain

The supply chain complexity and/or supply chain transparency was identified as a potential Opportunity factor that increases vulnerability to food fraud. 'A complex supply chain that lacks transparency, with short-term/ad-hoc relationships, and no/limited information exchange provided opportunities for fraud' (SSAFE 2016). This factor was the root cause of the incidents when a legitimate product with its' original packaging and labelling was either stolen or bought (or even fraudsters grabbed them from garbage bin) and was adulterated in the offender's house/ facilities and/or during processing the food. Examples of this factor occurred mostly in meat and poultry, alcoholic beverages and dairy products.

A famous example related to meat products was the horsemeat scandal in the UK where processed beef (e.g. burgers) were mixed with horsemeat in the supply chain to mask the adulteration. In this example, processing the beef in different supply chains (Slaughtered in Romania where selling horsemeat was legal) had led to the incident. While the beef products had its' original label, it was confirmed that horsemeat was found in many of these products.

'…. As horse meat was found in everything from frozen burgers to packaged lasagna, recalls of 50,000 tons of meat products were soon underway throughout Europe' (Incident ID: 27425)

An example in Alcoholic beverages was when the diluted product with its adulterants was detected during a supply chain inspection (e.g. van or other private vehicles as a means of transporting alcoholic beverages).

'……. Recently when a mini-auto coming to Visakhapatnam from Odisha was intercepted, liquor bottles were found along with those containing water and spirit. '…...Inquiries by the police revealed that the traders are resorting to two types of adulteration—mixing either spirit or water after removing 25 per cent original liquor and replacing the brand labels' (Incident ID: 54276)

In Dairy products, incidents that categorised into this factor (supply chain complexity) were related to the detection of fraudsters during a midnight raid into unregistered houses. The fraudsters were using these houses to complete their fraudulent activities.

'……The Special Operations Team (east) of Cyberabad police on Wednesday busted a milk adulteration racket after raiding a house at Ghatkesar'….'The accused Barkha Ravi and Md Rasheed prepare a paste by mixing urea, milk powder and sunflower oil

by putting the material in a mixer, Inspector SOT, Narsing Rao sad' (Incident ID:15234)

'…., an FDA team led by Food Safety Officers Manek Jadhav and Gopal Mahore carried out simultaneous raids at two residential apartments in Nutan Complex and Shanti Nagar area of Mira Road at about 6 a.m. on Friday' (Incident ID: 15234)

4.3.1.5 Opportunity in Time and Space

The opportunity in time and space was identified as a potential Opportunity factor that increases vulnerability to food fraud. Vulnerability to food fraud increased 'when potential fraudsters have legitimate access to the location in which the fraud can be committed, i.e. access to the product, processing lines, etc.' (Van Ruth, Huisman & Luning 2017, p. 71). Fraud detection, in this case, was difficult and the fraudulent product was detected only through surprise visits. This is because fraudsters can dilute/substitute the product through legitimate facilities.

'…. raided a factory near Moonak and arrested nine people, who were making synthetic milk in the factory by mixing chemicals' (Incident ID: 15229)

'…. Food inspectors seal facilities used to produce fake donkey meat during a raid in Hejian in China's northern Hebei province on January 9, 2018' (Incident ID: 1386401)

Summary. Vulnerability to food fraud related to Opportunity factor was further indexed into 5 sub-categories of (1) detection of adulterants requires advanced laboratory analysis, (2) physical form of product, (3) availability of knowledge and technology to adulterate food products, (4) supply chain complexity/ Transparency supply chain, and (5) opportunity in Time and Space. The incidents with the Opportunity factor may occur due to one or more of the above five sub-category factors.

Figure 4.15 shows Opportunity factor related to four product types in 5 country of origin of China, India, UK, USA, and Italy due to the fact that they cover more than 50% of incidents of food fraud. As Figure 4.15 illustrates, in Seafood products, opportunity factor was dominant in USA. In meat and alcoholic beverages, the opportunity factor was dominant in the UK. In Dairy products, the opportunity factor was almost dominant in India.

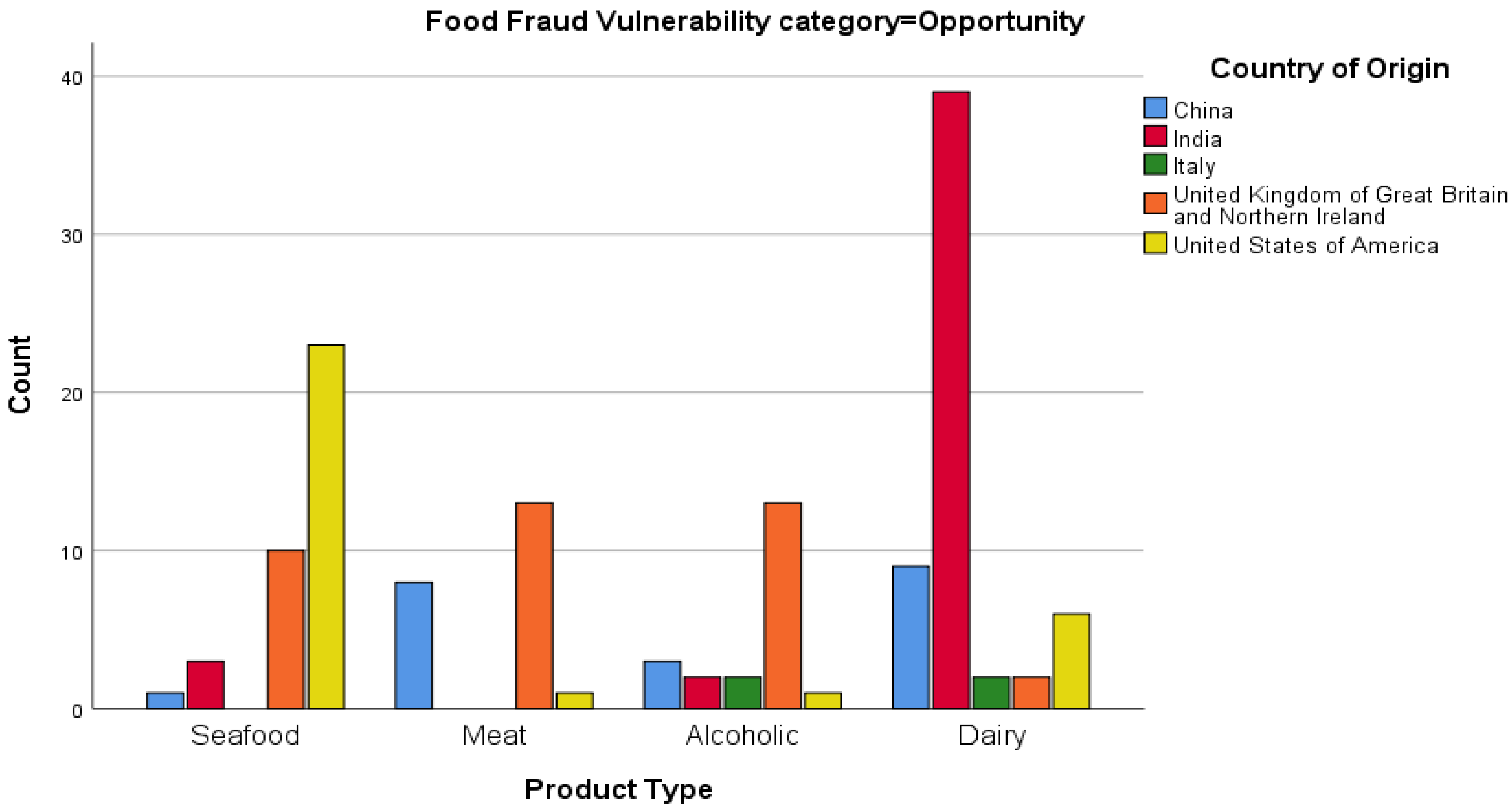


Figure 4.15: Frequency of Opportunity category of FFV in four product types

4.3.2 Motivation (probability: 6.7%)

4.3.2.1 Corruption Level of the Country

The corruption level of the country was identified as a potential Motivation factor that increases vulnerability to food fraud. Fraud detection could be impeded when the country had a higher level of illegal or immoral activities for economic gain. An example related to this factor was when fraudsters bribed police and authorities to bypass quality control inspection. Incidents in this category were mostly detected in Seafood, Meat and Alcoholic beverages.

'…. The fish were then routed by corrupt agricultural inspectors to avoid the usual controls, the statement said ' (Incident ID: 289925)

'…. Producers obtained the pigs by bribing government livestock insurance agents, several of whom were also sent for prosecution, it said' (Incident ID: 13361)

'……. A shop owner who sold the homemade spirit for about 20 pence per 200ml has been arrested and an investigation has been launched into police officers who allegedly took bribes to turn a blind eye to concerns about the drink' (Incident ID: 25575)

4.3.2.2 Economic Drivers

The economic drivers were identified as a potential Motivation factor that increased vulnerability to food fraud. It is important to differentiate economic drivers with those mentioned as economic profit or economic gain for food fraud. All food fraud incidents were related to profit gain. This factor was related to those incidents associated with the economic health of businesses (or countries), financial strains, and price spikes. The economic driver factors were the root causes of all four types of food products' fraud.

Financial strains were identified in incidents where there were instances of companies or businesses facing high turnover.

'......These matters arose from a turbulent time for the Foyles of Glasbury business in the summer of 2016 with a high turnover of staff at that time' (Incident ID: 588891)

The economic health of businesses was identified as a factor in times of global crisis or when the level of competition was high between companies (or companies' branches). In a competitive environment, companies may try illegal or immoral activities to cut their cost and increase their profit.

'…. The fraud was detected during an internal investigation by the hotel chain, prompted by another chain, Prince Hotels, admitting that its expensive 'domestically produced beef'…… 'luxury establishments mislabelling ingredients appears to have started at the time of the global economic crisis in 2008, probably driven by a desire to reduce costs while still keeping prices high' (Incident ID: 95420)

The economic condition of countries was identified as a potential FFV factor in developing countries. This factor was mainly contributed to alcoholic drinks when poor people cannot afford to buy licenced drinks (liquor). Therefore, they started drinking homemade or illicit alcoholic beverages which may have a high level of methanol or other toxic chemical causing severe sicknesses or death.

'……Deaths from drinking illegally brewed alcohol are common in India because the poor cannot afford licensed liquor. Illicit liquor is often spiked with chemicals such as pesticides to increase potency' (Incident ID: 136101)

The price spike was also identified as a motivation factor in Alcoholic Beverages. An example of this factor was when product price went up due to the rise in duties and/or decline of the country currency (where fraud was detected) against the dollar.

'…. liquor makers blame high duties for rise in bootleg booze…' (Incident ID: 1629449)

'…. IRNA says that as the nation's currency plummets against the dollar, and the price of liquor rises, consumers increasingly turn to home-made alcohol' (Incident ID: 1629395)

4.3.2.3 Culture and Belief

The culture was identified as a potential Motivation factor that increases vulnerability to food fraud. Vulnerability to food fraud associated with motivation increased when there was a religious belief against consuming specific products. This factor was detected only in alcoholic drinks where some countries' religious cultures prohibited consuming alcoholic beverages (e.g. Iran, Pakistan, etc.). So, as there was no licenced liquor available in the market, people usually bought them from the homemade or illicit market.

'……many people illegally brew alcohol at home, and there have been several cases of mass poisonings in the past - in 2014 some 40 people died within a few days as a result of drinking tainted alcohol in Sindh' (Incident ID: 132275)

4.3.2.4 Supply and Pricing

The supply and pricing factor was identified as a potential Motivation factor that increases vulnerability to food fraud. Vulnerability to food fraud associated with this factor increased when product demand exceeded its supply because of special occasions (e.g. Diwali), ban, and/or season supply shortages. This had happened mostly in alcoholic beverages and dairy products (i.e. where the grape harvest for making wines had shortages or during special festivals to deliver dairy products).

'…. During Diwali, consumption of sweets, milk and its products always increases making it the perfect occasion or the suppliers of adulterated 'khoya', 'ghee' and other milk products to get active. To check this, state officials have conducted random raids and checks at as many as 40 and odd places in the city within a week' (Incident ID:14231)

'…. asked to provide evidence by video because the timing of the trial conflicts with the grape harvest'(Incident ID:13347)

'…. The action was taken on a priority basis as the supply of milk and milk products reach its zenith during the festive season, especially during Diwali. 'Adulterated milk and its products are dangerous as it directly affects the health of its consumer' (Incident ID: 14384)

Summary. Vulnerability to food fraud related to Motivation factor was further indexed into 4 sub-categories of (1) corruption level of the country, (2) economic drivers, (3) culture and Belief, and (4) supply and Pricing. The incidents with the Motivation root cause may occur due to one or more of the above four sub-category factors.

Figure 4.16 shows Motivation factor related to four product types in 5 country of origin of China, India, UK, USA, and Italy due to the fact that they cover more than 50% of incidents of food fraud. As Figure 4.16 illustrates, in Seafood products, motivation factor was dominant in the UK and China. In meat and poultry products, the motivation factor was dominant in the UK and USA equally. In alcoholic beverages and dairy products, the motivation factor was almost dominant in India.

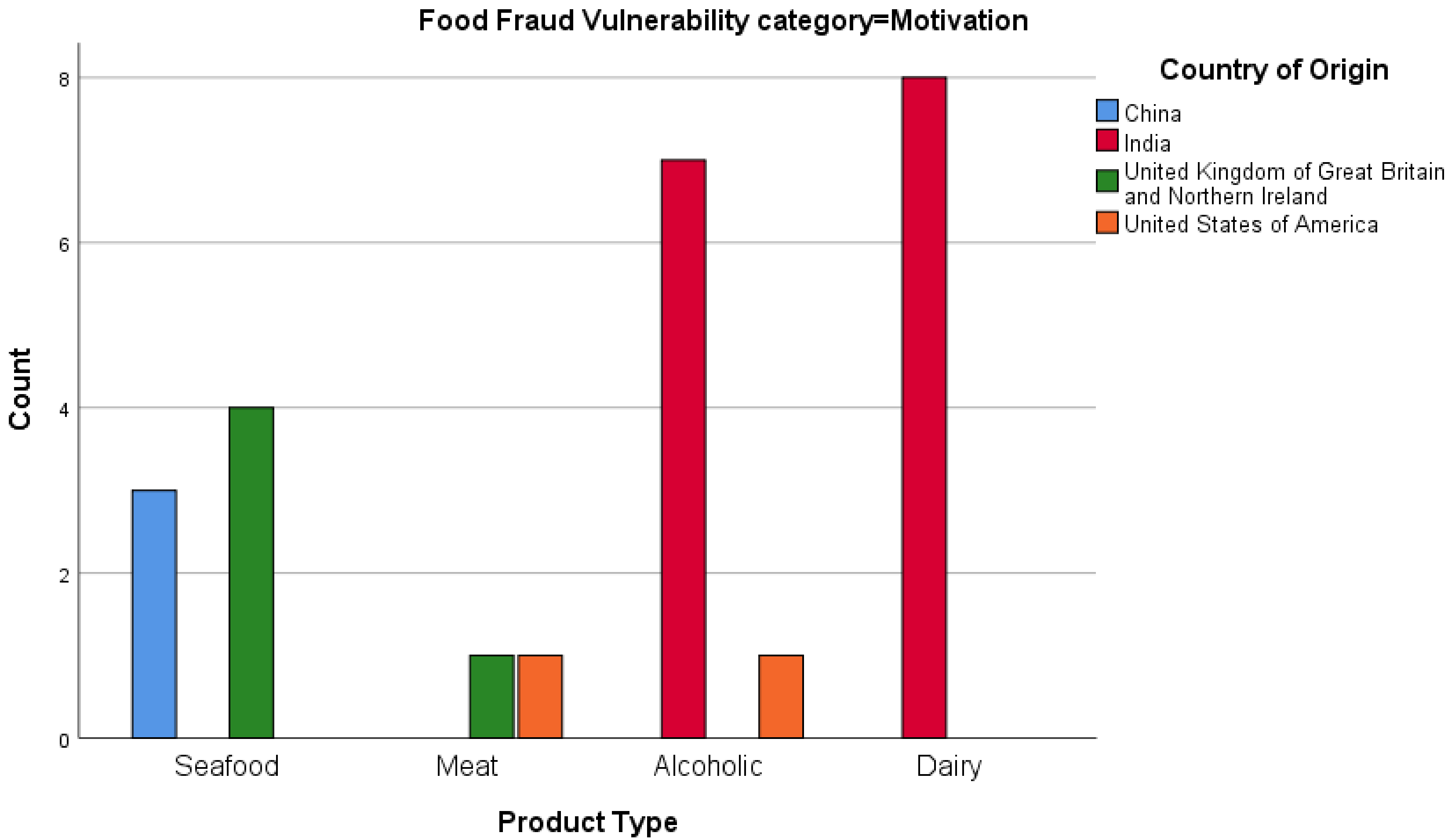


Figure 4.16: Frequency of Motivation category of FFV in four product types

4.3.3 Countermeasure (Probability: 46%)

4.3.3.1 Requires Coordination Between Law Enforcement Agencies

The need for coordination between law enforcement agencies was identified as a potential countermeasure factor that increases vulnerability to food fraud. Vulnerability to food fraud associated with this factor increased when detection of food fraud incidents required food control authorities and law enforcement agencies to cooperate. Examples were fraud incidences occurring in Europe that needed coordination of all European countries in acting against adulteration and fraudsters.

'They worked in co-ordination with Belgium, France, Italy, Portugal, Romania, Switzerland and the UK, Europol said in a statement' (Incident ID: 390535)

'….The result of OPSON demonstrate what can be achieved to protect consumers worldwide when law enforcement agencies join their efforts and perform coordinated actions…. It is a threat which requires such cooperation…' (Incident ID: 1528051)

The need for coordination between law enforcement agencies was also detected in instances related to border rejection. International cooperation has helped the customs authority in the border region to detect fraudulent products and prevent them from entering the country.

'….As reported by The Namibian, the shipment was stopped as part of a larger International Customs Operation by The World Customs Organization. This nineteen Customs Organizations were targeting nineteens ports of entry as part of this Operation' (Incident ID: 561485)

'….More than 18,600 bottles of counterfeit vodka were destroyed Monday after customs officers seized the goods before they entered the northern city of Tianjin……. Bath said the case also marked a positive progress on international cooperation to fight piracy and China's ability to prevent counterfeit goods from entering its border' (Incident ID: 142488)

Furthermore, in serious and organised crime where fraudsters were carefully organised and were professional, joint efforts with multiple law enforcement agencies seemed to be crucial in identifying fraudsters' ring.

'….Taipei, April 28 (CNA) Police in Taiwan and China have joined forces to break a Chinese counterfeiting ring that allegedly produced and sold fake Taiwanese brands of kaoliang liquor in the southeastern Chinese city of Xiamen' (Incident ID: 95223)

4.3.3.2 Extensiveness of Traceability

The extensiveness of traceability was identified as a potential countermeasure factor that increased vulnerability to food fraud. This factor was related to those cases of food fraud when there was a lack of traceability labelling system in the supply chain. Fraud detection can be impeded when there was no traceability system is in place. In this case, fraudulent products and/or expired products were identified when authorities became suspicions about a product with no necessary traceability certificate papers and/or technologies.

'…. Initially, the Spanish civil guard (La Guardia Civil) seized 10 tons of tuna for not having the necessary traceability for commercialization' (Incident ID: 1528051)

'……discovered products including canned food, salmon and octopus that were up to three years past their expiry date'…some of which had no identification or traceability details'

'…..60 boxes of shrimp weighing a total of 648 kg, all of them with suspicious labels, reports said' (Incident ID: 868801)

Another instance of this sub-category of countermeasure factor was when companies were using reactive control measures like holograms that could be easily counterfeited by fraudsters. Counterfeiting safety certificate was among instances where authorities were challenged to identify the original one as there were no differences between them. In addition, these reactive measures provided challenges for authorities to track and trace the product to understand its (country of) origin. These fraudulent products were detected by chance (mistakes and misspelling in the packages), bad smell (in alcoholic drinks), private detectives tracking illegal transactions, track and tracing smugglers, and close inspection of packages.

'…. The actions of Sea-Pac Ltd in disguising the traceability of the fishery products by fraudulently changing labels and documentation,' said Aberdeen City Council commercial team manager Andrew Morrison, 'had the potential to detrimentally impact on food safety of consumers as effective traceability is an essential part of the food safety requirements' (Incident ID: 480706)

'…. Prosecutors claimed that Chen received help from Hsiang Ting Kang Co (祥鼎康), which is owned by Liang, to change the dates on the seafood products and sold them'

'…accompanied by a falsified quarantine certificate. 'It was night, and the duty person might not have noticed that it was a fake certificate' (Incident ID: 100303)

4.3.3.3 Lack of Law Enforcement

The lack of law enforcement was identified as a potential countermeasure factor that increases vulnerability to food fraud. This factor was related to those incidents when authorities did little or nothing to protect consumers or there were no fines for fraudsters although a violation of laws was apparent (due to lack of evidence or laws). For example, when there were incidents of food fraud, authorities did not act until the media reported it. Another example was when cases of food fraud in court or in the preliminary investigation were abandoned as it was said that there was no supportive evidence or law to punish the fraudsters.

'….What was new, however, was the crackdown by low-functioning teams from city authorities and Uganda National Bureau of Standards. These teams didn't act until media reports highlighted the breadth and depth of the illegal and potentially harmful practice……. But the quality controllers are doing little or nothing to protect consumers' (Incident ID: 681928)

'……But when contacted by China Daily, the publicity department of the city said they had not heard anything about it' (Incident ID: 17806)

'…. The show included footage of ICA employees putting labels with new expiration dates on packages of meat and reselling them in four different ICA stores.'…. Four separate preliminary investigations were launched, but three of the investigations were abandoned due to a lack of corroborating evidence ' (Incident ID: 36959)

'…..This is illegal, but we cannot punish them unless written records are found,' he said' (Incident ID: 13331)

4.3.3.4 Food Safety

Food safety was identified as a potential countermeasure factor that increased vulnerability to food fraud. This factor was related to those incidents associated with unintentional or intentional contaminations with preservatives or banned chemicals. Detection of fraud related to these incidences was based on food safety detection methods as there was no food fraud protection plan in place (e.g. undertaking Food Fraud Vulnerability Assessment instead of HACCP for food safety management systems). These incidences occurred due to discrepancies between laws of importing country and exporting country about using preservatives (e.g. formalin) in food products, or lack of definitions of food fraud in some countries' law and regulations.

'…….there is very little public health risk because there was such a low level of malachite green detected.'….'Stolt Sea farms won't be able to sell on Canadian markets the 310,000 chinook still swimming at the farm in question.'......'CFIA approval is needed even if Stolt wants to export all of the fish to countries that don't have a zero-tolerance policy for malachite green.' (Incident ID: 68588)

'…USDA inspections send another shipment of Asian fish packing'Hopefully, before any vote they'll have access to more than seafood import lobbyists. '.... They might start with an updated review of Oceana's 2014 seafood fraud studies, which found fish fraud on every continent except Antarctica' (Incident ID: 67436)

'….Nobody told us it was illegal,' chief executive Francois Agussol said' 13363

'….a NSW Food Authority inspection revealed discrepancies in the abattoir livestock and slaughter records at the abattoir, making it apparent that older animals had been processed and supplied to its customers as lamb' (*Incident ID: 19932)*

'…. No authority has yet confirmed whether gelatin is harmless to humans' (Incident ID: 17141)

4.3.3.5 Whistleblowing System

The whistle-blowing system was identified as a potential countermeasure factor that increases vulnerability to food fraud. The fraud incidents related to whistleblowing factor were detected only when current or former (sacked) employees reported the fraudulent activity to the relevant authorities. The fraudulent product could be undetected without such a reporting system.

'….one whistle-blower said: 'I looked at the ingredients and noticed it actually contains pork and beef.'I queried it with management, but they didn't care. Three months on and the menus still say beef lasagne, and waiters have not been told to warn customers' (*Incident ID: 127619)*

'…. The alleged misconduct, dating back to 2011, 2012, and 2013 Marlborough and Waipara sauvignon blanc and pinot noir vintages, was brought to light by a whistleblower, the Herald has learned.' (*Incident ID: 423125)*

'….According to police, a senior employee disgruntled about being sacked tipped them off about alleged frauds in six wine-producing areas which included the Gironde, where Bordeaux is produced' (Incident ID: 18183)

'…In August, the employee informed the capital's health authorities, who sealed 425 boxes of four tastes of ice cream and ordered the payment of a NT$1.2 million (US$39,550) fine'

Summary. Vulnerability to food fraud related to Countermeasure factors was further indexed into 5 sub-categories of (1) requires coordination between law enforcement agencies, (2) extensiveness of traceability, (3) lack of law enforcement, (4) food safety, and (5) whistleblowing system. The incidents with the Countermeasure factor may occur due to one or more of the above five sub-category factors.

Figure 4.17 shows countermeasure factor related to four product types in 5 country of origin of China, India, UK, USA, and Italy due to the fact that they cover more than 50% of incidents of food fraud. As Figure 4.17 illustrates, in Seafood products, countermeasure factor was dominant in USA and China. In meat and alcoholic beverages, the countermeasure factor was dominant in China. In dairy products, the countermeasure factor was almost dominant in India and China.

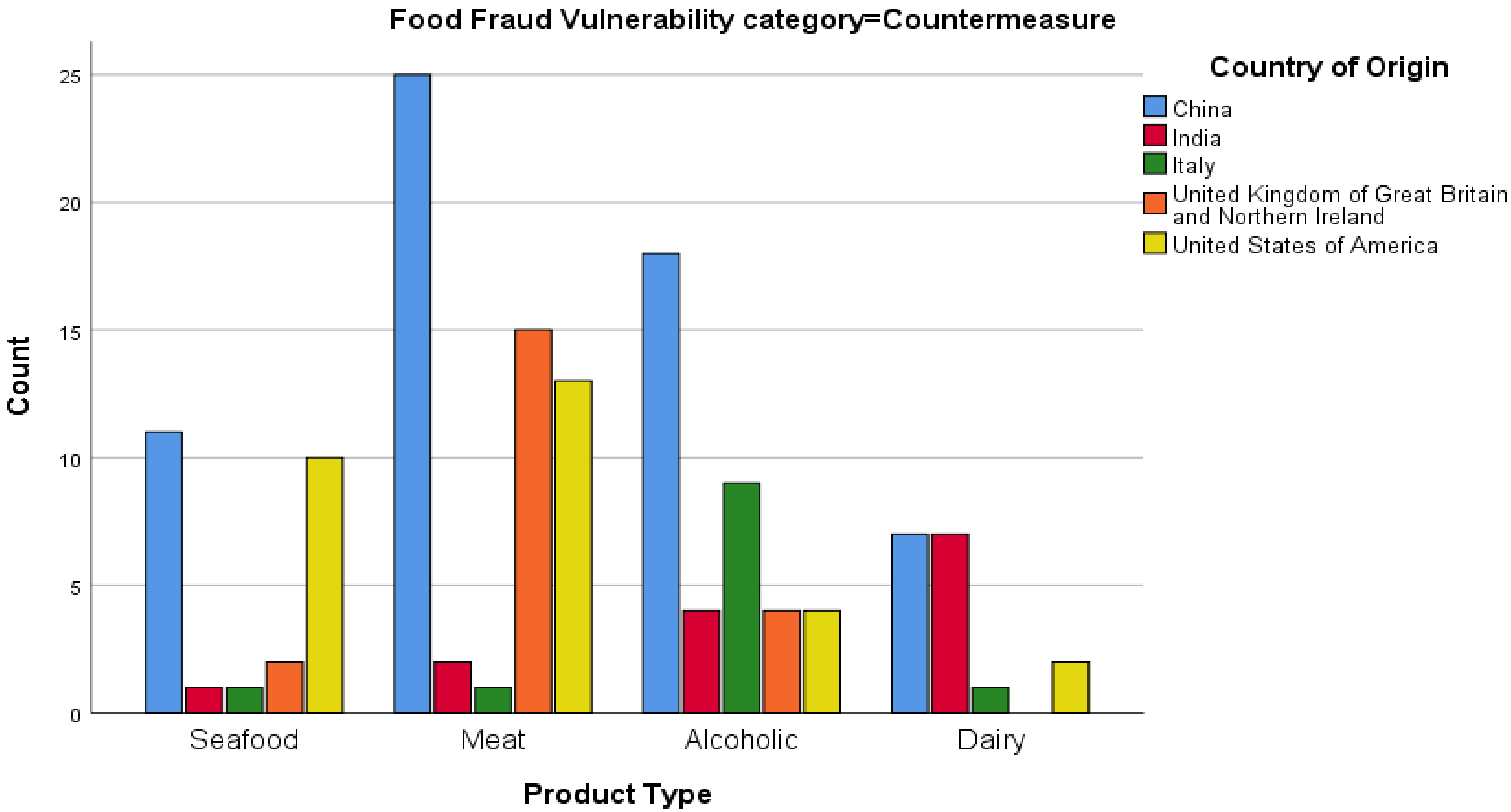


Figure 4.17: Frequency of Countermeasure category of FFV in four product types

4.4 Bayesian Network Modeling Approach

The previous section addressed Sub-question 1 and provided a comprehensive description of factors relevant to vulnerability to food fraud. This section utilised findings from Sub-question 1 for assessment of FFV. A holistic model based on Bayesian Analysis techniques is proposed using SPSS Modeler 18.2. The following research questions were addressed and discussed in this section:

Sub-question 2: How can the types of food fraud be used to assess Food Fraud Vulnerability factors?

Sub-question 3: Which of the variables, known to influence the vulnerability to food fraud, are most important?

Sub-question 2 investigated the impact of food fraud incident types (influencing variable) on FFV factors (Opportunity, Motivation, and Countermeasures). Sub-question 3 then explored all other known influencing variables and their impact on FFV factors. This section consists of three sub-sections of Bayesian Model building, the effect of fraud incident type on the level of vulnerability to food fraud, and all other known important influencing variables.

4.4.1 Bayesian Network (BN) Model Building

A Bayesian Network was proposed using the records from the USP FFD. Table 4.7 presents the input variables used to construct the BN model for assessment of FFV factors (the target variable), the types of measurement and the source of the input variable. The input variables shown with binary measurement categorisation (the type of fraudulent incidents; country of detection; and type of adulterant) were found to occur in the data base in multiple records. Thus it was important to apply a binary code to each category within these variables to avoid multiple entries being recorded for a single cell. This resulted in the identification of 128 input variables for the Bayesian network.

Table 4.7 : Dependant (FFV) and independent influencing variables

Variable Name	Data type/ Measurement	Description	Reference
Record ID	Categorical/ Nominal	Record ID	
Product type	Categorical/ Nominal	(1) Seafood and seafood products, (2) Meat and Poultry,(3) Alcoholic Beverages,(4) Dairy	
Food fraud type	Categorical/ Binary/Flag	DSAI, ODS, MGO, UNB, MAO, MVO, MNC, FLC, DSAS, FAP, AEC, AEP, AEO, Other, Unknown	
Type of adulterants	Categorical/ Binary/Flag	(1) Additive, (2) Chemicals, (3) Expired, (4) Counterfeit, (5) Species	
Country of Origin	Categorical/ Nominal	(1)Argentina, (2) Armenia, (3) Australia, (4) Austria, (5) Bangladesh, (6) Belgium, (7) Brazil, (8) Bulgaria, (9) Cambodia, (10) Canada, (11) Chile, (12) China, (13) Colombia, (14) Cyprus,(15) Czech Republic, (16) Egypt, (17) France, (18) Germany, (19) Greece, (20) Hong Kong, (21) Hungary, (22) India, (23) Indonesia, (24) Iran, (25) Ireland, (26) Italy, (27) Japan, (28) Jordan, (29) Kenya, (30) Korea(the Republic of) , (31) Lebanon, (32) Libya, (33) Lithuania, (34) Malaysia, (35) Mexico, (36) Moldova (The Republic of), (37) Myanmar, (38) Netherland, (39) New Zealand, (40) Nigeria, (41) Pakistan, (42) Palestine, (43) Puerto Rico, (44) Russian Federation, Rwanda, (45)Rwanda, (46) South Africa, (47) Spain, (48) Sweden, (49)Taiwan, (50) Thailand, (51) Turkey , (52) Uganda, (53) Ukraine, (54) United Arab Emirates, (55) United Kingdom of Great Britain and Northern Ireland, (56) United States of America, (57) Viet Nam, (58)Worldwide, (59) Zambia, (60) All Europe, (61)N/A	https://ffd.decernis.com/ffd-database/#/dashboard

Country of Detection	Categorical/ Binary/Flag	Argentina, Armenia, Australia, Austria, Bangladesh, Belgium, Brazil, Cambodia, Canada, Chile, China, Colombia, Czech Republic, Denmark, Egypt, Estonia, Fiji, Finland, France, Germany, Greece, Hong Kong, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Jordan, Kenya, Korea(the Republic of) , Latvia, Lebanon, Libya, Lithuania, Malaysia, Mexico, Myanmar, Namibia, Nigeria, Nigeria, Pakistan, Poland, Puerto Rico, Russian Federation, Rwanda, South Africa, Slovakia, Spain, Sweden, Taiwan, Thailand, Turkey ,Uganda, Ukraine, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland, United States of America, Venezuela (Bolivarian Republic of), Viet Nam, Worldwide, Zimbabwe, Zambia, All Europe, N/A	https://ffd.decernis.com/ffd-database/#/dashboard
Year	Categorical/ Binary/Flag	2000 to 2018	
Weight of Evidence	Categorical/ Ordinal	(1) Low, (2) Medium, (3) High	
FFV	Categorical/ Nominal	(1) Opportunity, (2) Motivation, (3) Countermeasures, (4) Unknown	(SSAFE 2016; Van Ruth, Huisman & Luning 2017; BRC 2015; Reilly 2018; Ting and Tang 2014; Hoecht & Trott 2014; Moyer et al., 2017; Everstine, Spink & Kennedy 2013; USP FFD, Marvin et al. 2016)

Figure 4.18 shows the Bayesian Model Stream constructed by IBM SPSS Modeler version 18.2. The steps used to create this Stream were:

1. Import the external source file as a “Source” node.
2. Apply the “Partition” node to divide the dataset into a training and a testing set. Similar to studies by Bouzembrak and Marvin (2016) and Marvin et al. (2016) for the BN validation, the data for this research was divided into 80% training and 20% testing set to help evaluate the holistic model (validation).
3. Apply the “Type” node to set the role of the variable, set the FFV factor field to “Target” and the remainder of the variables to “Input Variables” (except record ID which was set to Record ID).
4. Exclude cases where the target had a null value using a “Select” node.
5. Create two Bayesian Network models (Tree Augmented Naïve (TAN), and Markov Chain Model - with Maximum Likelihood parameter learning method) to identify which model will be more efficient in presenting the pattern of relationships between the variables. This results in two model nuggets being generated. Figure 4.19 presents the results which show that the TAN model correctly identified 86.09% of the FFV outcomes compared to 49.57% of the Markov model. Compare the two model nuggets by applying a “Filter” node and create a Gains chart and output analysis node to check the accuracy of the model for assessing the factors for food fraud vulnerability (Gains chart outputs shown in figure 4.20). Gains charts show the proportion of hits in each increment relative to the total number of hits in the tree using the equation: (hits in increment / total number of hits) x 100 % (IBM Nd(a)). Figure 4.20 illustrates the result that the TAN gain (blue line) is far superior to the Markov model gain (red line) in assessing FFV.

The BN was then constructed using SPSS Modeler 18.2. Two Bayesian Networks of TAN and Markov were selected in order to determine the most reliable holistic model (Chiroma et al. 2014; Elsayad & Fakhr 2015) Based on the analysis result the TAN model was shown to be able to assess the vulnerability to food fraud with a higher accuracy rate of 86%. The BN model was constructed with 128 input variables (or influencing variables). From this model it was identified that some variables were more relevant when attempting to assess the vulnerability to food fraud. In particular were the: the country of origin (76%); and type of food product (10%). The predictor importance analysis result also showed that knowing the food fraud type does not play a role in assessing the vulnerability to food fraud in this model. Finally, the predictor importance analysis for all variables known to play a role in the assessment of vulnerability to food fraud was conducted and the results provided in the form of Conditional Probability Tables (CPTs). These were provided in full in appendix B and C and summary extracts discussed in this chapter.

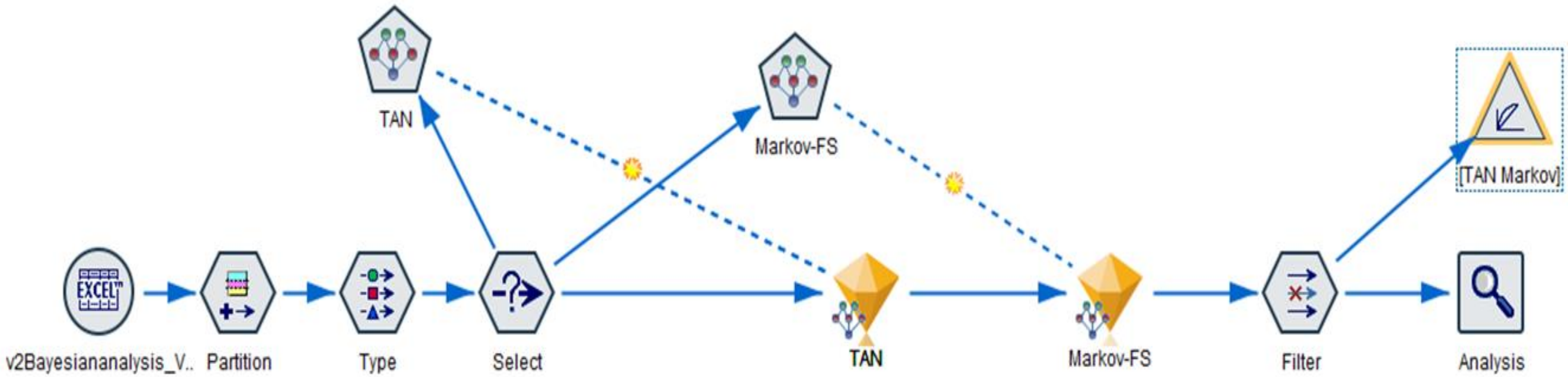


Figure 4.18: SPSS Modeler Stream

Results for output field FFV

Individual Models

Comparing TAN with FFV

'Partition'	Testing		Training	
Correct	99	86.09%	399	85.81%
Wrong	16	13.91%	66	14.19%
Total	115		465	

Comparing Markov with FFV

'Partition'	Testing		Training	
Correct	57	49.57%	357	76.77%
Wrong	58	50.43%	108	23.23%
Total	115		465	

Agreement between TAN Markov

'Partition'	Testing		Training	
Agree	59	51.3%	380	81.72%
Disagree	56	48.7%	85	18.28%
Total	115		465	

Comparing Agreement with FFV

'Partition'	Testing		Training	
Correct	52	88.14%	339	89.21%
Wrong	7	11.86%	41	10.79%
Total	59		380	

Figure 4.19 : Analysis result for TAN and Markov models

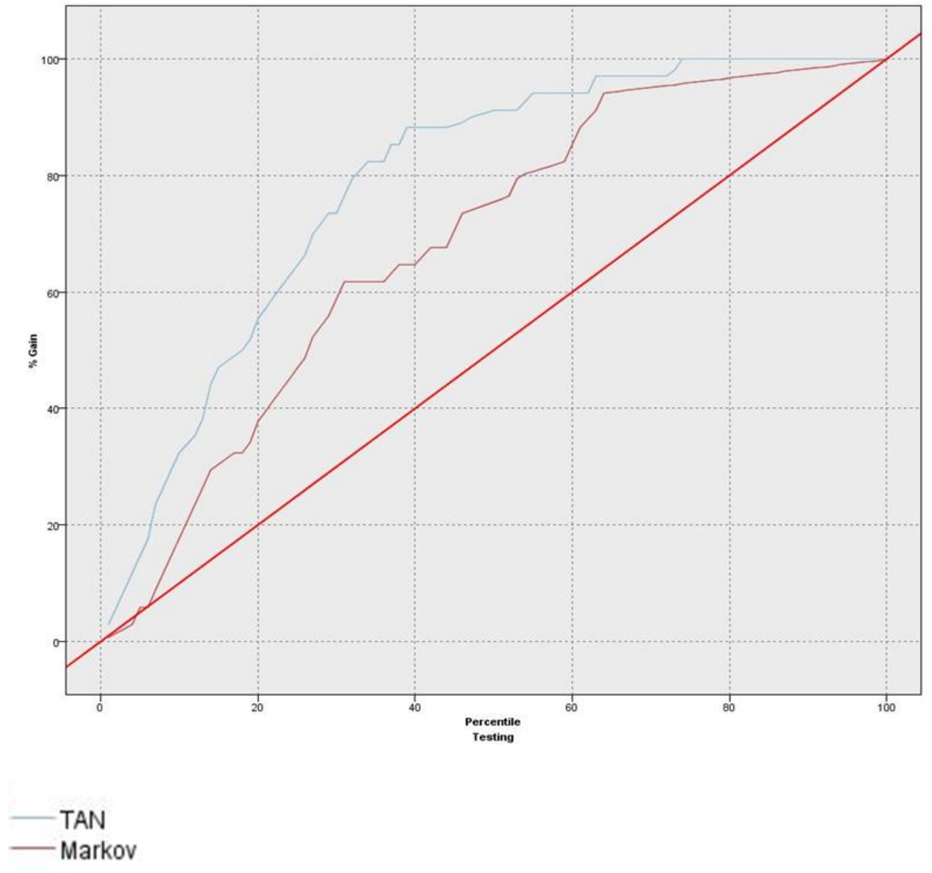


Figure 4.20 : Gain chart result for TAN and Markov models

4.4.2 FFV factors and Food Fraud Incident Types (Sub-question 2)

In order to initially determine the level of impact of FFV factors by food fraud type (Sub-question 2), food fraud incident types were selected as the only influencing variable and the Bayesian model was tested. The network (Figure 4.21) shows FFV factors as a parent node (or target node). Figure 4.22 shows the ranking of the impact of food fraud incident type on FFV factors by the pre-processing feature selection of the TAN (Bayesian Network) model. The predictor importance of the model suggested that FLC, MAO, ODS, OTHER, DSAS, in this order, were the most important variables for assessing vulnerability to food fraud. These results addressed the second research sub-question.

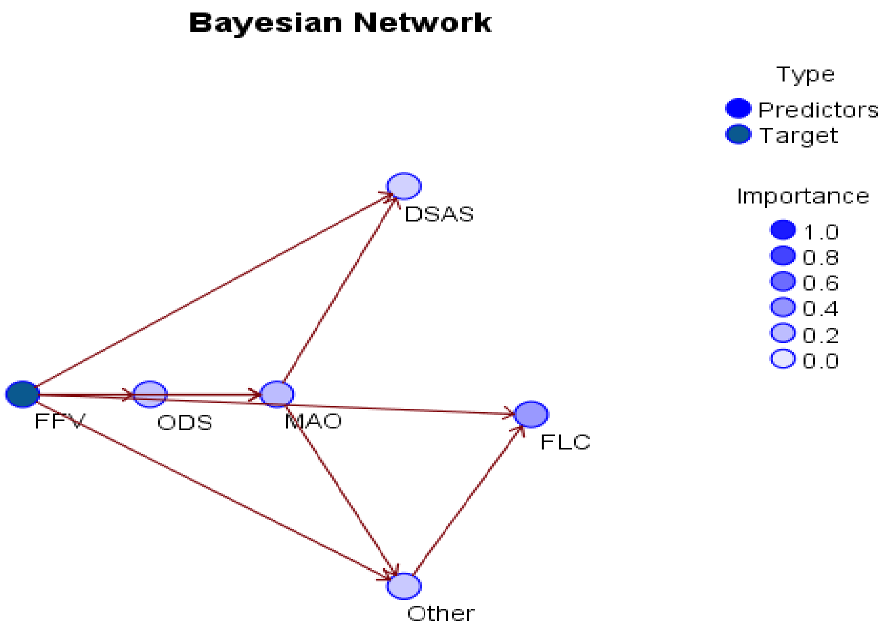
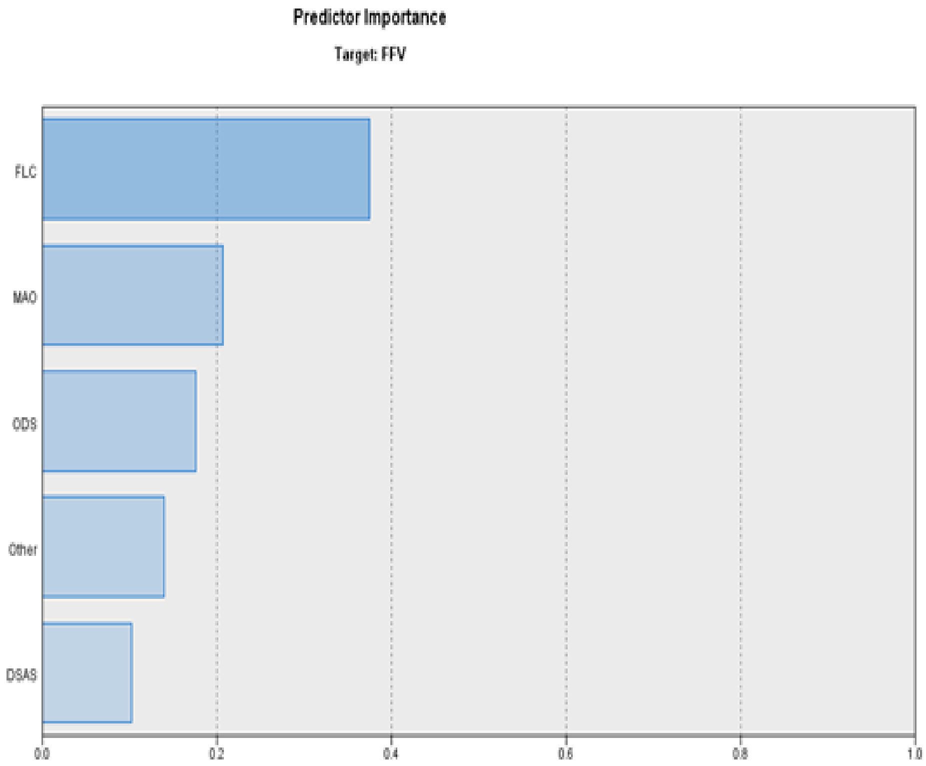


Figure 4.21: Bayesian TAN model for food fraud incident types and FFV



Nodes	Importance
DSAS	0.102
Other	0.1403
ODS	0.1758
MAO	0.2068
FLC	0.3751

Figure 4.22: Predictor importance

4.4.3 Patterns of Relationships

In order to answer the third research sub-question (Sub-question 3) determining the most important influencing variables of FFV factors (mentioned in Table 4.6), all input variables were selected as influencing variables and the Bayesian model was tested. Figure 4.23 shows the network between FFV factors and all the important variables and Figure 4.24 shows the predictor importance of the target node (FFV factors).

The model suggested that the Country of Origin of the food products is the biggest influencer (76%) in assessing vulnerability to food fraud. The next variables important in this assessment were (in order): the type of food product; Counterfeiting (as a type of adulterant); China (as a detecting country); and fraudulent labelling (as a type of food fraud incident).

These results mean that when the country of origin and type of food product is known, we have a greater ability to more accurately assess the vulnerability to food fraud for those products. In addition, the model suggests that food products are more likely to be vulnerable to counterfeiting than other types of adulterant. Finally, these results suggest that most incidents of food fraud (as recorded in these international databases) have been detected in China and that fraudulent labelling is the most often type of food fraud detected. Examples of how these variables can be further be used to assess the vulnerability to food fraud in a practical way, are shown through creation of conditional probability tables (CPT) discussed next (refer to section 3.5.4).

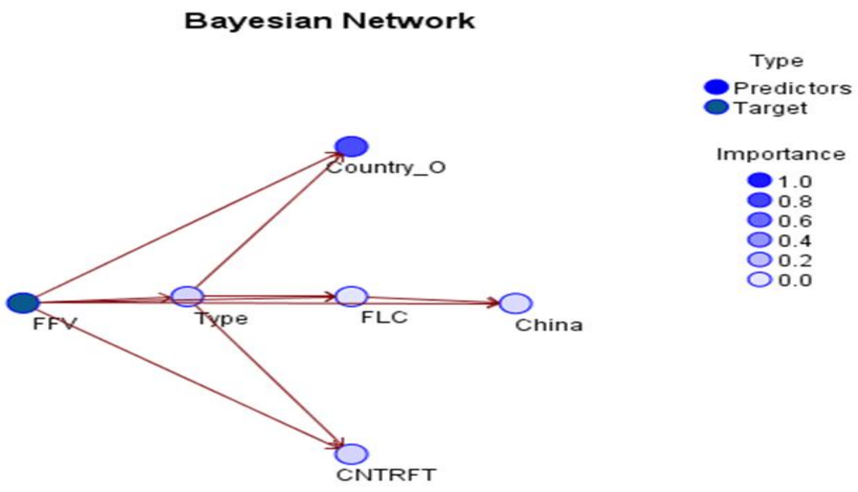
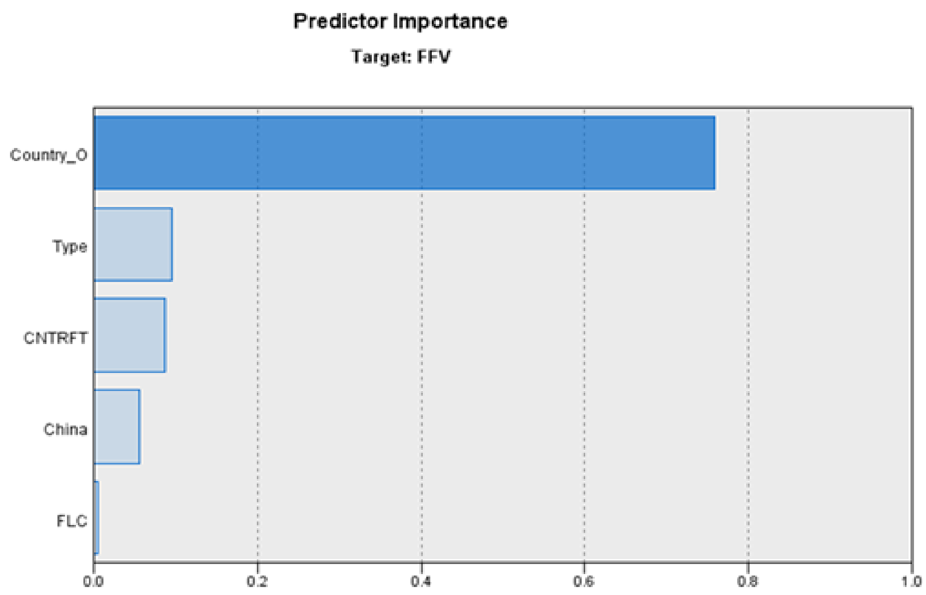


Figure 4.23: BN TAN model



Nodes	Importance
FLC	0.0042
China	0.0558
CNTRFT	0.0861
Type	0.0945
Country_O	0.7595

Figure 4.24: Predictor importance

Table 4.8 shows an extract from the Conditional Probability Table (CPT) for the influencing variable, Country of Origin (full table provided in Appendix B). When interpreting this table only results above 0.50 were considered. Thus, the table shows three combinations of conditions that assist in the understanding of the factors that contribute to a high probability of vulnerability for food fraud when we know the country of origin for the food. These combinations are:

1. Alcoholic Beverages (food product type) are most vulnerable to food fraud motivated by the desire for economic gain, or as a result of cultural influences (MOTIVATION), when those beverages originate from India (see red cells).
2. Dairy products (food product type) are most vulnerable to food fraud as a result of complex supply chains (OPPORTUNITY) when they originate from India (see the cell in light red); and
3. Seafood products (food product type) are most vulnerable to food fraud as a result of lack advanced laboratory testing for detection of fraud (OPPORTUNITY) when they originate from the USA (see red cells).

.

Table 4.8 : Extract from CPT for the country of origin (Full table provided in appendix B)

Parents		**Conditional Probability Table- Country of Origin**	
Type	**FFV**	**India**	**USA**
Seafood	**Opportunity**	0.07	0.5
	Motivation	0	0
	Countermeasure	0.02	0.16
	Unknown	0.09	0.18
Meat and Poultry	**Opportunity**	0	0.03
	Motivation	0	0.17
	Countermeasure	0.02	0.12
	Unknown	0	0.15
Alcoholic Beverages	**Opportunity**	0.05	0.03
	Motivation	0.58	0.08
	Countermeasure	0.05	0.05
	Unknown	0.09	0
Dairy	**Opportunity**	0.58	0.09
	Motivation	0.8	0
	Countermeasure	0.27	0.08
	Unknown	0.32	0.04

Appendix C provides the full Conditional probability tables the other important influencing variables discussed earlier. These tables show how the model can be used to assess the probability of vulnerability to food fraud when these factors are known

4.5 TAN Model Validation

There were two ways to verify the validity of the TAN Network Model developed in this research. First, the data was divided to a training (80%) and a testing (20%) dataset by the Partition Node (see Figure 4.16). The TAN model that was constructed based on 80% (465 cases) of the total data collected from USP FFD was used to assess vulnerability to food fraud in 20% (115 cases) of the testing subset. The testing sub-set was selected randomly from the whole dataset. All variables (except FFV factors) were selected as input parameters in the TAN model to assess the vulnerability to food fraud. The TAN model can assess vulnerability to food fraud in 86% of the cases with a probability of more than 0.5 (see Appendix D in the Appendices).

Second, the output of the TAN model was compared to the results previously addressed by other researchers. Marvin et al. (2016) developed a Bayesian Model to predict food fraud type in 91.5% of cases. These authors reported a similar result for predictor importance. They reported that country of origin was the most important factor (61%) in determining the type of food fraud. These authors used the BN model based on other databases (RASFF and EMA) to predict the type of food fraud and have used a number of food fraud drivers (or FFV) as predictors.

Another study by Bouzembrak and Marvin (2016) developed a Bayesian Model based on parameters of the country of origin and product type that could predict food fraud type in 88% of cases. They reported similar findings related to the influencing variables, albeit that they did not calculate the influence of each of these influencing variables (based on entropy analysis, etc.).

4.6 Conclusion

This chapter addressed the key findings based on the Barrier Analysis technique (Sub-question 1) and BN modelling approach (Sub-question 2, Sub-question 3). This research had identified new FFV dimensions by reviewing the incidents of food fraud recorded in the USP FFD using Barrier Analysis technique. The new dimensions then were assigned to one of three existing FFV factors of opportunity, motivation and countermeasures as described by Routine Activity Theory. FFV factors related to the opportunity category captures cases of food fraud where detection of adulterants requires advanced technologies, changes to the physical form of product (e.g. ground, mince, etc.), availability of knowledge to adulterate the product, transparency of supply chain, and opportunity in time and space.

FFV factors related to the motivation category captures cases of food fraud related to the corruption level of the country, the economic health of the business, financial strain, culture, price spike, and supply and pricing.

FFV factors related to countermeasures capture cases of food fraud related to the need for coordination between law enforcement agencies, the extensiveness of traceability, lack of law enforcement, food safety, and whistleblowing system. Findings emerging from the Barrier Analysis technique in this study indicated that the categories of countermeasures (46%) and opportunity (32.7%) were most likely to be a factor when assessing the vulnerability to food fraud.

The BN was then constructed using SPSS Modeler 18.2. Two Bayesian Network of TAN and Markov were selected in order to determine the most reliable holistic model. Based on the analysis result the TAN model was shown to assess the FFV factors with a higher accuracy rate of 86%. The BN model was constructed with 128 input variables (or influencing variables) to assess FFV factors. Important influencing variables were then analysed and were described as the country of origin (76%), type of food product (10%), counterfeit type of adulterants (9%), and China (6%). The predictor importance analysis result also showed that food fraud type (Fraudulent Labelling Claim) was among the least important factor. Therefore, the result highlighted that food fraud incident types does not impact on the level of FFV factors. In addition, the predictor importance analysis for all known influencing variables of FFV factors were described through Conditional Probability Tables (CPTs). The study is concluded in Chapter Five, which extensively presents findings of this investigation and focuses the theoretical and practical contribution produced by the research questions.

5 CHAPTER 5: CONCLUSION AND DISCUSSION

5.1 Introduction

This study developed a holistic model to assess the level (degree) of vulnerability to fraud for food products targeted at human consumption. This study achieved the goal of filling research gaps in the food fraud literature and in providing practical contributions and suggestions for food production companies, border protection authorities, governments and quality assurance agencies (i.e. BRC, PwC, etc.) about ways to reduce the vulnerability to food fraud. This chapter explores the relevant findings developed from the main research question and three sub-questions and presents the theoretical and practical contributions from the research.

This chapter begins by discussing the results and presenting the theoretical contributions for each of the sub research questions. The conclusions from each sub-question, will then be aggregated to address the overall research question which is: How can the vulnerability to food fraud for food products designed for human consumption be assessed? In addressing the overall research question, a revised research model demonstrating the value of the Barrier Analysis technique and the Bayesian Network modelling approach to assess FFV factors is also presented. The practical contributions of this research are presented next, followed by the limitations of the research and recommendations for future research. The structure of this chapter is presented in Table 5.1.

Table 5.1: Chapter 5 structure

Section	Purpose
5.1 Introduction	Introduction
5.2 Discussion of results and theoretical contribution for sub-question 1	Summary of the classified FFV factors and theoretical contributions related to the new dimensions and insights added to FFV factors
5.3 Discussion of results and theoretical contribution of Sub-questions 2 and 3	Summary of important influencing variables of FFV factors and theoretical contribution related to Sub-question 2 and 3
5.4 Theoretical contribution: A Revised Research Model (Main Research Question)	A theoretical contribution towards development of a holistic approach to assess FFV factors
5.5 Practical contribution	Practical implications of the research
5.7 Limitation of the research	What are the limitations of this research
5.8 Recommendations for future research	Insights for future studies

5.2 Discussion of Results and Theoretical Contribution for Sub-Question 1

What are the factors that influence the vulnerability to food fraud food products designed for human consumption?

5.2.1 Discussion of Results for Sub-Question 1

Analysis of the data in relation to sub-question 1 was presented in chapter 4. This analysis identified new dimensions of Food Fraud Vulnerability factors that were previously obscured in the literature. These new dimensions were added to the three existing factors of Food Fraud Vulnerability namely: opportunity; motivation; and countermeasures (BRC 2015; SSAFE 2016; Van Ruth, Huisman & Luning 2017;) for further testing in relation to sub-questions 2 and 3. Table 5.2 presents both the factors and dimensions with new additions highlighted and each is discussed in more detail next.

Table 5.2: Overview of FFV factors based on Barrier Analysis technique results and the literature

	FFV factors		
	Opportunity	***Motivation***	***Countermeasures***
Dimensions	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Corruption level of the country (Van Ruth, Huisman & Luning 2017) **Bribery and unethical behaviour**	**Requires coordination between law enforcement agencies**
	The physical form of products	The economic health of the business (country), financial strains (Van Ruth, Huisman & Luning 2017). **Culture and religion and price spikes**	**Extensiveness of Traceability**
	Availability of knowledge and technology to adulterate food products (SSAFE 2016)	Supply and Pricing (Van Ruth, Huisman & Luning 2017)	Lack of law enforcement (Hoecht & Trott 2014; SSAFE 2016)
	Supply chain complexity/ transparency supply chain		Food safety (Reilly 2018, SSAFE 2016)
	Opportunity in Time and space (Ruth et al 2017)		Whistleblowing system (SSAFE 2016; Van Ruth, Huisman & Luning 2017)

Opportunity for food fraud: The findings from the Barrier Analysis technique, which reviewed 580 cases of food fraud, identified two new dimensions for the Opportunity factor in relation to Vulnerability to Food Fraud. These new dimensions were: the physical form of products; and transparency or complexity of supply chains.

Quality assurance standard setting organisations such as BRC (2015) and SSAFE (2016) had indicated that the physical form of products should be an important consideration when identifying opportunities to commit fraud. For example, when the physical aspects of a product were altered (e.g. beef is minced or chicken is dyed) and/or where it was combined with other components (such as in the case of spices) it could become almost impossible to identify adulterated or substituted ingredients without sophisticated laboratory testing. For this reason, there have been no empirical studies to date that have included this dimension in their analysis. This gap has been addressed in this study as a result of the empirical evidence provided. Thus we propose to add this as a dimension to the literature.

The second new dimension added to the opportunity for food fraud factor is related to the complexity and transparency of the supply chain. The Barrier Analysis revealed that when supply chains became complex they tended to also become less transparent, providing more opportunities for fraudsters to operate. Global supply chains were particularly vulnerable to this action. The database analysed in this study provided a number of examples of adulterated or substituted products sold in original packaging as a result of complex and opaque supply chains. The most famous case of this type of incident was the horsemeat scandal in the UK (2013).

Motivation for food fraud: The results of the analysis of the Motivation for Food Fraud Vulnerability factor identified three new dimensions to be added. These were: the corruption level of the detecting country; the culture and religion of the detecting country; and the potential for price spikes due to currency fluctuations. The analysis revealed that when there was an increased tolerance and likelihood of corrupt business practices in detecting countries there was a corresponding increase in the motivation for fraudsters to act. In these cases, bribery was the most noted action and resulted in food fraud detection being impeded in the supply chain and/or in authorities passing the fraudulent products through borders without proper inspections.

The culture and religion of the detecting country was noted as particularly apparent in some developing countries where there were strong religious prejudices against some products (e.g. sharia law against using alcoholic beverages in Pakistan, Iran, etc.). In these cases, the economic motivation for fraud was seen in products disguised or altered to avoid sanction or detection by fraudsters. This dimension had been difficult to study to date as it was often illegal in these countries to consume these products and thus consumers were reluctant to participate in conversations about the incidence of this fraudulent activity. The benefit of using the Barrier Analysis of 580 cases of food fraud (as done in this study) has allowed this type of motivation to be identified and measured, further contributing to the food fraud literature.

The final dimension to be added to the motivation for Food Fraud Vulnerability factor was the potential for price spikes as a result of currency fluctuations. As the literature review highlighted, the motivation for food fraud has always been based on intentional behaviour for economic gain. Therefore motivation to capitalise on price differences, or profit gain due to currency changes provided a new dimension to consider when considering vulnerability to food fraud.

A good example of this dimension was noted in the case of Iran where adulterated or substituted homemade alcoholic beverage consumption increased because the currency plummeted against the dollar and people could not afford to buy the authentic product. In this case, fraudsters capitalised on the motivation to defraud consumers provided by the price spike due to currency fluctuations.

Once again the literature relating to food fraud motivations had not identified this dimension specifically. Rather, scholars had focused on the impact of price differential generally as a motivation (Van Ruth, Huisman & Luning 2017; Silvis et al. 2017; Van Ruth et al. 2018). Thus, the addition of this new dimension was a further contribution of this study

Countermeasures to detect food fraud: The Barrier Analysis revealed three additional dimensions for Countermeasures that are important in the determination of vulnerability to food fraud. These were: the requirement for coordination of law enforcement agencies; the extensiveness of traceability; and food safety. The incidents analysed in this study showed that where there was a lack of coordination by various law enforcement agencies and where this deficiency was known that this increased the vulnerability to food fraud. Thus, this study was able to conclude that when law enforcement agencies shared information about cases of fraud and cooperated across national and international borders, this was more effective as a countermeasure for deterring fraudsters.

The traceability of food products has been cited in the literature as an important countermeasure for food fraud (Silvis et al. 2017; Van Ruth, Huisman & Lunning 2017; Van Ruth et al. 2018). However, these studies largely dealt with reactive measures to be activated after a fraudulent activity had been detected. Measures such as holograms (e.g. organic certificates) and machine readable technologies can be counterfeited themselves (Ting & Tsang 2014) and have been shown to be not particularly effective as a food fraud countermeasure. Further, the lack of efficient traceability systems built into secure packaging and labelling by original companies have made it difficult for authorities to detect fraudulent products. This study has found that proactive countermeasures such as traceability systems like GS1 (including advanced information sharing system along the supply chain) are far more effective as countermeasures against food fraud.

The final dimension to be added to the Countermeasure for food fraud was related to the food safety management systems. Barrier Analysis revealed that some incidents of food fraud were detected through food safety quality controls/ inspections. Quality assurance standard setting organisations such as SSAFE (2016) have indicated that an evidenced based sampling plan specifically for food fraud detection is an important for identifying countermeasures for Food Fraud Vulnerability (FFV) factors. These sampling plans need to be in addition to any sampling that currently exists to detect issues of food safety.

As sampling plans designed for food safety are not able to detect intentional root causes of food fraud (Spink & Moyer 2011), many incidents of food fraud have remained undetected. For this reason, there are no empirical studies to date that have included the effectiveness of food safety sampling practices in their Food Fraud Vulnerability (FFV) analysis. This study has addressed this issue by providing empirical evidence of the importance of the inclusion of an evidence based sampling plan designed to detect food fraud as a countermeasure in food supply chains.

In addition to these new dimensions, the results of this study also identified new insights to the existing knowledge of other countermeasures that impact on FFV. These were: lack of law enforcement; and whistleblowing systems. Quality assurance standard setting organisations such as SSAFE (2016) have indicated that law enforcement practices with low fines (or no fines) increased the vulnerability to food fraud and impeded fraud detection. As an example, when an illegal or fake product is present in restaurants, it is almost impossible for authorities to fine fraudsters because written records or evidence are usually required to make arrests or to impose fines. For this reason, there had been no empirical studies to date that have included this insight to countermeasure factors in their FFV analysis. This study added to the literature by including this empirical evidence and confirmed this inclusion through the analysis phase.

The final insight to be added to Countermeasures for Food Fraud Vulnerability factors was the whistleblowing system. Previous studies and quality assurance standard setting organisations such as SSAFE (2016), highlighted the importance of improving the whistleblowing system for detection of fraudulent activities (SSAFE 2016; Van Ruth, Huisman & Lunning 2017). However, the Barrier Analysis revealed a number of examples where former employees who were sacked or fired from their job and who then informed authorities about adulteration practices. The Barrier Analysis revealed that whilst improving a whistleblowing system as a countermeasure for vulnerability reduction was important in some companies, it was less relevant when dealing with companies who intentionally engage in food fraud crimes.

In summary, this study has made substantial contributions to the food fraud literature through the application of a Barrier Analysis of 580 cases of real food fraud and these contributions are presented next.

5.2.2 Theoretical Contribution for Sub-question 1

Previous studies in the field of food fraud identified gaps in the literature related to factors affecting vulnerability to food fraud(Spink, Moyer & Peru 2016; Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). According to the food risk matrix described by Spink and Moyer (2011) (see Figure 2.1), reducing the risk of food fraud requires a prevention strategy rather than an intervention strategy. The debate about how to best develop prevention strategies all centre around the importance of being able to identify the root causes or factors that influence a product's vulnerability to food fraud.

The results from the analysis related to sub-question 1, address the gap in the literature, calling for greater insight about the factors that can influence the vulnerability to food fraud as evidenced from real data (Van Ruth, Huisman & Luning 2017; Van Ruth et al. 2018). In this study, a list of factors that had the potential to influence vulnerability to food fraud were initially developed from the literature (see chapter 2). The contribution of each of these factors was analysed using real data recorded by the USP Food Fraud Database[1]. Detailed classifications of FFV factors that emerged from the Barrier Analysis technique were presented in chapter Four.

This analysis empirically confirmed that each of these factors did impact the level of vulnerability to food fraud, and further, that there were new dimensions for each factor that previously were not evident in the literature (see highlighted factors in Table 5.2). The analysis also identified new insights into the performance of the existing practices relating to countermeasures which further contributed to the literature. Finally, the analysis also revealed that in most types of food fraud, more than one dimension of vulnerability was evident making a further contribution to the literature.

Building on the findings and conclusions from sub-question 1, sub-questions 2 and 3 addressed gaps in the literature about relationships between Food Fraud Vulnerability factors and the variables that influence them. The discussion and contribution of these questions are presented in order next.

[1] As at July 2018 The USP Food Fraud Database is now called Decernis, however for the purposes of this thesis the original database name will be used.

5.3 Discussion of Results and Theoretical Contribution of Sub-questions 2 and 3

How can the types of food fraud be used to assess Food Fraud Vulnerability factors?

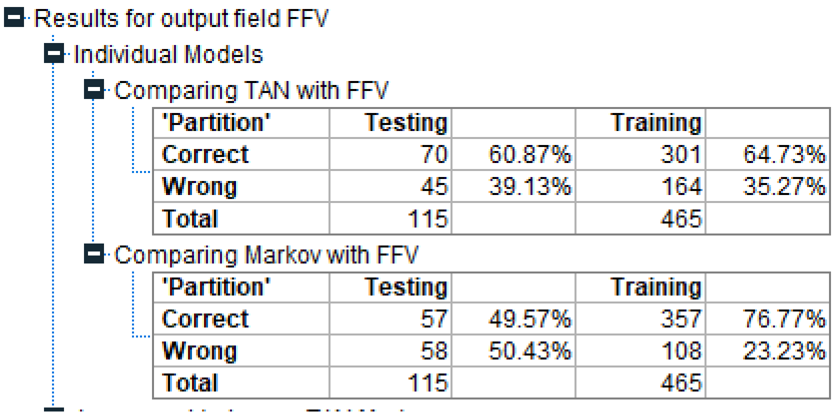
and

Which of the variables, known to influence the vulnerability to food fraud, are most important?

5.3.1 Discussion of results for sub-question 2

To address this sub-question a Bayesian Network model was constructed that included food fraud incident types as influencing variables and FFV factors as target variables. The relationship between food fraud incident types and FFV factors that emerged from the predictor importance analysis was presented in chapter Four. Whilst these results, provided evidence that three types of food fraud: Fraudulent Labelling Claims (FLC); Misrepresentation of Animal Origin (MAO); and Other Dilution/Substitution (ODS), were the most important influencing variables on Food Fraud Vulnerability factors, the accuracy of the TAN model was only 60.86% (see Figure 5.1). Thus, whilst this finding was interesting, it could not be used with a high degree of confidence or accuracy in assessment of FFV factors.

Therefore other variables needed to be considered, which was done with sub-question 3 discussed next.



Results for output field FFV

Individual Models

Comparing TAN with FFV

'Partition'	Testing		Training	
Correct	70	60.87%	301	64.73%
Wrong	45	39.13%	164	35.27%
Total	115		465	

Comparing Markov with FFV

'Partition'	Testing		Training	
Correct	57	49.57%	357	76.77%
Wrong	58	50.43%	108	23.23%
Total	115		465	

Figure 5.1: BN model analysis for food fraud incident type

5.3.2 Discussion of results for sub-question 3

To address this sub-question an additional Bayesian Network model was constructed that included all known food fraud influencing variables with FFV factors as target variables. The analysis aimed to identify the most important influencing variables for FFV factors (results provided in chapter 4). When all of the influencing variables were included in the TAN Bayesian Network analysis, the Food Fraud Vulnerability factors could be assessed with an accuracy of 86%. The predictor importance analysis showed that Country of Origin and Product Type, together, had the strongest influencing power for assessing Food Fraud Vulnerability factors.

For example, if we know the Product Type (Diary) was being exported from a particular country - Country of Origin (India) the model developed for this study using data from the USP FFD would be able to assess which Food Fraud Vulnerability factors should be considered if seeking to implement either deterrents or detection strategies to reduce vulnerability to food fraud. In this example, when we apply the Bayesian network analysis, the Opportunity group of FFV factors is shown as being the most important. So exporters of this product type (Dairy) would need to focus on the dimensions and actions in the Opportunity group of FFV factors when looking to reduce vulnerability to food fraud activity if exporting their product from India. These results aligned with findings from other studies (particularly those of Marvin et al. (2016) where the country of origin and type of food product were also shown to be more important than other factors in the assessment of food fraud incident types.

In addition to Country of Origin and Product Type, the analysis also identified, three other predictor variables that contributed to the influencing power of the Bayesian network analysis. These influencing variables were: Detecting country – where the fraud happened; Types of Adulterants; and Incident Type. The predictor importance analysis showed that within each of these broad variable categories, more detail could be detected. For example, within the Detecting Country influencing variable, China was the most commonly cited country where food fraud incidents were detected. Within the Types of Adulterants category, counterfeiting was the most commonly found action and fraudulent labelling claims were the most commonly found food fraud incident type.

Research by Berman (2008) cautioned exporters to carefully control and manage their food supply chains when engaging in the growing China market. Berman (2008) noted that when trading with China, counterfeiting issues were particularly problematic when it came to incidents of fraud. The results of this study support this cautionary advice, with empirical evidence that counterfeiting issues also feature more often in cases of food fraud in China. The results of this study found statistically that more food fraud incidents in the database used for the analysis, were detected in China than in any other country. The identification of Type of Adulterants and Incident Types as influencing variables of FFV factors was unexpected as this had not been previously suggested in the extant literature.

5.3.3 Theoretical Contribution for Sub-question 2 and 3

Previous research by Marvin et al. (2016) and Bouzembrak and Marvin (2016) had predicted food fraud incident types by looking at variables such as: the Year; Country of Origin; Types of food products; and other food fraud drivers (these are also known as predictor variables). The aim of these studies was to use these variables or factors to predict food fraud incident types. Whilst these studies made important contributions to the discourse in relation to food fraud, they did not explore the root causes of food fraud, which in turn would have assisted in assessment of the vulnerability of various food processing practices and supply-chains to food fraud (Marvin et al. 2016).

This study takes up this call from Marvin et al. (2016) to assess the root causes of food fraud to aid in the development of holistic models for Food Fraud Vulnerability. This was done by converting the Bayesian Network model into a dynamic model, which facilitated the understanding of the interrelationships between food fraud incident types and vulnerability to food fraud (Marvin et al. 2016). Using this modelling approach to investigate whether Food Fraud Vulnerability factors (once known – sub-question 1), could be assessed by food fraud incident type (sub-question 2) and/or by other known factors (sub-question 3) has addressed this gap in the food fraud literature and thus makes an important contribution to this body of knowledge.

The results of this study confirmed that Country of Origin, Product Type, Detecting Country; Types of Adulterants; and Incident Type were the most important variables in the assessment of Food Fraud Vulnerability. Whilst the identification of Country of Origin as a influencing variable of food fraud was suggested in the existing food fraud literature, this study provided empirical evidence to strengthen and validate this notion and thus made an important contribution to the discourse. In addition, the study also empirically identified other predictor variables that had not previously been evident in the literature and this finding has made additional theoretical contributions.

5.4 **Theoretical Contribution: A Revised Research Model (Main Research Question)**

The food fraud literature reviewed in chapter 2, called for an empirically tested holistic approach to combating and preventing food fraud through the identification of areas of vulnerability (Lord, Flores Elizondo & Spencer 2017; Silvis et al. 2017; Spink & Moyer 2011; Spink et al. 2017; Van Ruth, Huisman & Luning 2017). Taking up this call, this study adopted a holistic approach to the assessment of FFV factors, linking all of the influencing variables and their dependencies. The Bayesian modelling approach adopted in this study used real data from internationally reported cases of food fraud (e.g. USP FFD) to assess vulnerability to food fraud for different food types, from a range of countries and considering the three Routine Activity Theory classifications (Opportunity, Motivation and Countermeasures). This is the first study to have adopted this approach to developing a holistic model for assessment of vulnerability to food fraud. In addition this model provides a useful tool for food production companies and exporters in the management of their supply-chains. The holistic approach based on the revised research model (presented in chapter Two) is shown in Figure 5.2.

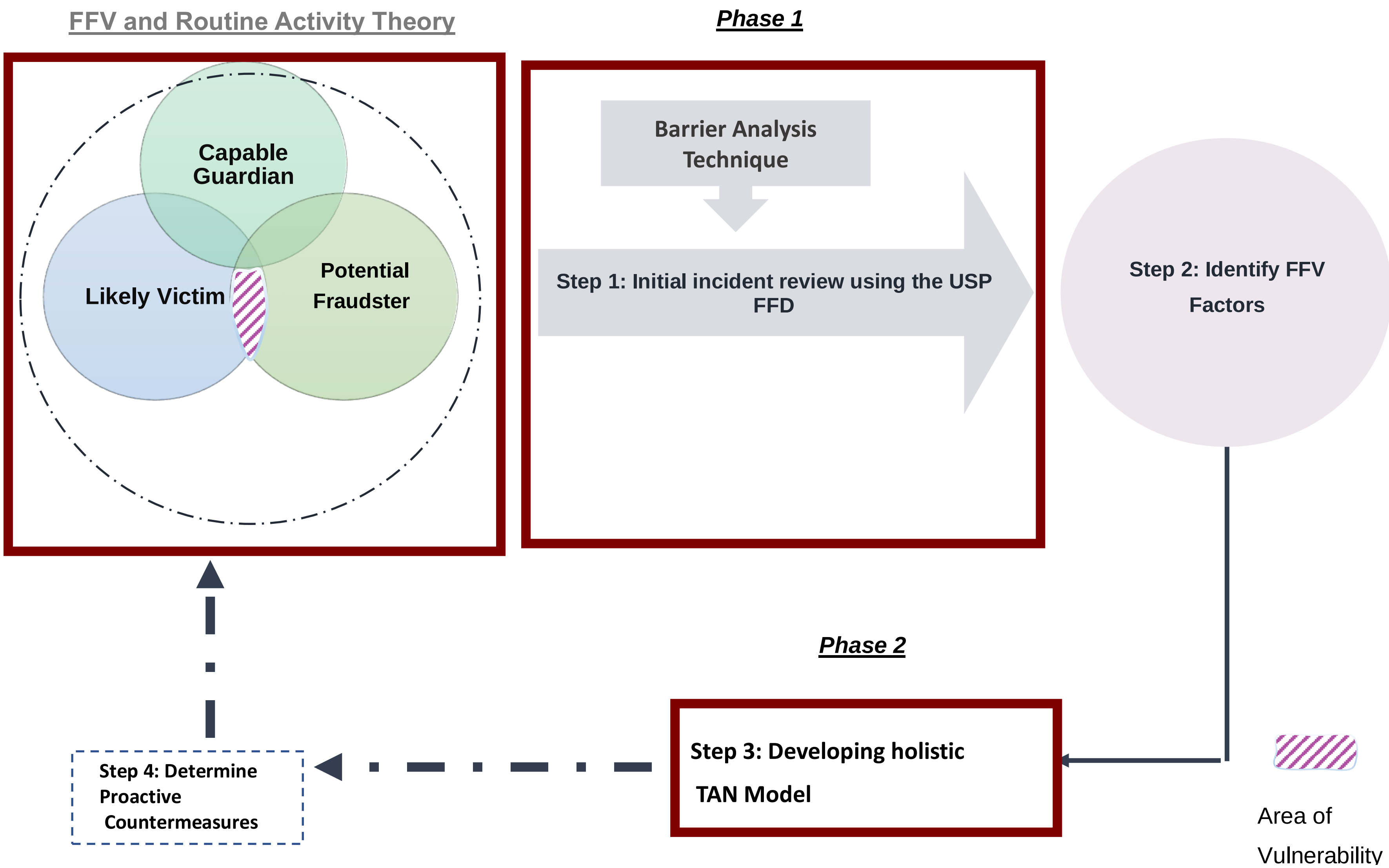


Figure 5.2: Revised research model

In order to assess vulnerability to food fraud, previous studies proposed that the best way was to initially screen, and review food fraud incidents recorded in an organised database (Spink, Moyer & Peru 2016) (e.g. USP FFD). This study added to the literature by reviewing 580 cases of food fraud from 2000 to 2018 related to four product types: seafood; meat: alcoholic beverages: and dairy products; recorded in the USP FFD. In addition to the initial screening of recorded food fraud incidents, this study adopted a Barrier Analysis technique in phase one to identify the root causes of vulnerability to food fraud. Through the Barrier Analysis technique, the Food Fraud Vulnerability factors were organised around the three classifications of the Routine Activity Theory: Opportunity; Motivation; and Countermeasures. The combination of Barrier Analysis and the Routine Activity Theory classifications has resulted in an effective way of identifying vulnerability to food fraud.

The Bayesian Network modelling approach was developed in phase two in order to test the existing theoretical assumptions provided by the Routine Activity Theory classifications and Barrier Analysis techniques. An algorithm consisting of two Bayesian Network models of Markov and TAN was developed using SPSS Modeler 18.2 Stream. Two Bayesian Models (TAN and Markov) were compared to find the most accurate model to assess the vulnerability to food fraud and to answer the research question for this study. Findings from the TAN model had shown that we could assess FFV factors with the accuracy of above 80% (86%) for food products.

This study was the first to combine the Barrier Analysis technique with the Routine Activity Theory classifications in a model to assess Food Fraud Vulnerability factors and the strength of the results from the TAN model has provided evidence that this approach is robust. The contribution of this approach to the food fraud literature is significant as future researchers will be able to build on this model to assess vulnerability to food fraud in other product categories.

In conclusion, this study has provided empirical evidence that it is possible to assess the vulnerability to food fraud for a range of product types.

Once known, these findings allow food manufacturers and others to design detection and/or prevention strategies to reduce their vulnerability to food fraud. The study identified four key steps (shown in figure 5.2) to be followed to achieve this outcome:

- Step 1: review previous cases of food fraud recorded in global food fraud databases (for example, USP FFD).
- Step 2: identify FFV factors using Barrier Analysis techniques and organise these factors into the classifications as indicated in the Routine Activity Theory framework (opportunity, motivation, and countermeasures).
- Step 3: develop a holistic model based on the extracted FFV factors and other variables addressed in this research; and
- Step 4: determine proactive measures to combat the specified FFV areas.

5.5 Practical Contributions

The result and contributions of this research will benefit food companies, border protection authorities, governments and quality assurance and compliance organisations. The study makes three practical contributions which are addressed next.

The first practical contribution of this study is for the managers of food production companies by providing them with guidance on how to guard against food fraud through the identification of specific areas of vulnerability. The revised model, presented in this chapter, showed that Country of Origin, Type of food product, Detecting country (e.g. China), Type of adulterants (counterfeiting) and Type of incident (Fraudulent Labelling Claims) are the most important predictors of FFV factors.

For example, the model shows that the level of vulnerability to food fraud will increase, when food is exported to China. In addition, if we include information about the Type of product and The Country of Origin into the model, we are able to gain more knowledge of the root causes of vulnerability and gain greater insights into which of the FFV factors will be most relevant.

Once we know this, we can eliminate or reduce the root cause of vulnerability through deployment of appropriate countermeasures and/or prevention strategies.

In order to break the cycle of fraud and minimise future vulnerability, it is important to deploy appropriate countermeasures. This study has shown that the Tan modelling technique will assist in identifying which vulnerability factors are most likely to be relevant for specific food types, which in turn, increases the likelihood of deploying the correct and most effective countermeasure.

The second practical contribution of this research is for border protection authorities. The holistic approach presented in Figure 5.2 can be further developed into a platform for these authorities to help assess the vulnerability to fraud for a range of food products for incoming (imported) food products, particularly if they know the country of origin, and/or type of food products. For example, based on the information provided in Table 4.8, the level of vulnerability to food fraud increases when the product type is dairy, and the country of origin is India. Therefore, border protection authorities for countries importing dairy products from India, might need to be more vigilant around issues of supply-chain sophistication.

The third practical contribution of this research is for governments and quality assurance and compliance agencies (e.g. PwC, SSAFE, etc.). Governments and standard-setting organisations should review their policies in relation to the detection and identification of food fraud to incorporate the new dimensions of vulnerability found in this research. In particular, these policies need to be more prescriptive in defining what is and what is not fraudulent practice, which in turn will allow authorities to apply appropriate legal recourse to fraudsters. Finally, systematic implementation of countermeasures, such as evidence based sampling to detect food fraud, will also assist in the reduction of opportunity for food fraudsters in the supply chain.

5.6 Limitations of the Research

There were two main limitations of this research. The first is temporal in nature and resulted in the research focusing on four categories of food fraud incidents rather than including all 16 categories provided by the data-base. The nature and time constraints of the PhD study program required a narrowing of the scope of the research to facilitate the rigour of analysis and to meet completion requirements. The full rationale for choosing four food fraud incident categories is outlined in chapter 3 and these incident categories represented more than half of all the cases in the database. Whilst this decision may have somewhat limited the applicability of the findings, the process, model and analysis results still provide valuable insights and contributions to food fraud researchers and food production managers. Once again this is an area that could be taken up by future researchers who may wish to compare these results against a wider range of categories to test the rigour of the model.

The second limitation of this research is contextual in nature and refers to the boundaries of discovery inherent in this study. Specifically, deeper and richer understanding of the issues involved in food fraud vulnerability could have added to the results through insights from supply chain or food industry experts. These additional insights may have allowed more practical contributions of the study to be identified. In spite of this, the study's strong empirical contributions to the literature through the results and the modelling approach, provide a valuable platform from which future researchers can extend the findings.

5.7 Recommendations for Future Research

There are a number of further research recommendations that could be undertaken to advance research on FFV factors and their influencing variables. These practical recommendations are based on the previous limitations identified to ensure congruency and scalability of the current study.

In terms of contextual boundaries of the study, future researchers could leverage on the already extensive insight of this study to further investigate other sub classification of FFV factors beyond the scope of the 4 identified.

Employing the Routine Activity Theory future researchers can sieve through other databases and discover new contextual classifications and re-run the model on these databases to enable consistency and validity of the initial findings (i.e. also in different food fraud cases). For example, this study has found that vulnerability to food fraud related to dairy product type has increased mostly due to the opportunity factor while in the other product category was due to the countermeasure factor. The identification of trends among different product types can lead to a better determination of countermeasures for a set of product types.

Linked to the previous recommendation, food fraud can be seen as both a temporal and spatial problem. As an example, horsemeat fraud cases was detected in the UK (2013) only after entering the retail market and consumed by customers. A suggestion would be to track the longitudinal extensiveness (forward and backward tracking) of the food fraud vulnerability incidents like the horsemeat incidents in order to determine the specific proactive measures that would have likely be imposed for the specific area of vulnerability.

In the current detrimental case of coronavirus (also known as covid-19) outbreak (Shaheen 2020)at the time of writing) which had been linked to the consumption of tampered wild animals (, further suggestions provided in section 5.6 such as geographical mapping and sequential analysis could help track spatial and temporal sequence and patterns of multi-disciplinary nature of food fraud, supply chain management, counterfeiting, criminology, and business that can help governments take proactive precautionary measures in time to reduce the area of vulnerability related to each product type. Understanding that these measures are importance first line detection to identifying sources of legitimate food fraud cases which could be linked to bigger repercussions if not identified sooner

For example, branding and brand registration can help minimize the vulnerability to food fraud for product exported in a carcass form (for meat and poultry product type). This can also encapsulate the mobilization of halal certification on certain food types (from preparation to production) where incidents of such efforts can add to the early detection and classification of food fraud with more accuracy in the future. Databases hence need to be updated with more stringent variables of significant protective measures such as this in order to accommodate these new classifications as these new variables could be in fact life-saving at its best. This will reduce the FFV factor related to the nature of the product when detected early.

Finally, methodologically the revised BN model constructed for this study can further be developed with new variables based on expert judgement or other data sources. For example, perhaps considering the level of hazard potential (direct risk; Spink & Moyer 2011) for each food fraud incident could add new insights to our understanding of how these variables interact. Further behavioural models and expert interviews could help to construct a more robust holistic model which can periodically be updated to meet need expectations and circumstances within the industry.

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7 Appendices

Appendix A: Food Fraud Vulnerability Factors

Records ID	Text	Fraud vulnerability sub-category	Fraud Vulnerability category
1591315		N/A	N/A
1528051	'Initially, the Spanish civil guard (La Guardia Civil) seized 10 tons of tuna for not having the necessary traceability for commercialization'......'The result of OPSON demonstrate what can be achieved to protect consumers worldwide when law enforcement agencies join their efforts and perform coordinated actions', 'It is a threat which requires such cooperation…'	Requires coordination between law enforcement agencies/ Extensiveness of traceability	Countermeasure
1476705	'The squad confirmed the presence of the preservative using a testing strip developed by the Central Institute of Fisheries Technology (CIFT).'....'We have been checking all the suspected stocks in the wake of recent reports on adulterated fish. In support of the drive, we have been given three testing kits containing the newly developed strips,' said Mr. Jithinraj	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016), Historic evidence	Opportunity
1292755		N/a	N/A
1292722		N/a	N/A

1292682		N/a	N/A
1135452	‘in absence of a proven testing methodology to detect the presence of formalin or ammonia several such cases went undetected, he said’…… ‘Drives would be held in check-posts as well as local markets. If the lab tests prove adulteration of fish, all stakeholders, including transporters, in the supply chain would be prosecuted. If required, the food safety department would seek the help of police also. The seized truck loads have been sent back to their points of origin for disposing,’ Shylaja said.’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
1135455		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
973684	‘Two out of 75 kinds of food samples were found to have illegal chemicals and dyes,’ he said.	Detectability, Food safety (lack of Food Fraud Vulnerability assessment)	Countermeasure
913161		opportunity in time and Space/Nature of product, Detection of adulterants requires advanced laboratory testing	Opportunity
913178		opportunity in time and Space/Nature of product	Opportunity
868801	‘discovered products including canned food, salmon and octopus that were up to three years past their expiry date’…some of which had no identification or traceability details’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
778679		Requires coordination between law enforcement agencies	Countermeasure

794150	‘The problem was discovered on March 8, 2018, after routine FSIS sampling results revealed violative levels of the chemical leucomalachite green in the products’	Food safety	Countermeasure
681932	This was confirmed by Wilfred Emeku, a veterinary pathologist at Makerere University. ‘If it can kill all organisms then it can also kill the consumer. It can cause damage to the digestive tract, right from the mouth to the lower parts. You would probably expect people to have symptoms like abdominal pain, vomiting, diarrhea and in severe cases even death. Formaldehyde, of course, can destroy human tissue, or even damage the nucleus of the cells and if this occurs, cancers can develop.’	Detection of adulterants requires advanced laboratory testing	Opportunity
588891	‘Except that the restaurant had made a vital mistake. It is virtually impossible to legally buy salmon caught on the River Wye as Natural Resource Wales insists that ‘all salmon and sea trout must be returned with minimum injury and minimum delay’ to protect the fish populations of the rivers.’......These matters arose from a turbulent time for the Foyles of Glasbury business in the summer of 2016 with a high turnover of staff at that time	Special product attributes, Financial Strains (Van Ruth, Huisman & Luning 2017)	Motivation
588881		Special product attributes, Financial Strains (Van Ruth, Huisman & Luning 2017)	Motivation

588875		Special product attributes, Financial Strains (Van Ruth, Huisman & Luning 2017)	Motivation
588869		Special product attributes, Financial Strains (Van Ruth, Huisman & Luning 2017)	Motivation
289925	'…. The fish were then routed by corrupt agricultural inspectors to avoid the usual controls, the statement said '	Corruption level of the country (Van Ruth, Huisman & Luning 2017)	Motivation
289919		Corruption level of the country (Van Ruth, Huisman & Luning 2017)	Motivation
289913		Corruption level of the country (Van Ruth, Huisman & Luning 2017)	Motivation
295758		N/A	N/A
507550		N/A	N/A
308648	'Taiwan has been hit by a wave of recent incidents where food producers and distributors forged labels in order to sell products way past their sell-by dates'	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
480706	'The actions of Sea-Pac Ltd in disguising the traceability of the fishery products by fraudulently changing labels and documentation,' said Aberdeen City Council commercial team manager Andrew Morrison, 'had the potential to detrimentally impact on food safety of consumers as effective traceability is an essential part of the food safety requirements.'	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure

303024	‘ 60 boxes of shrimp weighing a total of 648 kg, all of them with suspicious labels, reports said’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
303022		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
315389	‘Federal criminal experts collected samples of the products for examination in order to prove the evidence produced with the apprehensions already made throughout the investigations’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
115077	‘Trading standards are able to trace some of the sellers but often buyers pay in cash and don’t see the van that the sellers use.’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
572342	The companies failed to pass food safety checks to enter the EU, according to the Rapid Alert System for Food and Feed (RASFF).	Food Safety/Lack of definition of food fraud/ border rejection	Countermeasure
116602		Food Safety/Lack of definition of food fraud/ border rejection	Countermeasure
93093		Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
197572		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
213209		N/A	N/A
214247		Lack of Law Enforcement (SSAFE 2016)	Countermeasure

132219	Dr T K Shankar, head of quality assurance, CIFT, Kochi, said, 'Food safety officers (FSO) from different parts of the state send samples of fish to check contamination in the institute's laboratories. The reports are sent to the respective food safety authorities.'	Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
112951		Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
112949		Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
100303	'The Taipei District Prosecutors Office raided a site on Taipei's Renai Road Thursday where they found evidence dating back to 2014 that dates had been changed on the products, which included three types of abalone from Chile's Panamericana Seafood, ice fish and salmon.'.....'Prosecutors claimed that Chen received help from Hsiang Ting Kang Co (祥鼎康), which is owned by Liang, to change the dates on the seafood products and sold them.'	Extensiveness of Traceability	Countermeasure
100301		Extensiveness of Traceability	Countermeasure
100299		Extensiveness of Traceability	Countermeasure
96418	The problem was discovered on July 11, 2016, after routine FSIS sampling results revealed a violative level of the chemical gentian (crystal) violet in the product.	Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure

95420	‘The fraud was detected during an internal investigation by the hotel chain, prompted by another chain, Prince Hotels, admitting that its expensive ‘domestically produced beef’ had in fact come from Chile.’.....’luxury establishments mislabelling ingredients appears to have started at the time of the global economic crisis in 2008, probably driven by a desire to reduce costs while still keeping prices high’	Economic Health and Level of Competition, Special product attributes	Motivation
94316		Economic Health and Level of Competition, Special product attributes	Motivation
93207		Economic Health and Level of Competition, Special product attributes	Motivation
93194		Economic Health and Level of Competition, Special product attributes	Motivation
90337	ECNS) -- Police in Jinan, capital of East China's Shandong province, have seized tons of turbot fish contaminated with banned drug furacilin, and arrested three suspects, dzwww.com reported on Monday. Furacilin has been banned as a veterinary drug by the Chinese Ministry of Agriculture since 2005 due to health risks that could lead to cancer and birth defects.	Food safety, Lack of law enforcement	Countermeasure
71657		Detection of adulterants requires advanced laboratory testing	Opportunity

71573	‘Analysis showed the fish was actually Pangasius Hypophthalmus, a type of catfish known as the iridescent shark.’…..The market-town chippy that sold counterfeit cod shops have been able to get away with the scam because neither fish has a strong taste, and any difference is often masked by batter, salt and vinegar’	Ease of alteration, detection of adulterants requires advanced laboratory testing	Opportunity
71452	‘The Times had the crab DNA tested by Bob Ulrich in USF’s College of Marine Science, the identification performed by PureMolecular’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
71220	‘The meat was scooped out from a variety of lobster dishes and sent off to a lab, where DNA tests were carried out to see if there was anything fishy about the lobster’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
69802		Ease of alteration- DETECTION REQUIRES ADVANCED LABORATORY TESTING	Opportunity
68861	Ito-Yokado, and the others are suspected of conspiring to falsely name the importer as Takayama Seafood Co., a fisheries wholesaler in Tokyo, and reselling the eel products to Yokoyama-based seafood distributor Yamato Foods Co. and others last year, the police said	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure

68588	‘However, Stephen said there is very little public health risk because there was such a low level of malachite green detected.’,,,,,’Stolt Sea farms won't be able to sell on Canadian markets the 310,000 chinook still swimming at the farm in question.’......’CFIA approval is needed even if Stolt wants to export all of the fish to countries that don't have a zero-tolerance policy for malachite green.’	Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
68286	‘…..Kaohsiung, Sept. 14 (CNA) Kaohsiung authorities have seized more than 51 tonnes of expired and unlabeled food from two food companies in the city’ ‘The suspects allegedly sold the products to downstream vendors after replacing the original expiry date labels with new forged ones, the authorities said’....’The authorities seized 51 tonnes of frozen food products during the raid, including soft-shell shrimp, squid and lumpfish, as well as packing lists, sales slips, and inventory lists of the companies.’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
68284		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
67436	‘USDA inspections send another shipment of Asian fish packing’Hopefully, before any vote they’ll have access to more than seafood import lobbyists. ‘....They might start with an updated review of Oceana’s 2014 seafood fraud studies, which found fish fraud on every continent except Antarctica’	Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure

66976		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
62896		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
62862		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
58088	where they changed the items' packaging and altered their production dates to evade taxes and avoid quarantine, Li Fudong of the QCD Anti-Smuggling Department told CCTV.	Extensiveness of Traceability- Requires coordination between law enforcement agencies , Food safety	Countermeasure
58082		Extensiveness of Traceability- Requires coordination between law enforcement agencies	Countermeasure
58080		Extensiveness of Traceability- Requires coordination between law enforcement agencies	Countermeasure
58076		Extensiveness of Traceability- Requires coordination between law enforcement agencies	Countermeasure
56929	the production cost of the artificial jellyfish was less than half the cost of processing real jellyfish. In addition, less time is required to produce artificial jellyfish than is needed to process real ones.	Ease of alteration	Opportunity
56326		Opportunity in time and Space	Opportunity

56021		Opportunity in time and Space	Opportunity
56019		Opportunity in time and Space	Opportunity
52904	‘ ...the Consumer and Environmental Protection Unit of the Office of the City Attorneypurchased advertised ‘lobster rolls’ from various sushi restaurants throughout San Diego, then sent them to alaboratory where DNA testing confirmed that no lobster was in fact in any of the rolls.’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
51808		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
51462	‘CBC found empty cartons for frozen fish fillets imported from Kazakhstan in the Wildcat's garbage bin. The fillets are marketed as a cheaper substitute for pickerel’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
50413	‘Chinese food authorities have not been particularly active in pursuing the cases brought to their attention, according to interviews and news reports, and there is not even a consensus at which point in the production line the operation takes place’…..Such gel, the presence of which is not typically detectable upon superficial inspection, is injected some time between when the shrimp are caught and when they’re sold, in order to add weight and thus earn a greater profit.	Lack of Law Enforcement (SSAFE 2016)	Countermeasure
36416	‘sold him what he claimed was Russian sevruga caviar, but DNA testing proved it was not; the vast majority of the eggs came from American paddlefish, a protected species indigenous to the United States’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity

36412		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
36076	‘The problem was discovered on July 11, 2016, after routine FSIS sampling results revealed a violative level of the chemical gentian (crystal) violet in the product’	Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
34335		Requires coordination between law enforcement agencies	Countermeasure
31884	‘state and U.S. authorities have begun to clamp down with inspections, DNA testing and even indictments’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	opportunity
31495		Nature of Product (BRC 2015), Easy alteration	opportunity
31321	The following day, at MKG’s customer’s business premises, FDACS inspectors found the same 54, ten pound cases, of the haddock observed on September 15, again bearing false ‘Product of the USA’ labels. An additional 20 cases of haddock were located in the customer’s place of business, also falsely labeled by MKG to conceal the origin of the product being China.	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
31088	‘Between June and August 2004, Universal Group purchased over 90,000 pounds of frozen fish fillets worth over $300,000 that was invoiced as ‘China basa’, a type of Asian catfish. Universal commissioned a cold storage facility to re-label the containers of the fish as grouper, and sold the relabeled fish to a national restaurant chain.’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017), Food safety (inspection)	Countermeasure

31030		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
30990	‘Selling farm-raised Asian catfish and Lake Victoria perch falsely labeled as grouper, selling foreign farm-raised shrimp falsely labeled as U.S. wild caught shrimp, selling shrimp they falsely claimed to be larger, more expensive shrimp than they actually were, and for buying fish they knew had been illegally imported into the United States’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
30981		Detection of adulterants requires advanced laboratory testing	opportunity
30979		Detection of adulterants requires advanced laboratory testing	opportunity
30969		Detection of adulterants requires advanced laboratory testing	opportunity
30737		Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure

30667	‘a scheme through which Platt oversaw the false repackaging and labeling of 1,500 pounds of frozen chum Salmon fillets. The fillets, which were ‘Product of China,’ were re-labeled as being chum Salmon fillets, ‘Product of Russia.’ In addition, Platt and Shifco pled guilty to a scheme to re-label more than a million pounds of less marketable shrimp from Thailand, Malaysia, and Indonesia, as being from Panama, Ecuador, and Honduras’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
29852	‘The falsely labeled shrimp was later sold by Alphin Brothers in interstate commerce to customers in Louisiana’ ‘Federal regulations require seafood retailers to provide customers with notice of the country of origin and the method of production, wild-caught or farm-raised, of shrimp and other shellfish. These regulations are known by the acronym COOL, which stands for ‘country of origin labeling.’’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
29317	‘Independent DNA testing’ confirmed that the largest Hispanic-owned U.S. food company made the switch, according to a complaint filed late Wednesday in the federal court in San Jose, California.	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
28451	at DNA tests on several Casey's Seafood products purchased in Virginia, North Carolina and Delaware contained mixtures of Atlantic blue crab and some cheaper alternatives native to foreign waters.	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
24820		N/A	N/A

24799	‘Garcia kept the shrimp in the same plastic crates but got rid of labels reading ‘Pollo Supermercado’ and other messages in Spanish. It shipped the crates to Brownsville, Texas, and slapped new tags on them, indicating the shrimp had been caught by a Texas shrimp boat, the Regio.Then the company created false bills of lading and sold the shrimp to a New Orleans-based distributor, according to U.S. Attorney Kenneth Polite’s office’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
23390		Lack of Law Enforcement (SSAFE 2016)	Countermeasure
20363	Researchers at the University of South Florida tested restaurant and raw grouper samples from across metro Atlanta, using a new technology designed to quickly detect mislabeled fish ‘Paul and his partner, Dr. Bob Ulrich, invented a new genetic test that is designed to spot fish imposters in less than an hour, rather than several days needed for traditional DNA testing’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
19423		Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
17806	‘But when contacted by China Daily, the publicity department of the city said they had not heard anything about it’	Lack of Law Enforcement (SSAFE 2016), Food safety	Countermeasure
17788	‘We will also conduct an internal test to re-check the products. Usually, we only make random checks,’ he said.	Food safety	Countermeasure
17786		Food safety	Countermeasure

17741	‘Indonesia's parliament blamed the Ministry of Health for failing to properly monitor food standards’	Lack of Law Enforcement (SSAFE 2016), Food safety	Countermeasure
17419		N/A	N/A
17357	The CFS spokesman said a warning letter was sent to the retailer involved. The agency is ‘collecting sufficient evidence for prosecution.’…..’CFS, a unit of the Food and Environmental Hygiene Department that serves the Special Administrative Region that governs Hong Kong, targeted formaldehyde in noodlefish in a recent targeted food surveillance exercise. Results showed that one of the 10 samples taken contained formaldehyde at a level of 600 parts per million (PPM). The test samples were collected from various retail outlets.’	Food safety	Countermeasure
17271	The exporter had ‘significantly impeded this proceeding by submitting information containing material misrepresentations and inaccuracies.’	Requires coordination between law enforcement agencies /Extensiveness of Traceability	Countermeasure
17213			n/A
17141	No authority has yet confirmed whether gelatin is harmless to humans	Lack of Law Enforcement (SSAFE 2016), Food safety (lack of definition of food fraud)	Countermeasure
17022	N/A	N/A	N/A
16910	seized four shipments of black eggs from Caviarteria after DNA testing said it was underrated,	Detection of adulterants requires advanced laboratory testing	Opportunity

16833		Detection of adulterants requires advanced laboratory testing	Opportunity
16788		Detection of adulterants requires advanced laboratory testing	Opportunity
16784		Detection of adulterants requires advanced laboratory testing	Opportunity
16780		Detection of adulterants requires advanced laboratory testing	Opportunity
16778		Detection of adulterants requires advanced laboratory testing	Opportunity
16774		Detection of adulterants requires advanced laboratory testing	Opportunity
16772		Detection of adulterants requires advanced laboratory testing	Opportunity
16086	Some results were positive for chloramphenicol, and Mr. Odom issued an emergency order requiring tests of all Chinese shrimp and crawfish sold in the state. But Mr. Odom said he had also found traces of the drug in some boxes of shrimp labeled "Product of Louisiana," meaning that somewhere along the line processors may have mixed foreign shrimp with the local catch.	Food safety/border rejection	Countermeasures

16079	‘The test, conducted by Taiwan?s Eastern Television on Tuesday, showed the crab sample contained the harmful chemical chloramphenicol, Ming Pao Daily reported on Wednesday’ test will be done to all products imported from China	Food safety/border rejection	Countermeasures
16070	Until recently, the sensitivity of the methodology to detect chloramphenicol in shrimp could find the drug down to 5 parts per billion (ppb). Recently, Canada, and the European Union (EU), have refined their methods to detect even lower levels, and, have taken action on food products from China and Viet Nam found to be contaminated by chloramphenicol	Food safety/border rejection	Countermeasures
15663	‘….replaced sea bass with a cheaper oriental perch, then forged an email confirming it was the same fish’	Extensiveness of Traceability (SSAFE 2016; Van Ruth, Huisman & Luning 2017)	Countermeasure
13386		Detection of adulterants requires advanced laboratory testing	Opportunity
13363	Nobody told us it was illegal,’ chief executive Francois Agussol said.	Food Safety/Lack of definition of food fraudBorder rejection	Countermeasure
13319	‘The Sunday Mail can reveal that DNA testing of samples taken off shelves found that expensive fillets being sold as haddock were a different fish altogether’ ‘As a problem has been found in the smoked fish, it would be worthwhile carrying out DNA analysis on prepared uncooked meals claiming to contain a specific species.’	Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity

13315		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
13307		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
13305		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
13303		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
13300		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
13298		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
13296		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity
7517		Detection of adulterants requires advanced laboratory analysis (SSAFE 2016)	Opportunity

1609906	‘It came after trading standards officers visited the store in June last year, following a complaint, and found a 1kg sample of lamb actually contained 10 per cent beef as well as 23 food items past their use-by date. Collectively these items added up to over a year - 374 days - past their use by dates. Both the supermarket and Mr Iqbal had been cautioned before for the same offences’	Detection of adulterants requires advanced laboratory testing	Opportunity
1589639	‘ The chemical which is purchased for KSh 650 for a 500 grams packet is readily available in local agrovets and pharmacies’	availability of adulterants/ Detection requires laboratory testing	Opportunity
1529784	‘A Grand Jury indicted Randal Hamby, a corporate official of the Atlanta-based Amigos Meat Distributor, June 26 for conspiracy, forging an official device and mark, and the adulteration and misbranding of poultry products’.... ‘He is accused of seeking a ‘technology specialist’ to create, manufacture, and print fraudulent labels that included the USDA mark of inspection’.	Extensiveness of Traceability/ Food safety (inspection)	Countermeasures
1422102	‘In three separate raids conducted over the course of a few weeks, officers found that individuals and companies were apparently tampering with seals and labels to extend the shelf life of expired food products’...... ‘This latest fraud involves taking expired food products that should legally be destroyed, altering their labels, and putting them back on the market’.........’ An inspection of the warehouse revealed ‘anomalous’ labeling, and signs that these had been tampered with, said Civil Guard sources.	Extensiveness of Traceability/ Food safety (inspection)	Countermeasures

1273632		Extensiveness of Traceability	Countermeasures
1386401	'Food inspectors seal facilities used to produce fake donkey meat during a raid in Hejian in China's northern Hebei province on January 9, 2018'.....'That is the warning from authorities in China after a media investigation revealed that some butchers in a city famed for its donkey burgers had engaged in a nefarious plot to substitute donkey with cheaper meats'	Nature of Product (mixed/mince/burgers), Opportunity in time and space	Opportunity
1142822	N/A	N/A	N/A
1059858	N/A	N/A	N/A
913376	'On Friday, officers with the committee inspected the factory and found 340 kilos of beef meatballs, 25 kilos of pork meatballs and some ingredients, such as 60 kilos of tapioca starch flour, 125 kilos of Master Chef seasoning and other ingredients to mix with the meat.'........' The committee said the business was operating without legal permission, adding that the location had no proper technical specifications or sanitary standards'	Food safety/ Lack of definition of food fraud/lack of law enforcement	Countermeasures
913372		Food safety/ Lack of definition of food fraud/lack of law enforcement	Countermeasures
868799	' police found a freezer with 30000 kilos of meat, some of which had no identification or traceability details'	Extensiveness of Traceability	Countermeasures
766007		Nature of Product (ground/mince)	Opportunity

788477		Food safety	Countermeasures
788492		Extensiveness of Traceability	Countermeasures
655996	‘ A man has appeared in court charged with selling mislabelled meat which falsely advertised the produce as British’...... ‘The charges included the sale of non-British meat under banners stating ‘Best British Beef, Best British Pork, Best British Chicken and Poultry and Best British Lamb’’...... ‘The food labelling system, announced by Defra Secretary Michael Gove, will showcase Britain's animal welfare standards coupled with a detailed country of origin label, and could be rolled out across supermarkets after Brexit’.	Extensiveness of Traceability	Countermeasures
656002		Extensiveness of Traceability	Countermeasures
656012		Extensiveness of Traceability	Countermeasures
656018		Extensiveness of Traceability	Countermeasures
681928	‘What was new, however, was the crackdown by low-functioning teams from city authorities and Uganda National Bureau of Standards.These teams didn’t act until media reports highlighted the breadth and depth of the illegal and potentially harmful practice’....’. But the quality controllers are doing little or nothing to protect consumers’.	Lack of law enforcement/ Food safety (weak controls over food fraud)	Countermeasures

681930		Lack of law enforcement/ Food safety (weak controls over food fraud)	Countermeasures
518940	'The country's largest supplier of supermarket chicken suspended production at one of its main processing plants on Sunday in the wake of a Guardian and ITV News investigation that revealed poor hygiene standards and food safety records being altered'....'The food group said the problems related to food hygiene rather than regulatory breaches at the factory'.	Food safety /staff needs training on food fraud and food safety compliance with law	Countermeasures
303110	'Upon inspection the Health Bureau of Taichung City found 1,674 boxes of frozen pig intestines without any expiration date labels, 333 boxes with the labels ripped off'	Extensiveness of Traceability/ Food safety (inspection)	Countermeasures
303108		Extensiveness of Traceability/ Food safety (inspection)	Countermeasures
390535	' They worked in co-ordination with Belgium, France, Italy, Portugal, Romania, Switzerland and the UK, Europol said in a statement'…...' Microchips and documentation were modified by the crime group'	Requires coordination between law enforcement agencies / Extensiveness of Traceability (easily can be modified or counterfeited)	Countermeasures

390509	'The Ras Al Khaimah Police, in collaboration with the RAK Municipality, have busted a factory involved in manufacturing and selling expired meat'.... ''The factory management proved to have manipulated the validity dates of their meat products by repacking them in new plastic bags and cans with revised dates, and offering them for sale,' said Brig Menakhas'...... 'The public health section of the RAK Municipality has an efficient cooperation mechanism with the RAK Police to crack down on all such crimes,' added Brig Menakhas.	Extensiveness of Traceability/ requires coordination	Countermeasures
309055	'He said it was almost impossible for farmers to know when restaurants are falsely claiming to be serving their products. 'In a lot of cases it comes from whistle blowers or strong supporters of our brand who bring it to our attention,' Mr Jones said.'.......'I don't really know how we fix the problem long term because there is no one to police it, which is really frustrating,' she said.'.... 'In a lot of cases it comes from whistle blowers or strong supporters of our brand who bring it to our attention,' Mr Jones said.	Lack of law enforcement/Whistle blowing system	Countermeasures
317190	'It said the food consignment was seized by the Jordan Food and Drug Administration, and that those involved were arrested, noting the efforts of official and security agencies and the follow-up by the competent authorities to stop spoiled food from reaching the public and ensure food safety in the country'	Requires coordination between law enforcement agencies , Food safety	Countermeasures
287441	'but the nature of the products – hamburgers, meat balls etc – meant that the deception could only be uncovered through analysis in a specialised laboratory'	Nature of Product (hamburger)/ detection needs laboratory testing	Opportunity

121424	'Buildings were dilapidated, in places open to the elements, the surrounding land is infested with rats and parts were covered with standing water which was contaminated with sewage.'	Food safety	Countermeasures
121420		Food safety	Countermeasures
22770	The applicants had investigated the matter after a Samic employee alleged he had discovered in June that Orion had imported water buffalo meat from India and sold it to Frey's Food Brands as AB/B grade beef. The informant, Tobias Lombard, a former Orion sales agent, had provided cellphone videos allegedly showing Orion employees using heat guns to remove the original labels from goods.	Extensiveness of Traceability / Whistle blowing system	Countermeasures
22767		Extensiveness of Traceability	Countermeasures
22760		Extensiveness of Traceability	Countermeasures
22756		Extensiveness of Traceability	Opportunity
22754		Extensiveness of Traceability	Opportunity
22746		Extensiveness of Traceability	Opportunity
22744		Extensiveness of Traceability	Countermeasures
22737		Extensiveness of Traceability	Countermeasures

22731		Extensiveness of Traceability	Countermeasures
22727		Extensiveness of Traceability	Countermeasures
13437		Extensiveness of Traceability	Countermeasures
262939	N/A	N/A	N/A
128972	‘We have sampled dishes from a number of takeaways across Gateshead to make sure the customer is being sold what is advertised on the menu.	Detection of adulterants requires advanced laboratory analysis	Opportunity
213257	‘Current and former employees of German pizza and pasta chain Vapiano told Welt am Sonntag that the restaurants regularly serve up discoloured noodles and change expiration dates on spoiling food.’........’Meats and vegetables were re-labelled, sometimes with extended expiration dates. These foods then ended up on the plates of customers, smelling peculiar’.	Extensiveness of Traceability/whistle blowing system	Countermeasures
213253		Extensiveness of Traceability/whistle blowing system	Countermeasures
212910	‘Federal Food, Agriculture and Consumer Protection Minister Horst Seehofer said in the Bavarian capital of Munich that the EU authorities had been informed, as there appeared to be a European dimension to the fraud’.... ‘German politicians are demanding action at European Union level’	Extensiveness of Traceability/ Requires coordination between law enforcement agencies / lack of law enforcement	Countermeasures

158917	‘ Food tests discovered turkey DNA in dishes that were supposed to be lamb’	Detection of adulterants requires advanced laboratory analysis	Opportunity
213062	‘The date labels have been forged, so that their real use-by dates are extended by up to another twelve months’	Extensiveness of Traceability/ lack of law enforcement/food safety	Countermeasures
213060		Extensiveness of Traceability/ lack of law enforcement/food safety	Countermeasures
210798	‘ bribing inspectors to allow rotten meals to be served in public schools and salmonella-contaminated meat to be exported to Europe’.... ‘ investigators said that employees at two food-processing giants, JBS and BRF, paid federal inspectors to ignore the adulteration or expiration of processed foods’...... Inspectors also falsified sanitary permits, and bribes were channeled to the Brazilian Democratic Movement Party of President Michel Temer, according to the authorities’.......’one more element that will add to the picture of political instability.	(Inter)national corruption level	Motivation
210792		(Inter)national corruption level	Motivation
165969		Special product attributes	Motivation
130979	N/A	N/A	N/A

127619	'Speaking to The Sun, one whistle-blower said: 'I looked at the ingredients and noticed it actually contains pork and beef.'I queried it with management but they didn't care. Three months on and the menus still say beef lasagne, and waiters have not been told to warn customers.''	whistle blowing system	Countermeasures
123057	'because some of these people that roast chicken do mix them with vulture and customers will not know they will buy and eat. What a terrible thing.'	Nature of Product/mixed	Opportunity
122960		Nature of Product/ Detection of adulterants requires advanced laboratory analysis	Opportunity
122955		Nature of Product/ Detection of adulterants requires advanced laboratory analysis	Opportunity
122912	'Evidence was found that rancid chicken that had turned yellow through putrefaction was bleached with chemical agents to make it look like healthy meat. Much of the boxed meat at the plant had begun decomposing before it was frozen. Rick Mason, head of food safety at Tower Hamlets, said the meat was destined for specialist food shops including halal butchers and Afro-Caribbean outlets.'	Extensiveness of Traceability/ lack of law enforcement/food safety/requires coordination	Countermeasures
122906		Extensiveness of Traceability/ lack of law enforcement/food safety/requires coordination	Countermeasures

121360		Extensiveness of Traceability/Food safety	Countermeasures
118807	‘ Officers conducting a raid of the restaurant on Wednesday morning discovered caged dogs in the kitchen, a decapitated puppy in the trash and the owner himself in the process of decapitating and butchering a canine carcass, putting the meat in a cooking pot Samples of meat were also taken from the kitchen fridges in order to determine the origin of the meat.	Nature of Product (carcass)/detection requires advanced technology testing	Opportunity
118699	‘The defendants had allegedly mixed their meat with spices to cover up the bad odour of the meat and sold it for 20 Egyptian pounds [about Dh13.6] per kg.’...’the vets says its kinda hard to know the different between the donkey's meat and the cow's meat’	ease of adulteration/ Nature of Product (carcass), Detection of adulterants requires advanced laboratory testing	Opportunity
116586	‘The duck meat is ground into small pieces and mixed with a special red-color sauce, which makes it looks and tastes like real beef’	ease of adulteration/ Nature of Product (carcass)	Opportunity
104861		ease of adulteration/ Nature of Product (carcass)	Opportunity
102159		Lack of law enforcement/Food safety	Countermeasures
100188	N/A	N/A	N/A
94320		Economic Health and Level of Competition	Motivation

93111		Economic Health and Level of Competition	Motivation
88834		Food safety	Countermeasures
75999	‘Cericola Farms was the subject of allegations by its former director of operations, Vashti Dalipsingh, who said fraudulent labelling had been happening as far back as April, 2015.’.....’Ontario supplier charged with mislabelling chicken as organic- An Ontario poultry producer that supplied meat to some of Canada's largest grocers has been charged with mislabelling conventional chicken as ‘certified organic.’…..’They are also charged with violating the Organic Products Regulations, which sets strict standards for what types of products can be labelled ‘organic.’’	Extensiveness of Traceability /Whistle blowing system	Countermeasures
70149		Detection of adulterants requires advanced laboratory analysis	Opportunity
70147		Detection of adulterants requires advanced laboratory analysis	Opportunity
69819		Nature of Product (whole chopped leg carcass), Detection of adulterants requires advanced laboratory testing	Opportunity
69796		Ease of alteration	Opportunity
69794		Ease of alteration	Opportunity

65654	‘But I just don’t understand, how difficult is it to implement the rule of law?’	Lack of law enforcement/Food safety	Countermeasures
65652		Lack of law enforcement/Food safety	Countermeasures
65650		Lack of law enforcement/Food safety	Countermeasures
63306	The arrests Monday followed an investigation by the Israel Police, Agriculture Ministry, and Health Ministry. Additional arrests were expected. Officials Monday confiscated 30 tons of meat, thousands of dollars in cash, and vehicles with secret compartments used in the scheme, which involved the cooperative efforts of Palestinian and Israeli smugglers.	requires coordination between law enforcement agencies	Countermeasures
56555	‘told the paper that fake duck blood was made from poor-quality pork blood and might be mixed with formaldehyde and industrial pigment, which are harmful to liver and kidney’	Ease of alteration	Opportunity
56416		Transparency supply chain/Nature of Product/ detection requires laboratory testing	Opportunity
54738		Lack of law enforcement/food safety	Countermeasures
54210		Food safety/lack of law enforcement	Countermeasures

54182	The factory had improved its conditions when the officials returned for a second inspection on August 5, and it was only fined 5,000 yuan for incorrect information on its ingredients, the report said.	Lack of law enforcement/food safety	Countermeasures
54159		Detection of adulterants requires advanced laboratory testing	Opportunity
51918	‘They were prosecuted after tests revealed that ‘lamb’ mince was being bulked up with cheap cuts of beef before being sold on’…...’A sample pattie taken from a Trafford bakery was found to contain only 50pc lamb.’	Nature of Product/Detection of adulterants requires advanced laboratory analysis	Opportunity
51537	In a statement following the court ruling on Friday, the Food Safety Authority of Ireland (FSAI), which had investigated the company in conjunction with Meath County Council, welcomed the decision. The FSAI said the ruling was important for consumer confidence in the system.	Food safety, Requires coordination between law enforcement agencies	Countermeasures
51156		Extensiveness of Traceability/ /requires coordination	Countermeasures
50430		Extensiveness of Traceability/ /requires coordination	Countermeasures
36959	‘The show included footage of ICA employees putting labels with new expiration dates on packages of meat and reselling them in four different ICA stores.’…...Four separate preliminary investigations were launched, but three of the investigations were abandoned due to a lack of corroborating evidence. ‘	Extensiveness of Traceability/ lack of law enforcement	Countermeasures

36274	No information available for this report	N/A	N/A
34495		Extensiveness of Traceability/ lack of law enforcement	Countermeasures
34493		Extensiveness of Traceability/ lack of law enforcement	Countermeasures
34113		Requires coordination between law enforcement agencies	Countermeasures
180030		Requires coordination between law enforcement agencies	Countermeasures
180015		Requires coordination between law enforcement agencies	Countermeasures
27425	‘Overnight, investigators were testing in virtually every country for horse DNA potentially showing up where it shouldn’t be. As horse meat was found in everything from frozen burgers to packaged lasagna, recalls of 50,000 tons of meat products were soon underway throughout Europe	Transparency supply chain/Nature of Product/ detection requires laboratory testing	Opportunity
27179	N/A	N/A	N/A
27024	The council's environmental health department, together with the Food Standards Agency, detected the illegal operation after an extensive and costly investigation.	Requires coordination between law enforcement agencies	Countermeasures
27013		Requires coordination between law enforcement agencies	Countermeasures

26786	Allemang of Clearwater, NE in January after federal inspectors discovered 300 pounds of sausages, 400 pounds of beef jerky, bacon and deer meat in bags labeled as ground pork. The mislabeled meats had not undergone inspection by the U.S. Department of Agriculture, but still bore the USDA mark of inspection.	Extensiveness of Traceability/food safety	Countermeasures
26777		Extensiveness of Traceability/food safety	Countermeasures
26773		Extensiveness of Traceability/food safety	Countermeasures
26024	The federal jury in Cedar Rapids, IA, found William B. Aossey Jr. guilty on 15 counts, including conspiracy, falsifying export certificates, and wire fraud.	Extensiveness of Traceability	Countermeasures
25961		Nature of Product (mixed)/detection requires laboratory testing	Opportunity
25530		No information is available for this Incident	N/A
25475		lack of law enforcement (Hoecht and Trott 2014)	Countermeasures
25401		Extensiveness of Traceability	Countermeasures
24975		Lack of law enforcement	Countermeasures

24965	'Jiangsu police said the illegal traders started operating soon after the ban was imposed, but were not discovered until earlier this year because of their cautious sales practice.'….They would take orders for the smuggled beef only by phone and dispatch a driver to deliver the beef after receiving money via bank transfer, police said'	Extensiveness of Traceability	Countermeasures
24384		Extensiveness of Traceability	Countermeasures
24376	'The swindle was only detected by the Food Standards Agency (FSA) using new scientific techniques because the non-chicken material had been so highly processed it passed standard DNA tests.'....'When complaints began to surface again last year, the FSA launched a secret investigation to ascertain whether chicken – the most eaten meat in the UK – was being adulterated again. At first, scientists could not find any non-chicken protein because the meat had been 'de-natured' (made unrecognisable). The Central Science Laboratory in York and York University developed special DNA market tests'....'It's like Olympic drug tests; they stay one step ahead of the testers,' said a source close to the investigation'......'Using a new DNA marker technique, the FSA tested five protein powders from three companies. All five were found to contain a non-poultry material identified as bovine collagen. Further tests found the presence of porcine material in two powders'	Detection of adulterants requires advanced laboratory analysis	Opportunity
24227		Extensiveness of Traceability	Countermeasures
23517		Detection of adulterants requires advanced laboratory testing	Opportunity

23515		Detection of adulterants requires advanced laboratory testing	Opportunity
23498	The Chinese branch of Wal-Mart super stores is issuing a recall of donkey meat products after some of it was found to contain fox DNA.	Detection of adulterants requires advanced laboratory analysis	Opportunity
23465		Detection of adulterants requires advanced laboratory analysis	Opportunity
23371	Samples of meat were taken and sent to a laboratory to be analysed.	Nature of Product/Detection of adulterants requires advanced laboratory analysis	Opportunity
23317	'…. said on Sunday that Husi, owned by OSI Group of Aurora, Ill., repackaged stale beef and chicken and put new expiration dates on them. It said they were sold to McDonald's, KFC and Pizza Hut restaurants'	Extensiveness of Traceability	Countermeasures
23313		Extensiveness of Traceability	Countermeasures
23239	'One of the pieces of sausage tested, made by Aktual and supplied by Expo Foods, was found to contain the high levels of horsemeat'	Detection of adulterants requires advanced laboratory analysis /Nature of Product (sausage mixed)	Opportunity
22839	'accompanied by a falsified quarantine certificate. 'It was night, and the duty person might not have noticed that it was a fake certificate'	Food safety/ lack of definition/ Extensiveness of Traceability (falsifying certificates), Weak import controls	Countermeasures
22776		Food safety	Countermeasures
22611		Food safety	Countermeasures

22293	‘The case was prosecuted by Assistant United States Attorney Richard L. Murphy and Timothy L. Vavricek and investigated by the United States Department of Agriculture Office of Inspector General Investigations and Internal Revenue Service Criminal Investigations. ‘......’As part of the scheme to ship misbranded meat products, USDA export documents were falsified and fake health certificates were generated by Midamar and ISA employees USDA, Food Safety and Inspection Service (FSIS) letterhead’	Extensiveness of Traceability (paper certificates), Requires coordination between law enforcement agencies	Countermeasures
22166	‘ The minced beef was found to contain DNA of pork, chicken, and lamb not listed on the label. The minced pork detected the DNA of beef, chicken, lamb, and a beef and lamb semi-kebab also found pork traces’	Detection of adulterants requires advanced laboratory analysis	Opportunity
22161		Detection of adulterants requires advanced laboratory analysis	Opportunity
22095	‘Bashas’ upper management became aware of the USDA’s investigation and cooperated with investigators, court records show. Store officials provided investigators with internal records, made employees available for interviews and initiated an internal investigation.’......’The Arizona-based retailer is operated by Bashas’ Inc., reports the Associated Press, and was accused of selling meat wrongly labeled ‘.... ‘Officials say workers in the meat department at some stores would slap the ‘prime’ label on steaks that had been graded as ‘choice’ under the USDA system and also mislabeled ‘Kobe’ ground beef’	Extensiveness of Traceability , Food safety	Countermeasures

21165		Extensiveness of Traceability , Whistle blowing system	Countermeasures
20303	N/A	N/A	N/A
19932	a NSW Food Authority inspection revealed discrepancies in the abattoir livestock and slaughter records at the abattoir, making it apparent that older animals had been processed and supplied to its customers as lamb'	Food safety	Countermeasures
19740	'ivestigation tested 60 lamb takeaways from a selection of Birmingham and London restaurants and revealed that 40% of the meals were contaminated with other meats. '..The meals that tested positive for undeclared meat showed the presence of beef, chicken, and in one sample pork, although the latter was not sold as a halal product.	Detection of adulterants requires advanced laboratory analysis	Opportunity
19038	Inside the bunker, police discovered an elaborate operation, where the Polish ham was repackaged and issued with counterfeit labels of Italian companies - including prestigious Parma ham producers. Police confiscated an array of equipment used in the fraud such as fridges, knives, hair nets and work stations. It may sound like a professional operation - but according to police, the workshop was a veritable pigsty.	Extensiveness of Traceability	Countermeasures
18778	''The floor was spattered with blood and there was bad smell,' the local Modern Express newspaper reported in a grisly dispatch from inside the slaughterhouse. '	Food safety/lack of law enforcement	Countermeasures

18546		Extensiveness of Traceability (relabelled beef from USA as Australian due to suspension of JBS USA	Countermeasures
17392		lack of law enforcement/ Extensiveness of Traceability	Countermeasures
17365	Experts called for the establishment of a nationwide supervision network and enhanced controls in border regions to prevent the products from entering China.	Requires coordination between law enforcement agencies	Countermeasures
17363		Requires coordination between law enforcement agencies	Countermeasures
17361		Requires coordination between law enforcement agencies	Countermeasures
17269	'The pair were due to stand trial at the court but pleaded guilty to falsely describing food and failing to comply with food traceability requirements.'...'He continued: 'The rule is that food should be traceable from the farmyard to the fork'…..Food inspectors found 19 boxes of meat falsely labelled as lamb at Farmbox Meats near Aberystwyth in Wales, Southwark Crown Court heard.	Extensiveness of Traceability/ Food safety (inspection)	Countermeasures
17267		Extensiveness of Traceability	Countermeasures
17250	N/A	N/A	N/A

17059		Extensiveness of Traceability/lack of law enforcement	Countermeasures
16499	‘AN analysis of eight beef products imported into the country by Zambeef seen by The Post has confirmed the presence of aromatic aldehyde’	Food safety	Countermeasure
16491	The chicken feet tested were found to be unsafe for consumption, poisoned with bleach and other chemicals meant to make the feet appear fresh-looking and extend their shelf life,	Food safety	Countermeasures
16467	‘An investigator at the agency, Pontus Elvingson, told the BBC that tests were still being done to identify the dye.’	Detection of adulterants requires advanced laboratory analysis	Opportunity
16432	three employees of the animal quarantine and inspection station in Qinyang were sentenced to five to six years in prison for dereliction of duty. They were found to have issued permits without testing pigs and allowed 38,000 contaminated animals to be sold to Jiangsu and Henan, China National Radio reports.	Food safety (weak quality controls)	Countermeasures
16373	N/A	N/A	N/A

15265	' Pitt Meadows Meats had reportedly received a positive test result for E. coli O157:H7 in September 2010 but did not recall the meat, according to the court's statement of facts. However, after a plant employee informed the Canadian Food Inspection Agency (CFIA) about the positive test result, products were recalled and the plant was shut down for a month'	Food safety/ Lack of law enforcement	Countermeasure
15263		Food safety	Countermeasure
15261		Food safety	Countermeasure
14781		Nature of Product	Opportunity
14631		No information is available for this Incident	N/A
14349	'.....and misbranded because of the unauthorized use of a USDA mark of inspection,'. ......', has been processing products from federally inspected establishments and re-packaging them without the benefit of inspection'	Extensiveness of Traceability/ Food safety (Weak quality controls)	Countermeasures
14347		Extensiveness of Traceability/ Food safety (Weak quality controls)	Countermeasures
14343		Extensiveness of Traceability/ Food safety (Weak quality controls)	Countermeasures

13557		Detection of adulterants requires advanced laboratory analysis	Opportunity
13461		lack of law enforcement	Countermeasures
13419	‘ the USDA sampled two of the remaining pork shoulders in storage and determined that it was not fit for human consumption.’	Food safety	Countermeasures
13361	Producers obtained the pigs by bribing government livestock insurance agents, several of whom were also sent for prosecution, it said.	Corruption level of country	Motivation
13331	This is illegal but we cannot punish them unless written records are found,’ he said.’	lack of law enforcement	Countermeasures
13270		No information is available for this Incident	N/A
1629449	After methanol deaths, liquor makers blame high duties for rise in bootleg booze- Attention fell on illicit alcohol in the country on September 18 when seven people died and 16 were hospitalised after consuming suspected moonshine in Sungai Buloh. — AFP pic KUALA LUMPUR, Sept 27 — A near three-fold increase in alcohol excise has created strong demand for illicit liquor makers, said the Malaysian Liquor Manufacturer and Bottler Association in response to recent methanol poisoning deaths.	Price spike- Motivation	Motivation

1629395	IRNA says that as the nation’s currency plummets against the dollar, and the price of liquor rises, consumers increasingly turn to home-made alcohol.	Price spike- Motivation	Motivation
1589980	The authorities uncovered approximately 1,800 fake Pingus and Vega Sicilia labels, computer equipment used to falsify labels, and a punching machine to print on corks. The restaurant's owner was among four of the suspects arrested. ‘The route of the fake wine bottles has been traced, from falsification to distribution,’ Civil Guard Lieutenant Abel Marín told Wine Spectator.	Extensiveness of Traceability	Countermeasures
1525049	found POSITIVE traces of the highly toxic form of alcohol — normally used to make antifreeze — in bootleg vodka sold in one of the town’s bars.	Detection requires advanced laboratory testing	Opportunity
1272597		Detection requires advanced laboratory testing	Opportunity
1044355	‘ An invoice book and samples were also seized, with subsequent analysis by authorities identifying ‘large discrepancies’ in the alcohol volume stated on the products.’	Detection of adulterants requires advanced laboratory testing	Opportunity

1044101	‘However, close inspection of the label, reveals several red flags. Each brand of tequila is given a unique serial number, but regulator CRT has no record of the one on Blue Cactus, which a company called Fernbrew Pty Ltd claims to import. Australia's Trademarks Act requires tequila bottles to include the name of its ‘authorised producer’ in Mexico, yet the CRT has no record of the one named by Blue Cactus.’	Requires coordination between law enforcement agencies/ Extensiveness of traceability	Countermeasures
1044095	‘However, close inspection of the label, reveals several red flags. Each brand of tequila is given a unique serial number, but regulator CRT has no record of the one on Blue Cactus, which a company called Fernbrew Pty Ltd claims to import. Australia's Trademarks Act requires tequila bottles to include the name of its ‘authorised producer’ in Mexico, yet the CRT has no record of the one named by Blue Cactus.’	Requires coordination between law enforcement agencies/ Extensiveness of traceability	Countermeasures
1010697		Requires coordination between law enforcement agencies	Countermeasures
1005211		Extensiveness of Traceability	Countermeasures

999209	The chances that wine lovers would see a 2004 KWV Reserve sauvignon blanc were 'very slim', because none of the contaminated wine had reached consumers. An independent laboratory had cleared the remaining stock for consumption. An investigation was launched and two batches of wine were isolated when found to contain flavourants. It then took a month to complete the internal investigation, Barnard said. 'Eventually, after an intense process of even going so far as having people do lie detector tests, I got an admission from two of my wine makers on December 1 that they in fact did dabble with those wines. It took me until December 3	Detection requires advanced laboratory testing	Opportunity
997594	The Food Standards Agency (FSA) has said that it appears the bottles originated from Moldova, which currently lies outside the EU but has been pursuing membership. The Italian government and the country's Prosecco producer consortium has been desperately trying to clamp down on the illegal trade, both within Italy and overseas.	Extensiveness of traceability, Requires coordination between law enforcement agencies	Countermeasures
994251		Extensiveness of Traceability	Countermeasures
910238	Laboratory tests revealed the deadly brew contained pure alcohol mixed with herbal beverages and high-caffeine energy drinks.	detection requires advanced laboratory testing, Transparency supply chain	Opportunity

1525351	8,000 bottles of fake Penfolds busted in northern China- Local media in Tie Ling city said the city's Food and Drug Administration and police department made the bust after nearly half a year of investigation following a raid earlier in February on a local winery, which led them to discover 1,956 bottles of fake Penfolds worth over RMB 2 million (US$301,000), in addition to Chinese stickers bearing names of Penfolds' Chinese name '奔富', QR codes and label printing machines. Further investigation from the February case revealed a more extensive network across different provinces, according to Chinese media reports.	Extensiveness of traceability, Requires coordination between law enforcement agencies	Countermeasures
590944		Extensiveness of Traceability	Countermeasures
597655	Tests revealed they contained methanol, which is similar to but far more potent than ethanol, the alcohol commonly found in liquor.	Detection requires advanced laboratory testing	Opportunity
772892		Requires coordination between law enforcement agencies	Countermeasures
772890		Requires coordination between law enforcement agencies	Countermeasures

833618	Investigators were alerted to the alleged fraud during a routine audit of GVG's massive cellar in St.-Loubès on Bordeaux's Right Bank in 2014. They found that Borie Manoux, a négociant firm also owned by the Castéja family that uses the GVG cellar, was missing 200,000 liters of wine, while GVG had mysteriously gained 220,000 liters.	Food safety (inspection), Lack of Food Fraud Vulnerability assessment	Countermeasures
828615	NA		N/A
819390	has been under investigation since last year after French customs officials found discrepancies and potential violations during a routine audit. Raphael Michel's chief executive Guillaume Ryckwaert was arrested last June on charges of fraud, deception and violations of France's consumer and tax codes, and accused of masterminding the wine fraud racket. He has denied any wrongdoing.	Food safety (inspection), Lack of Food Fraud Vulnerability assessment	Countermeasures
811195		Extensiveness of Traceability	Countermeasures
743342			N/A
604068	Revenue officers seized 586 litres of a finished 'vodka' type product that was bottled, sealed, labelled and boxed, along with 4,000 litres of the raw alcohol product, which would produce in the region of 12,000 litres of 'vodka' type spirits. They also seized all of the production line apparatus, the	Extensiveness of Traceability	Countermeasures

	mixing tank and containers, along with packaging, bottle caps and labels which were all counterfeit.		
606888	The ‘factory’ was arranged in a production line system; Officers seized all the production line apparatus, mixing tank, and containers, along with packaging, bottles and labels which were all counterfeit.	Exteensiveness of Traceability	Countermeasures
616800	Rare Whisky 101’s founders, Andy Simpson and David Robertson, reportedly acquired the bottle of Laphroaig at an auction in 2015 (the Macallans were simply authenticated) and subjected it to a series of tests over six months; including examinations of its glass, cork and capsule and an analysis of its peat derived compounds and malt and grain compounds to prove its provenance.	Detection requires advanced laboratory analysis	Opportunity
561485	As reported by The Namibian, the shipment was stopped as part of a larger International Customs Operation by The World Customs Organization. This nineteen Customs Organizations were targeting nineteens ports of entry as part of this Operation. Trusted Customs Brokers were inspected as part of this coordinated effort to stop the importation of counterfeit products into Africa.	Requires coordination between law enforcement agencies	Countermeasures
561491		Requires coordination between law enforcement agencies	Countermeasures

423125	‘have been charged with a litany of fraudulent actions by the Ministry of Primary Industries, including intentionally mislabeling wines as the wrong vintage, falsely identifying some wine's country of origin, destroying winery records, and blending wines from different vineyards.’....’The alleged misconduct, dating back to 2011, 2012, and 2013 Marlborough and Waipara sauvignon blanc and pinot noir vintages, was brought to light by a whistleblower, the Herald has learned.’	Extensiveness of Traceability/ Whistle blowing system	Countermeasures
423121		Extensiveness of Traceability	Countermeasures
461143		NA	N/A
193310		NA	N/A
142488	‘ More than 18,600 bottles of counterfeit vodka were destroyed Monday after customs officers seized the goods before they entered the northern city of Tianjin.’....’Bath said the case also marked a positive progress on international cooperation to fight piracy and China's ability to prevent counterfeit goods from entering its border’....’The products copied the trademark of the Russian brand Stolichnaya and were seized last October’.....	Requires coordination between law enforcement agencies/ Extensiveness of traceability	countermeasures

126752	But on closer examination they found the vodka was fake and the bottles actually contained industrial alcohol often used in antifreeze and cleaning products. The council raided the premises after a tip-off that it may be selling counterfeit booze and found 96 full, six partly-drunk and 134 empty bottles.	Detection requires advanced laboratory testing	Opportunity
312826	‘A Budweiser representative told Hong Kong-based Ming Pao that the company had reported the matter to the police and is seeking legal action. ‘........’Footage from the factory has emerged since and has started going viral. It's not hard to see why; in the clips, workers dunk used cans into a tub of beer with their bare hands to fill them up’… ‘The filled cans are then sent down a conveyor belt to get sealed’	Extensiveness of Traceability/ Whistle blowing system	Countermeasures
142348	NA		N/A
142346	NA		N/A
191531	‘The top security official in Libya’s capital said Tuesday 79 people have died over the past four days from drinking homemade alcohol, suspected of containing poisonous methanol’…’authorities are looking into whether it was the methanol or bad fermentation that caused the large number of victims’	Detection requires advanced laboratory testing	Opportunity
191433	With more than half of Kenyans living below the poverty line, few can afford to buy legally sanctioned alcoholic drinks. Illicit brews are popular, but occasionally lead to deaths when unscrupulous traders lace them with methanol to boost profits.	Economic health condition of the country	Motivation
278598		Detection requires advanced laboratory testing	Opportunity

269902	‘But this one failed for being essentially neutral spirit that had never seen the inside of a cask. Following a tip-off from a German businessman in Iran, ‘it was tracked down to a company in Austria who were canning millions of units’, says Low’.....’‘From there it moved to Turkey to be distributed into all the neighbouring countries, where alcohol is not traditionally allowed.’’...’In 2007, Grants Regal Deluxe appeared in a Channel 4 report on smuggling across the Kurdistan border into Iran. As one smuggler gleefully declared: ‘Everyone drinks it. The mullahs are first.’	Extensiveness of traceability	Countermeasures
136101	‘Deaths from drinking illegally brewed alcohol are common in India because the poor cannot afford licensed liquor. Illicit liquor is often spiked with chemicals such as pesticides to increase potency.’	Economic health condition of the country, Culture	Motivation
135654		Economic health condition of the country	Motivation
262983		Requires coordination between law enforcement agencies	Countermeasures
244848		N/A	N/A

190178	''Laboratory tests found the deaths were caused by the high methanol level in the wine,' Ly Sovann, a spokesman for the health ministry, told AFP'...' Tests carried out by the Ministry of Health have found that some of the wine involved in at least five separate incidents contained up to 12 percent methanol — the usual level is around 0.15 percent'	Detection requires advanced laboratory testing	Opportunity
107111		Extensiveness of Traceability	Countermeasures

108263	‘After our bureau received the complaint, we were given information from the company and also samples of counterfeit Johnnie Walker Red Label and Black Label bottles obtained from a retail outlet. We conducted a further investigation that lasted for about two weeks and presented the evidence we gathered to the Central Intellectual Property and International Trade Court, with a request for a search warrant, which was granted by the judge,’ said Police Lieutenant Colonel Sumit Chanovit, Director of Section 1 of the DSI’s Intellectual Property Crime Bureau.	Detection requires advanced laboratory testing	Opportunity
106911	‘Worse, you can't even detect it by its cap or the label. ‘…’Police have also recovered a consignment of the spurious liquor. A source said three cartons of Black Label and a carton of Absolut vodka had been seized’… ‘Our investigation is at an initial phase. A team led by additional CP Ashok Chand and ACP KPS Malhotra is trying to uneearth the source of the racket,’ he said’	Detectability, Extensiveness of Traceability, Requires coordination between law enforcement agencies	Countermeasures
106909			Countermeasures
106985	NA		N/A
105008		N/A	N/A

136235		N/A	N/A
239102	‘The Kaohsiung District Prosecutors Office in southern Taiwan has cracked down on a tax evasion and fraud case involving importers allegedly importing edible alcohol in the name of alcohol for industrial use, and distilleries allegedly using the products to make spirits they promoted as being naturally brewed.’.... ‘During the investigation by the Criminal Investigation Bureau (CIB), two men were found to have imported what they called ‘undenatured (or pure) alcohol for industrial use’ since February 2016, but in fact the alcohol was food-grade, prosecutors said’	Extensiveness of Traceability	Countermeasures
239100		Extensiveness of Traceability	Countermeasures
239098		Extensiveness of Traceability	Countermeasures
243508		N/A	N/A
243506		N/A	N/A
154580	reported that after surveilling an illegal transaction between two drivers at a remote part of Airport East Road, detectives followed one of the vehicles back to a workshop located in Hejinying, Gaoliying. .’	Extensiveness of Traceability	Countermeasures

158922	'According to the online auction listing, the wine was described as a first growth wine from the Bordeaux region in France, which are considered the top ranked wines, of which Château Lafite Rothschild is considered one of the best. However, there were discrepancies with the label, which was significantly different from genuine Château Lafite Rothschild. According to the description, the wine should have been labelled as a Pauillac first growth, reflecting the most prestigious wine-growing district of Médoc in the Bordeaux region and where Château Lafite Rothschild is produced. But the wine was labelled 'Chapelle Lafils' with Vin de Pays Bordeaux also appearing on the label, which is a 'country wine' classification of lower quality.'...... a statement sent to SecuringIndustry.com, JD.com said: 'We identified a third party merchant selling wine with a Chinese name similar to another brand and confirmed that this could easily be confusing to consumers. As a result, we immediately removed the product from the site before any had reached customers.'	Extensiveness of Traceability	Countermeasures
203871	NA		N/A
204762		Extensiveness of traceability	Countermeasures
182612	''It was only when we really examined the bottles that we noticed things, like the labels didn't look quite right, the colour of the liquid didn't look quite the same as others, or the level of the liquid was just a bit higher than you'd expect for a bottle of that age or producer.'	Extensiveness of traceability	Countermeasures
184479		N/A	N/A

187639	NA	N/A	N/A
187681		N/A	N/A
135669		N/A	N/A
132275	‘Because of Pakistan's liquor regulations, many people illegally brew alcohol at home, and there have been several cases of mass poisonings in the past - in 2014 some 40 people died within a few days as a result of drinking tainted alcohol in Sindh.’…...’The local sellers were out of stock so they went and bought it from somewhere else. Both have died.’.......’With alcohol sales tightly regulated, cheap homebrewed spirits often contain poisonous methanol. ‘	Economic health condition of the country, Culture	Motivation
129898	N/A	N/A	N/A
126768	‘Trading standards officers said fake Spar own-label vodka was found in a non-Spar store in Norwich on Friday. ‘….. ‘No cases of ill health associated with this counterfeit vodka have currently been reported, but the counterfeit Spar Imperial Vodka is said to have a hint of acetone smell (similar to nail varnish), with the printed wording smudged on the labelling found on the bottles in Norwich. ‘	Extensiveness of Traceability	Countermeasures

107125	'She had been selling unaged Chinese spirits, with artificial flavouring, labelled as Scotch whisky.'….	Extensiveness of Traceability	Countermeasures
106957	Thirty-four bottles of Black Label, one carton of Chivas Regal, one carton of Mcdowell No 1 and one carton of Blenders' Pride were recovered from the car which Khan was driving.	Extensiveness of Traceability	Countermeasures
106955		Extensiveness of Traceability	Countermeasures
102200	'Analysis showed that rather then whisky it was mainly water but instead of alcohol there was bacteria and mould that could kill people,' said Staffordshire trading standards officer Graham Russell.	Detection requires advanced laboratory testing	Opportunity
100852	Tests confirmed that both the packaging and the liquid inside the bottle were fake.	Detection requires advanced laboratory testing	Opportunity
100810	'Tests carried out on the counterfeit whisky show that it has been contaminated with methanol.	Detection requires advanced laboratory testing	Opportunity
95295	'Taipei, June 11 (CNA) Police arrested 12 people for allegedlymaking fake red-label rice wine and Kinmen Kaoliang Liquor,confiscating more than 9,000 bottles of counterfeit brand-namebeverages, officials said Friday. Police said that the fakes look almost the same as the real ones,and even carry labels adopted by Taiwan Tobacco and LiquorCorporation late last year to distinguish counterfeits from genuineproducts.'	Extensiveness of Traceability	Countermeasures

95293		Extensiveness of Traceability	Countermeasures
95282		Extensiveness of Traceability	Countermeasures
95223	‘Taipei, April 28 (CNA) Police in Taiwan and China have joined forces to break a Chinese counterfeiting ring that allegedly produced and sold fake Taiwanese brands of kaoliang liquor in the southeastern Chinese city of Xiamen, police said Thursday.’ ‘After an investigation, police found that the fake liquor originated from Xiamen.’	Extensiveness of Traceability/ Requires coordination between law enforcement agencies	Countermeasures
95170	Police said they had started surveilling the ring since October after receiving a tip from a local resident. The ring operates from a dilapidated building in Nanhai district and has a very organised line of production including refilling, bottling, transporting and distribution, said the police.	Extensiveness of Traceability	Countermeasures
95166		Extensiveness of Traceability	Countermeasures
95164		Extensiveness of Traceability	Countermeasures
91946	Samples were sent off for analysis and were found to contain isopropanol, which acts as a depressant on the nervous system, and Butanol.	Detection requires advanced laboratory testing	Opportunity

87684	Hill allegedly did to hide his conduct was alter or create false bills of lading and other records; maintain false records of inventory so as to misstate the geographic origin or varietal of grapes, wine, or grape juice in his company's inventory; falsely state to his company's employees that grapes grown outside of Napa Valley were grown in Napa Valley; move grapes or wine between his company's three facilities to obscure the origin of the grapes	Extensiveness of Traceability/lack of law enforcement	Countermeasure
86117	N/A		N/A
83332	The offence was detected by Revenue officials after a visit to his Coppinger's Bar on Parnell St, Thurles, on January 29, 2015. The court heard in September a sample from one of 23 bottles taken from Coppinger's Bar was found by the state laboratories to be 'neither pure vodka nor… Smirnoff vodka'. which it purported to be.	Detection requires advanced laboratory testing	Opportunity
83326			N/A
76870	NA		N/A
73577	A preliminary investigation found the fake alcohol to be vodka mixed with methyl alcohol, which was being made in the eastern Kharkov region and then sold in small grocery shops for about $1 (under the minimum retail price) for a half litre bottle.	Detection requires advanced laboratory testing	Opportunity

66947		Detection requires advanced laboratory testing	Opportunity
66665		Detection requires advanced laboratory testing/nature of product (mixed)	Opportunity
66602		Detection requires advanced laboratory testing/nature of product (mixed)	Opportunity
66589	The results of an autopsy on a promising young rugby player who died in Bali have revealed he was killed by methanol poisoning - likely to have come from an incorrectly distilled local brew.	Detection requires advanced laboratory testing/nature of product (mixed)	Opportunity
66311		Detection requires advanced laboratory testing/nature of product (mixed)	Opportunity
59331		Extensiveness of Traceability	Countermeasures
59250	From March 23 to 25, police raided 272 production and sales outlets nationwide and found more than 300 devices used for counterfeiting as well as over 13.5 million pieces of forged packaging materials, such as bottle caps, labels and boxes of well-known brands.	Extensiveness of Traceability	Countermeasures

57501	‘In early January, inspectors from the city's commerce authority informed the local police they had found that hundreds of fake bottles of Kweichow Moutai and Wuliangye liquor, both famous Chinese brews, were being sold in two restaurants in Shaoxing. ‘....’The Shaoxing case was just the first step to crack down on fake liquors in China and the police will cooperate with the industry and commerce authorities across the country to fight against forgers in the future,’ Xu said. ‘....’It is hard for most consumers to spot the real liquors only by the bottles and taste,’ said Cheng Jian, a worker with a Beijing-based media company. ‘So I think police and related departments should intensify their efforts to crack down on fake ones,’ Cheng said. ‘	Requires coordination between law enforcement agencies	Countermeasures
57327		Requires coordination between law enforcement agencies	Countermeasures
57020	The analysis showed the seized spirits were not genuine and were below the required alcoholic strength for vodka.	Detection requires advanced laboratory testing	Opportunity
54374	Police in Padova said an analysis of the supposed champagne revealed it was sparkling table wine.	Detection requires advanced laboratory testing	Opportunity

54276	‘Recently when a mini-auto coming to Visakhapatnam from Odisha was intercepted, liquor bottles were found along with those containing water and spirit. ‘…...Inquiries by the police revealed that the traders are resorting to two types of adulteration—mixing either spirit or water after removing 25 per cent original liquor and replacing the brand labels. They are using spirit procured from Pune and Bihar, as it does not raise any suspicion among consumers. The traders are allegedly paying experts in adulteration Rs 5,000 each for preparing such stocks.	Transparency supply chain	Opportunity
46949	The label looked normal and legit, so she drank the gin, not realising it was laced with methanol, which has a high toxicity in humans; it takes just 10ml (two tablespoons) of the stuff to cause permanent blindness. Its main use is to be transformed into formaldehyde, an embalming fluid.	Detection requires advanced laboratory testing	Opportunity
46444		Detection requires advanced laboratory testing	Opportunity
38085	Laboratory analyses detected deficiencies in following two cases: Hraběnka, dry white wine, lot No. 176, country of origin: Hungary and Hraběnka, dry red wine, lot No. 155, country of origin: Hungary. Presence of added water amounting to 66% was detected in white wine. As regards red wine, presence of unauthorised synthetic dyes was revealed (azorubine, patent blue V and tartrazine).	Detection requires advanced laboratory testing	Opportunity
38083		detection requires advanced laboratory testing	Opportunity

36860	NA		N/A
36762	'The counterfeiters had blundered by making spelling mistakes.'....'The front labels read 'Produced and botteled in Great Britain'. The text below the wording 'Enjoy Glen's Vodka responsibly' on the rear label should read 'DRINKAWARE.CO.UK', but says 'D-RINK AWARE.CO.UK'.'…...'Investigations by trading standards officers in conjunction with the Food Standards agency and Glen's manufacturer Loch Lomond Group have revealed the counterfeit spirits have also been offered for sale by independent retailers in London, the English Midland and other parts of the north of Scotland.'.....'These drinks can be produced in clandestine premises where there are no controls over hygiene or of the composition of the drinks.'	Extensiveness of Traceability, Lack of law enforcement, requires coordination between law enforcement agencies	Countermeasures
36747	Trading standards officers discovered the drink contained isopropanol, a chemicals used in cleaning liquids and aerosol de-icers.	Detection requires advanced laboratory testing	Opportunity
34383		Requires coordination between law enforcement agencies	Countermeasures
34363		Requires coordination between law enforcement agencies	Countermeasures
34359		Requires coordination between law enforcement agencies	Countermeasures

34201		Requires coordination between law enforcement agencies	Countermeasures
34157		Requires coordination between law enforcement agencies	Countermeasures
34085		Requires coordination between law enforcement agencies	Countermeasures
33415	'The settlement, approved by U.S. Magistrate Judge John J. O'Sullivan, came in a lawsuit filed in 2013 by several Beck's drinkers who noticed there was almost no visible 'made in the U.S.A.' language on the beer's packaging even though it has been brewed in St. Louis, Missouri, since 2012'.....'We reached a compromise in the Beck's labeling case,' said Jorn Socquet, Anheuser-Busch vice president for marketing. 'We believe our labeling, packaging and marketing of Beck's has always been truthful, transparent and in compliance with all legal requirements.'	Extensiveness of Traceability	Countermeasures
30733	'The bottles appear identical to the real thing, apart from a tell-tale misspelling on the label on the back, where Australia is spelt Austrlia.'	Extensiveness of Traceability	Countermeasures
30170	NA		N/A
30166	NA		N/A
30117	In 2008, during an audit by the French fraud agency, officials found several inconsistencies.	Extensiveness of Traceability- Lack of vulnerability assessment, food safety	Countermeasures

29331	Provincial Russian towns from the Baltic Sea to Siberia have declared a state of emergency and thousands of other victims -- mainly poor -- are receiving medical treatment, although hospitals say they are running out of beds. Police have started criminal investigations to find the origins of the toxic vodka.	Food safety/ Extensiveness of Traceability	Countermeasures
27526	The fake Smirnoff is labelled ‘Produced in Ireland’ whereas real Smirnoff states ‘Produced in the United Kingdom’.	Extensiveness of Traceability	Countermeasures
26354	An undercover investigation by Channel 5 infiltrated the crime gangs behind the trade and found one factory in east London producing 7,000 fake bottles of Smirnoff vodka a day....’The criminals use the latest machinery to repackage the bottles with perfect labels replicating leading brands’	Extensiveness of Traceability	Countermeasures
25575	A shop owner who sold the homemade spirit for about 20 pence per 200ml has been arrested and an investigation has been launched into police officers who allegedly took bribes to turn a blind eye to concerns about the drink.	corruption level of country	Motivation
25463	‘when there is law against selling and drinking any alcohol, so illegal trade of that will increase ‘…’. Embarrassed by the scale of the tragedy in a state where consumption and sale of liquor is officially banned, police have swept through Gujarat in search of those illegally selling home-made liquor. ‘	Culture, Economic condition of the country	Motivation

23285	The police, in collaboration with the Inspectorate for the Suppression of Fraud (ICQRF), uncovered some 75,000 liters of wine labeled Brunello di Montalcino, 90,000 liters of supposed Rosso di Montalcino and 2350 fake labels. Large quantities of the fake wine were allegedly sold between 2011 and 2013. Alarms were raised in a report by the Brunello di Montalcino Consortium.	Requires coordination between law enforcement agencies	Countermeasures
23279		Requires coordination between law enforcement agencies	Countermeasures
23185		Requires coordination between law enforcement agencies	Countermeasures
22406		Requires coordination between law enforcement agencies	Countermeasures
22402		Requires coordination between law enforcement agencies	Countermeasures
22399		Requires coordination between law enforcement agencies	Countermeasures
22247	NA		N/A
21551	The licensee, who is a member of Weston's Pubwatch scheme, became suspicious of the legitimacy of the vodka and contacted North Somerset Trading Standards. Samples of the fake vodka were sent for testing by Trading Standards officers and were shown to contain iso-propanol – a chemicals commonly found in screen-wash and antifreeze.	Detection requires advanced laboratory testing	opportunity

21486	police were regularly bribed: ‘There is an officer nominated for collecting the bribe. We call this person the 'dak master'. In every law enforcement office, there is one 'dak master'. If you pay him, you can carry on with your activity.’	Culture, Economic condition of the country	Motivation
20124	Forensic testing of counterfeit alcohol has now been carried out and vodka seized was found to contain Isopropyl alcohol, which is widely-used as a solvent and cleaning fluid – and unsafe for human consumption.	Detection requires advanced laboratory testing	Opportunity
20086		Economic condition of the country (or people?)- CULTURE	Motivation
20054	NA	N/A	N/A
18319		N/A	N/A
18183	According to police, a senior employee disgruntled about being sacked tipped them off about alleged frauds in six wine-producing areas which included the Gironde, where Bordeaux is produced.	Whistle blowing system, Extensiveness of Traceability	Countermeasures
17912		NA	N/A
17844	‘The website said its reporter, after a tip-off from ‘insiders,’ had purchased four bottles of Jiugui from an official store in Beijing and sent them to the National Food Quality Supervision and Inspection Center for checks. ‘….’Its tests showed that samples of the liquor contained three plasticizers - diethylhexyl phthalate (DEHP), diisobutyl phthalate (DIBP) and dibutyl phthalate (DBP), the website said. ‘	Detection requires advanced laboratory testing	Opportunity

17077	NA		N/A
16573	The bottles were intercepted during a routine stop of a truck in Chita, eastern Siberia. The owner of the shipment was arrested in March while trying to bribe police to release the fake bottles, which bore fake tax stamps.	Extensiveness of Traceability	Countermeasures
16471	'The HCMC police department's economic crimes division caught So and Tan on May 18, 2012 loading 23 cases of Heineken onto a truck in Binh Chanh District, according to the indictment. '….'Giang confessed to renting houses in early May, 2012, and to buying device and hiring Cu, Hung and An to clean used bottles, mix and bottle the beer.'	Transparency supply chain	Opportunity
16444	NA		N/A
16412	NA		N/A
16154			N/A
16099		NA	N/A
16081		Extensiveness of Traceability	Countermeasures
16018	'Specialist equipment was used as part of the inspections to check the authenticity and safety of spirits. The suspect vodka was discovered on sale in a Long Eaton store and officers are continuing their investigations into the extent of the problem.'….'Tests showed that the product was deficient in alcohol and contained iso-propanol, which made it unfit for consumption.'	Detection requires advnaced laboratory testing	Opportunity

15865	Tests at Mont Tauch's laboratory in France revealed that the bottles contained inferior quality bulk wine from South America.	Detection requires advnaced laboratory testing	Opportunity
14642	Tests revealed the bottles had excessive levels of methanol, which can cause or blindness or even death.	Detection requires advanced laboratory testing	Opportunity
13747	NA (Russian)		N/A
13724	NA (Russian)		N/A
13417	‘much of it in rural areas where it is distributed by a wide network of sellers who bribe police. The liquor is sold in small plastic pouches for as little as 10 rupees, or 2 cents.’	Corruption level of country	Motivation
13398	The Siena edition of the Italian national daily La Nazione and the Florentine edition of the Corriere della Sera reported yesterday that 17 people and 42 companies are currently under investigation for falsifying public documents with the intent to commit fraud Read more at https://www.decanter.com/wine-news/adulteration-scandal-surfaces-in-tuscany-62442/#kJpHiGswAbCSBbmR.99	Extensiveness of Traceability	Countermeasures
13394		Extensiveness of Traceability	Countermeasures
13390		Extensiveness of Traceability	Countermeasures

13347	‘Hernandez said that as Kurniawan's fame grew in the business of rare wines, suspicions about him rose.’... ‘was arrested by the US Federal Bureau of Investigation (FBI) just over a year ago after a raid on his home in Los Angeles revealed a locked room which - according to the agency - housed a wine counterfeiting workshop.’….’asked to provide evidence by video because the timing of the trial conflicts with the grape harvest.’	Special product attributes, supply and pricing	Motivation
13260	‘The investigation, known as ‘Operation Swill,’ resulted from public complaints, confidential sources, and samples taken from investigators.’….’ investigators procured more than 1,000 open bottles of liquor for testing. ‘	Detection of adulterants requires advanced laboratory testing	Opportunity
1636479		Food safety/ Requires coordination between law enforcement agencies	Countermeasure
1637250	The police said that Senior Inspector Mahesh Desai of Crime Branch unit 9 had formed a team of officials who raided the houses around 4 am and found four people replacing the milk with water. The gang's modus operandi was : it would slightly cut the packet of branded milk from the edges and remove at least half of the milk from it. They would then fill the packet with water, and neatlypack it again, using candle flame. The milkextracted from the branded packets would then be mixed with water and put into empty packets withmarkings of noted brands. These packets were then distributed to various shops selling packaged milk in the suburbs.	Ease of alteration/ Nature of product / Transparency supply chain	Opportunity

1621064	The bus, which came to Pune from Gujarat, was intercepted near Purnima Towers building in Swargate, following a tip-off. 'Upon inspection, police found khoya being packed in gunny sacks in the luggage space of the bus. Soon after the recovery, police contacted Food and Drugs Administration (FDA), Pune. 'The FDA officials checked the khoya and found it to be adulterated,' police said, adding that the gunny sacks containing the adulterated khoya was immediately seized.	Transparency supply chain/Nature of product, Detection of adulteration requires advanced laboratory testing	Opportunity
1596726	They caught two men and one woman in the act of cutting plastic bags of branded milk and mixing water in them.	Transparency supply chain, Availability of knowledge and technology for adulteration	Opportunity
1546286		NA	N/A
1036209		Transparency supply chain	N/A
1028380			N/A
953235	Civil surgeon Dr Usha Dhingra, and her team collected samples of the seized 'milk' and other items ,including white powder resembling condensed milk. 'Though we are going to get the seized material tested at food laboratories, prima facie, the entire quantity of seized 'milk' is synthetic.	Detection requires advanced laboratory testing	opportunity

953240	A food inspector had been suspended for failing to check the malpractice, the official added. Additonal collector KP Mishra said that a joint team from the food and revenue departments had raided the factory at Chinnoni village and seized 1000 litres of synthetic milk yesterday. Read more at: //economictimes.indiatimes.com/articleshow/62053564.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst	Food safety, weak quality control, Requires coordination between law enforcement agencies	Countermeasure
958182		Opportunity in time and space	Opportunity
958482	'….e the samples collected by the Food Safety Department officials are found containing ingredients harmful to human health.'	Detection of adulterants requires advanced laboratory testing/ Availability of knowledge and technology for adulteration	Opportunity
894255	Four people were arrested on Saturday in Spain because of packaging counterfeit baby milk mostly destined for China. Eight tons of faked milk was found, according to police in Girona on Saturday	Extensiveness of Traceability	Countermeasure

662892	'Following credible information, the Task Force raided the godown late night on Monday and arrested him on the spot and seized the adulterated stuff. Srinivasan and the adulterated products were handed over to the Nallakunta police for action.'….'The East Zone Task Force raided a godown at Nallakunta and nabbed one person for allegedly preparing and selling adulterated ghee by mixing dalda and selling it in the market.'	Availability of knowledge and technology for adulteration/Transparency supply chain	Opportunity
719779		Availability of knowledge and technology for adulteration, Nature of product	Opportunity
651659	and that the laboratory examination results have been forged at his order.	Detection of adulterants requires advanced laboratory testing	Opportunity
631001			N/A
524537	In August, the employee informed the capital's health authorities, who sealed 425 boxes of four tastes of ice cream and ordered the payment of a NT$1.2 million (US$39,550) fine.	Whistle blowing system	Countermeasures
504612	NA		N/A

279451	'The company's forged kosher certificates were brought to the CFIA's attention in June 2015 after an employee of The Kashruth Council of Canada, a non-profit that provides kosher certification, noticed some inconsistently in the labeling on some of the boxes of cheese delivered to one of the two overnight summer camps. When he asked Sadiklar to send over certificates to verify the kosher status of the cheese, Sadiklar first sent in a kosher certificate for the wrong food, according to the Toronto Star.'.....The Canadian Food Inspection Agency has charged Creation Foods and its vice-president, Kefir Sadiklar, with sending cheddar cheese falsely described as 'kosher' to Jewish summer camps in June 2015. The agency alleges forged documents were created to make it seem like the cheese adhered to Jewish dietary laws.	Extensiveness of Traceability	Countermeasure
214328	Following this news, the mother company of Aptamil—Danone issued a quick statement, reassuring consumers that the packages of the faked milk powder are in German language and are not authorized for sale through official channels in China. Currently, there's no information that indicate the problematic products have made their way into the Chinese market.	Extensiveness of Traceability	Countermeasures
461064		Availability of knowledge and technology for adulteration/Transparency supply chain	Opportunity

107071	When investigators tested milk samples at the Cantile di Sparanise factory, in Santa Maria Capua Vetere, they found bacteria more than 2,000 times the authorized level, Il Mattino said. Prosecutor Raffaella Capasso said the findings showed the adulterated cheese was 'potentially harmful to public health'. In addition to the arrests, the factory and sales points were shut down.	Detection of adulterants requires advanced laboratory testing	Opportunity
321683		Lack of law enforcement, food safety	Countermeasure
278559	N/A		N/A
264812		Detection of adulterants requires advanced laboratory testing	Opportunity
22741		Extensivenss of Traceability	Countermeasures
253449	N/A		N/A
195939	N/A		N/A
205097	N/A		N/A

132152	PFA officials examined 40 containers of milk in Faisalabad today. They found it to be adulterated with formalin - a chemical used chiefly as a preservative for biological specimens - as well as urea, salt and water. The food authority disposed of 800 litres of substandard milk and arrested two persons in connection with it. On December 27, the Supreme Court asked the Punjab Food Authority to check all milk plants in the province and get milk samples tested in labs, as it was found out they contained harmful ingredients.	Detection of adulterantion requires advanced laboratory testing	opportunity
94059	NA		N/A
89508		Detection of adulterants requires advanced laboratory testing	Opportunity
84917	they have received complaints of adulterated peak milk from consumers which prompted them to swing into action leading to the arrest of the suspect while making supplies to stores. Kolawole said Nnabuihe, 56, who resides at No 42, Cameroun Road, Calabar, confessed to be refilling 440g (promotion pack) of peak powdered milk with another cheaper brand of milk product which he buys in large quantity (50kg) and uses to refill the packs.	Availability of adulteration knowledge and technology/ Transparency supply chain	Opportunity
82434	NA		N/A
75514		Extensiveness of Traceability	Countermeasure

74149	The Ministry of Health (MOH) on Wednesday recalled a batch of baby formula, ‘Xiang Xue Hai’ with batch number 20050112, found to be of hazardously low nutritional value.	Food safety	Countermeasure
73836	Following a tip-off, mobile unit of FDA raided a premise at ... Read more at: http://timesofindia.indiatimes.com/articleshow/54788248.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst	Transparency supply chain	Opportunity
70145		Detection of adulterants requires advanced laboratory testing	Opportunity
70138		Detection of adulterants requires advanced laboratory testing	Opportunity
61718	NA		N/A
54341	‘Independent testing shows that at least seven per cent to 10 per cent of the product is not parmesan cheese,’ Moschetta said in his suit, filed in a U.S. federal court in New York. ‘In fact, at least seven per cent to 10 per cent of the product is cellulose, an anti-clumping agent derived from wood chips.’	Detection of adulterants requires advanced laboratory testing	Opportunity

54110	‘Two drums of chemicals, 50 bags of glucose, hundreds of box ... ‘Samples of the product have been taken and we are investiga ... Read more at: http://timesofindia.indiatimes.com/articleshow/53534134.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst	Availability of adulterants/technology/knowledge, Detection of adulterants requires advanced laboratory testing	Opportunity
53880		Supply and pricing due to ban	Motivation
53875		Supply and pricing due to ban	Motivation
53256	Court documents filed by Howe allege that McDonald's mozzarella sticks were tested and found to contain more water and starch than federal food labeling laws allow.	Detection of adulterants requires advanced laboratory testing	Opportunity
50469		Supply and Pricing (Diwali)	Motivation
50465		Supply and Pricing (Diwali)	Motivation
50462		Supply and Pricing (Diwali)	Motivation
50457		Supply and Pricing (Diwali)	Motivation
50444	NA		N/A

50439	NA		N/A
50017	Out of the total samples sent, as many as six were found to ... Read more at: http://timesofindia.indiatimes.com/articleshow/49988332.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst	Detection of adulterants requires advanced laboratory testing	Opportunity
49990	Mother Dairy officials challenged the test reports and demanded for a re-test of samples at Kolkata-based Central Laboratory, he said. The test report of Kolkata's Central Laboratory has been submitted to the District Magistrate Vimal Kumar Sharma, who in turn will forward it to the Commissioner to seek his approval to initiate legal action against Mother Dairy, the official said	Detection of adulterants requires advanced laboratory testing	Opportunity
46974		Detection of adulterants requires advanced laboratory testing	Opportunity
46472		Availability of knowledge and technology, Transparency supply chain	Opportunity
46408		Availability of knowledge and technology, Transparency supply chain	Opportunity
36081		Detection of adulterants requires advanced laboratory testing	Opportunity

34350		Requires cooperation between law enforcement agencies	Countermeasures
33803	The gang was busted by Shanghai police in September 2015 after Abbott reported the case to the authorities.	Extensiveness of Traceability/ Whistle blowing system	Countermeasures
33748		Detection of adulterants requires advanced laboratory testing	Opportunity
33702		Transparency supply chain, Detection of adulterants requires advanced laboratory testing	Opportunity
31836	CUTTACK: Cuttack district police on Tuesday busted a massive food adulteration racket operating from Tangi and nabbed two persons while seizing spurious raw materials, empty packs and pouches of reputed companies.	Nature of products/Availability of technology/availability of adulterants, Transparency supply chain	Opportunity
31681	The police team seized from here 92 adulterated milk bags and 81 liters of adulterated milk. Explaining the modus operandi, police said the accused had devised two methods to adulterate milk packets. In the first method, they would tear open branded milk packets and remove some of the milk. Then, they would add dirty water to it before resealing the pack with a stapling machine. In the second method, the vendors would rummage through garbage bins and collect empty milk bags. They would then fill 60 per cent milk in the packet and add 40 per cent dirty water to it, before resealing it with a burning candle.	Nature of products/Availability of technology/availability of adulterants, Transparency supply chain	Opportunity

31106		Detection of adulterants requires advanced laboratory testing	Opportunity
29999		Detection of adulterants requires advanced laboratory testing	Opportunity
29987		Food safety, Lack of law enforcement, Ectensiveness of traceability	Countermeasures
29977	The powder had been ordered destroyed, but a dairy firm in the Ningxia Hua autonomous region received the batch as debt payment from another company, said the China Daily newspaper. The company then sold the milk to five other factories in Fujian and Guangdong provinces and in the Inner Mongolia autonomous region.	Food safety, Lack of law enforcement, Ectensiveness of traceability	Countermeasures
29797		Detection of adulterants requires advanced laboratory testing	Opportunity
29064	The State Public Health Laboratory has found the presence of gum in this delicacy which is an act of adulteration as per the provisions of the Prevention of Food Adulteration (PFA) Act.	Detection of adulterants requires advanced laboratory testing	Opportunity

27316	The products were found substandard after the SMC for the first time sent samples to referral laboratories outside the state for quality check. SMC Health Officer Shafqat Khan said they had found food products such as 'saunf' powder of the Kanwal group and the Khyber-packaged milk unsafe for consumption.	Detection of adulterants requires advanced laboratory testing	Opportunity
26684	NA		N/A
25926	The protein content of many dietary supplements is often determined by measuring the amount of nitrogen it contains.	Detection of adulterants reqires advanced laboratory testing	Opportunity
25387	After analysing the samples, it was found that six well-known companies are involved in this act. According to an officer from FDA, Thane, case has been registered against Vasundhara Dairy (Amul), Gujarat Co-op Milk Federation, BG Chithale, Mahananda Dairy, Khopoli government milk scheme, and Kolhapur District Co-op Milk Distribution Group Ltd (Gokul).	Detection of adulterants requires advanced laboratory testing	Opportunity
25019		Transparency supply chain/Nature of product	Opportunity
24697		Availability of adulterants/Nature of product/ Transparency supply chain	Opportunity
23594	NA	NA	N/A

23421		NA	N/A
23417		NA	N/A
23381	'…. fraud was confirmed after a chemical analysis of raw milk traced the use of formaldehyde in its final product. '	Detection of adulterants requires advanced laboratory testing	Opportunity
23339		Detection of adulterants requires advanced laboratory testing	Opportunity
23203	In 10 of the samples, high alkalinity was found, indicating the presence of chemical agents used to mask the addition of water and the deterioration of the product through the action of bacteria	Detection of adulterants requires advanced laboratory testing	Opportunity
23158	'According to the prosecution, a raid was conducted by a food inspector at the hotel here on June 3, 2006. Samples were collected for analysis. '…...An analysis found that the sample was adulterated because the milk fat was found to be less than the minimum prescribed standard of 25 per cent, the food inspector said.	Detection of adulterants requires advanced laboratory testing	Opportunity

22991	'......Surve undertook the investigation after permissions were secured From Sr Inspector of Khar police station, Mangesh Pote. At around 0530 hrs this morning. police raided around 7 places in Khar including Chaupada chawl, Dhanpada chawl near Khar (west). Around 572 Liters of adulteratedf milk was seized and FDA officials took the sampling for investigations and the remaining quantities were destroyed. The adulterated milk had packing of Amul, Gokul and Priyadarshan brands.'	Availability of adulterants or technology/ Detection of adulterants requires advanced laboratory testing, Transparency supply chain	Opportunity
22960	used to buy empty packets of branded milk companies. 'They would then fill in adulterated milk in these packets and sell them. We had received information that the water that was used in the adulteration was contaminated and can cause illness.	Availability of adulterants or technology/ Detection of adulterants requires advanced laboratory testing, Transparency supply chain	Opportunity
22947	Four people were caught red-handed by the Samta Nagar police after they were found mixing water in packets of milk of different brands in an apartment at Poisar in Kandivali.	Availability of adulterants or technology/ Detection of adulterants requires advanced laboratory testing, Transparency supply chain	Opportunity
22928	On Friday morning, the Dongri police busted a milk adul ... Read more at: http://timesofindia.indiatimes.com/articleshow/23549355.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst	Availability of adulterants/ Nature of products, Transparency supply chain	Opportunity
22804	NA		N/A

22684		Supply and Pricing (Diwali)	Motivation
22676		Supply and Pricing (Diwali)	Motivation
22570	owns two transport companies and a fleet of over 100 tankers belonging to him are engaged in transporting milk from the facilities of Aavin in several districts across the state. According to the police, the stolen milk was taken in cans and transported in two mini lorries in a well-planned operation. The police seized the mini lorries with milk cans on board near Tindivanam and arrested eight persons, including Sathyaraj, Suresh and Ramesh of Tiruvannamalai.	Transparency supply chain	Opportunity
22326	they had test results showing several brands of milk formula were grossly deficient in protein.	Detection of adulterants requires advanced laboratory testing	Opportunity
21524	‘The national inspection agency further discovered that milk products manufactured by 21 other diary companies tested positive for melamine’	Detection requires advanced laboratory testing/ Historical evidence	Opportunity
20697	According to a handout from office of the district coordination officer (DCO), Dipalpur Assistant Commissioner Imtiaz Khichi, District Officer (health) Dr Shabbir Chishti with police team took sample of the milk in the vans and found it adulterated with the unhealthy ingredients, including urea, formalin, detergent, ammonia with some other chemicals.	Detection of adulterants requires advanced laboratory testing	Opportunity
20469		N/A	N/A

20128	‘Most of they confiscated products carried fake versions of the GOST quality label’	Food safety/ Extensiveness of Traceability	Countermeasure
19921		Nature of product/ Transparency supply chain	Opportunity
19147	NA		N/A
18604		Detection of adulterants requires advanced laboratory testing	Opportunity
17569		Detection requires advanced laboratory testing	Opportunity
17556		Detection requires advanced laboratory testing	Opportunity
17229		NA	N/A
17207		NA	N/A
17029	‘The suspects were picked up in a joint operation by the Diary Development Authority-DDA personnel and police to crackdown on the sale of adulterated milk. ‘…...’Harriet Nnamuli, the Principal Dairy Inspector Soroti says the operation was prompted by several complaints from residents over poor quality milk.’	Requires coordination between law enforcement agencies	Countermeasure

16765	At the heart of the case was what happened to a cheese shipment that FDA found ‘contained violative presence of micro-biologic material and filth.’ With further examination, FDA found the cheese was contaminated with Salmonella, E. coli, alkaline phosphatase and Staphylococcus. FDA would ultimately order the cheese ‘refused,’ meaning it could not be imported to the U.S.	Food safety/border rejection	Countermeasures
16534	in Atlanta reported the presence of bacteria (Staphylococcus aureus) in the samples taken from the shipment, demonstrating that the cheese was not in fact pasteurized as claimed on the entry documents.	Food safety, border rejection	Countermeasure
16450		Requires coordination between law enforcement agencies/Extensiveness of Traceability	Countermeasure
16419		Extensiveness of Traceability	Countermeasure
16188		Food safety	Countermeasure

16052	The accused were produced at Bandra Magistrate court and have been remanded to police custody till May 31. Further elaborating on the modus operandi, cops informed that the accused had devised two methods to adulterate milk packets. In the first method, they would tear open branded milk packets, and mix dirty water in them before sealing them with a stapling machine. In the second method, the vendors would rummage through garbage bins and collect empty milk packets. They would then fill 60 per cent milk in the packet and mix it with 40 per cent gutter water, and seal it with a burning candle. Cops got specific information about milk adulteration being carried out in Vile Parle (E) from an informer on Sunday, and under the supervision of senior police inspector Talegaonkar, PI Tavre hatched a plan with PSI Vidhate, Patil and Mudhiraj to nab them. On Monday at around 7 am when the accused were about to sell the milk packets, cops arrested them.	Availability of adulterants/Availability of technology, Transparency supply chain	Opportunity
15529	'However, there was a message on the box that it is not edible though there was no such warning on cartons of those ghee packets, he said.'	Extensiveness of Traceability	Countermeasure
15458		Extensiveness of Traceability	Countermeasure
15317		Transparency supply chain/ availability of adulterants	Opportunity

15247	A government sampling of cheeses across Italy revealed, however, that 25 percent of the cheeses tested also included milk from dairy cows -- less expensive, but also less rich.	Detection of adulterants requires advanced laboratory testing	opportunity
15234	‘The Special Operations Team (east) of Cyberabad police on Wednesday busted a milk adulteration racket after raiding a house at Ghatkesar’…..’The accused Barkha Ravi and Md Rasheed prepare a paste by mixing urea, milk powder and sunflower oil by putting the material in a mixer, Inspector SOT, Narsing Rao said.’	Transparency supply chain/ availability of adulterants	opportunity
15229	Deputy superintendent of police (DSP) Krishan Kumar said that the police, on a tip-off, raided a factory near Moonak and arrested nine people, who were making synthetic milk in the factory by mixing chemicals.	Opportunity in time and space	opportunity
14965		Detection requires advanced laboratory testing	opportunity
14398	Our review of your Certificates of Analysis for environmental samples analyzed by a private laboratory indicated that at least two of your environmental samples collected on November 24, 2013 and December 11, 2013 resulted in presumptive positives for Listeria monocytogenes in your processing environment.	Detection requires advanced laboratory testing	Opportunity

14384	The action was taken on a priority basis as the supply of milk and milk products reach its zenith during the festive season, especially during Diwali. ‘Adulterated milk and its products are dangerous as it directly affects the health of its consumer.	Supply and Pricing	Motivation
14231	‘During Diwali, consumption of sweets, milk and its products always increases making it the perfect occasion or the suppliers of adulterated ‘khoya’, ‘ghee’ and other milk products to get active. To check this, state officials have conducted random raids and checks at as many as 40 and odd places in the city within a week’	Supply and Pricing	Motivation
14222	NA		N/A
14216		Requires coordination between law enforcement agencies	Countermeasure
13896	N/A	N/A	N/A
13381	Wang Xiaofeng, a Beijing food inspection expert, said it is more difficult to detect leather hydrolyzed protein than melamine, because it is a type of protein itself. The inspection method devised by the Ministry of Agriculture checks if hydroxyproline, a type of hydrolyzed animal collagen, is contained in the dairy products. If so, it can be inferred that the product contains leather hydrolyzed protein.	Detection of adulterants requires advanced laboratory testing	Opportunity

13327	Officials said that the samples failed to meet the stringent quality specifications prescribed under the Food Safety and Standards Act 2011.	Detection of adulterants requires advanced laboratory testing	Opportunity
13286	Ten samples were sent to lab where all of them were found adulterated and sub-standard.	Detection of adulterants requires advanced laboratory testing	Opportunity
13282	‘On Wednesday, the food safety department officials seized 200 bottles of misbranded soft drinks and 1,875 unhygienic water and buttermilk sachets from various shops in areas such as T. Nagar and Teynampet.’	Food safety/ Extensiveness of Traceability	Countermeasure
13232		Extensiveness of Traceability	Countermeasure
13224	Acting on a tip-off, a FDA team led by Food Safety Officers Manek Jadhav and Gopal Mahore carried out simultaneous raids at two residential apartments in Nutan Complex and Shanti Nagar area of Mira Road at about 6 a.m. on Friday. According to FDA officials the accused would buy branded milk packets from distributors. They would then remove about 100 to 200 ml milk from each packet and then refill it with tap water before sealing it using hot wax.	Transparency supply chain	Opportunity

Appendix B: Conditional Probabaility Tables (CPT) for country of Origin

Parents		Conditional Probability Table- Country of Origin																								
Type	**FFV**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Seafood	**Opportunity**	0	0	0	0	0	0	0.02	0	0.04	0	0.02	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0
	Motivation	0	0	0	0	0	0	0	0	0	0	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Countermeasure	0	0	0	0	0.02	0	0	0	0	0.03	0.18	0	0	0	0	0	0	0	0.02	0	0.02	0.05	0	0	0.02
	Unknown	0	0	0	0	0.09	0	0	0	0	0	0.09	0.09	0	0	0	0	0	0	0	0	0.09	0	0	0	0.36
Meat and Poultry	**Opportunity**	0	0	0	0	0	0	0	0.03	0	0	0.21	0	0	0	0.03	0	0	0	0	0.03	0	0	0	0	0
	Motivation	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Countermeasure	0	0	0.02	0	0	0.02	0.03	0	0.02	0.04	0.24	0	0	0	0	0	0.05	0	0	0	0.02	0.01	0	0.03	0.01
	Unknown	0	0	0	0	0	0	0	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.08
Alcoholic Beverages	**Opportunity**	0	0	0.03	0	0	0	0	0	0.03	0	0.08	0	0	0.05	0	0	0	0.05	0	0	0.05	0.15	0	0.03	0.05
	Motivation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.58	0	0.08	0	0
	Countermeasure	0	0	0.03	0.01	0	0	0	0	0	0	0.24	0.03	0	0	0	0.07	0	0.01	0	0	0.05	0	0	0.03	0.12
	Unknown	0.03	0	0	0	0	0	0	0	0.03	0	0.03	0.03	0.03	0.06	0	0.09	0.06	0	0	0	0.09	0	0	0	0.11
Dairy	**Opportunity**	0	0.01	0	0	0	0	0.03	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0.58	0	0	0	0.03
	Motivation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0
	Countermeasure	0	0	0	0	0	0	0	0	0	0.04	0.27	0	0	0	0	0	0	0	0	0	0.27	0	0	0	0.04
	Unknown	0	0	0	0	0.04	0	0.08	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0.32	0	0	0	0.12

Parents		Conditional Probability Table- Country of Origin																								
Type	**FFV**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**
Seafood	Opportunity	0.07	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Motivation	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Countermeasure	0.08	0	0	0.02	0	0	0	0.03	0.02	0	0.02	0	0	0	0	0	0	0	0	0	0.03	0.02	0.2	0	0
	Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0
Meat and Poultry	Opportunity	0	0	0.03	0	0	0	0	0	0.03	0	0	0.03	0	0.03	0	0	0	0.08	0	0.08	0.03	0	0.03	0	0
	Motivation	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Countermeasure	0	0.01	0	0.01	0	0	0	0	0.01	0	0	0	0	0	0	0.03	0.01	0	0	0.08	0.04	0.01	0.02	0	0
	Unknown	0	0	0	0	0	0	0	0.08	0.08	0	0	0	0	0	0	0	0	0.15	0	0	0	0	0	0	0
Alcoholic Beverages	Opportunity	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0.03	0
	Motivation	0	0	0.08	0	0	0	0	0.08	0	0	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0	0
	Countermeasure	0	0	0.03	0	0	0	0	0	0	0.01	0	0	0.03	0.03	0	0	0	0.05	0.03	0	0.01	0	0.04	0.01	0
	Unknown	0	0	0.03	0	0.06	0	0	0	0	0	0	0	0	0.03	0	0	0	0.03	0	0	0	0	0	0	0.09
Dairy	Opportunity	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.06	0	0	0	0	0	0	0	0	0	0
	Motivation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
	Countermeasure	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0.04	0.04	0	0	0	0	0.04	0.04	0	0.04	0	0
	Unknown	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0.12	0	0	0.04	0	0	0	0	0	0	0

Parents		Conditional Probability Table- Country of Origin								
Type	**FFV**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Seafood	**Opportunity**	0.02	0	0	0.22	0.5	0	0	0	0
	Motivation	0	0	0	0.36	0	0	0	0	0
	Countermeasure	0	0	0	0.03	0.16	0.05	0	0	0
	Unknown	0	0	0	0	0.18	0	0	0	0
Meat and Poultry	**Opportunity**	0	0	0	0.34	0.03	0	0	0	0.03
	Motivation	0	0	0	0.17	0.17	0	0	0	0
	Countermeasure	0.02	0	0.02	0.14	0.12	0	0	0.01	0
	Unknown	0	0	0	0.15	0.15	0.08	0	0	0
Alcoholic Beverages	**Opportunity**	0	0.03	0	0.33	0.03	0.03	0	0	0
	Motivation	0	0	0	0	0.08	0	0	0	0
	Countermeasure	0	0	0	0.05	0.05	0	0.01	0.01	0
	Unknown	0	0.09	0	0.09	0	0	0	0	0
Dairy	**Opportunity**	0	0	0	0.03	0.09	0	0	0	0
	Motivation	0	0	0	0	0	0	0	0	0
	Countermeasure	0.04	0.04	0	0	0.08	0	0	0	0
	Unknown	0	0.04	0	0	0.04	0	0	0	0

Appendix C: Conditional Probability Tables (CPT)

Conditional Probabilities of CNTRFT			
Parents		**Probability**	
Type	**FFV**	**1**	**0**
1	1	0.04	0.96
1	2	0.00	1.00
1	3	0.26	0.74
2	1	0.00	1.00
2	2	0.00	1.00
2	3	0.32	0.68
3	1	0.41	0.59
3	2	0.08	0.92

3	3	0.97	0.03
4	1	0.09	0.91
4	2	0.00	1.00
4	3	0.50	0.50

Conditional Probabilities of Type

Parents	Probability			
FFV	**1**	**2**	**3**	**4**
1	0.24	0.20	0.21	0.35
2	0.28	0.15	0.31	0.26
3	0.23	0.39	0.28	0.10

Conditional Probabilities of FLC			
Parents		**Probability**	
Type	**FFV**	**1**	**0**
1	1	0.00	1.00
1	2	0.55	0.45
1	3	0.30	0.70
2	1	0.05	0.95
2	2	0.50	0.50
2	3	0.53	0.47
3	1	0.13	0.87
3	2	0.00	1.00
3	3	0.12	0.88

4	1	0.06	0.94
4	2	0.00	1.00
4	3	0.35	0.65

Conditional Probabilities of China			
Parents		**Probability**	
FLC	**FFV**	**1**	**0**
1	1	0.00	1.00
1	2	0.00	1.00
1	3	0.12	0.88
0	1	0.12	0.88
0	2	0.00	1.00
0	3	0.29	0.71

Appendix D: Assessment Accuracy

ID	FFV	TAN	$BP-FFV
1528051	3	3	1
913178	1	1	1
289925	2	2	0.99758567
289919	2	2	0.99758567
197572	1	1	0.989840435
112951	3	3	0.876018242
90337	3	3	0.977842454
68861	3	3	0.992059917
62896	3	3	0.999520531
58076	3	3	0.999975065
56019	1	1	0.998240596
51808	3	3	0.999520531

51462	3	3	1
17419	4	4	1
17213	4	4	1
17141	3	3	0.741353187
16780	1	1	0.999999048
16778	1	1	0.999999048
16774	1	1	0.999999048
16772	1	1	0.999999048
16086	3	3	0.945414977
13319	1	1	0.607666094
13296	1	1	0.607666094
788492	3	3	1
390535	3	3	0.936464035
121420	3	3	1
22770	3	3	1

22731	3	3	0.918745204
213060	3	3	1
122912	3	3	0.906289431
118699	1	1	1
94320	2	2	1
93111	2	2	1
69794	1	1	0.997960086
65654	3	3	0.987642311
65650	3	3	0.987642311
63306	3	3	1
54159	3	3	0.707213208
51537	3	3	1
34113	3	3	1
27179	4	4	1
26773	3	3	0.998111932

25961	1	1	0.945788698
25475	3	3	0.973100091
23313	3	3	0.999237774
22293	3	3	1
22166	1	1	0.960104719
22161	1	1	0.960104719
20303	4	4	1
18778	3	3	1
17361	3	3	1
17269	3	3	0.98865135
17267	3	3	0.98865135
16499	3	3	1
15261	3	3	1
13557	1	1	0.885504533
13361	2	2	1

1629449	2	2	1
1044095	3	3	0.926555131
828615	4	4	1
191531	1	1	1
269902	3	3	1
244848	4	4	0.511281743
91946	1	1	0.987555274
66589	1	1	1
34363	3	3	1
34359	3	3	1
34201	3	3	0.877191916
34085	3	3	1
30170	4	4	1
25575	2	2	0.985500917
25463	2	2	0.999989005

23185	3	3	1
22406	3	3	0.94880778
13747	4	4	1
13724	4	4	1
13417	2	2	0.999509216
13398	3	3	1
13260	1	1	0.811741271
1596726	1	1	0.909537089
631001	4	4	1
279451	3	3	1
461064	1	1	0.520506488
61718	4	4	1
53875	2	2	1
53256	1	1	0.970646895
50469	2	2	0.991298833

50457	2	2	0.997488168
33748	1	1	0.999666777
31106	1	1	0.900078711
29797	1	1	0.7916972
23594	4	4	1
22960	1	1	0.855686946
22570	1	1	0.918031127
17207	4	4	1
16450	3	3	0.968345746
13282	3	3	0.498705735
13224	1	1	0.940245524