Advancing understanding of pinch-points and crime prevention in the food supply chain

JAN MEI SOON[1], LOUISE MANNING[2] AND ROBERT SMITH[3]

[1]International Institute of Nutritional Sciences and Applied Food Safety Studies, School of Sport and Wellbeing, University of Central Lancashire, Preston PR1 2HE UK
[2]Harper Adams University, Newport, Shropshire, UK TF10 8NB
[3] School of Business and Enterprise, University of the West of Scotland, Dumfries, DG1 4ZN UK

Abstract

From a crime prevention perspective, food crime remains a challenge. Whilst opportunity for crime can be reduced by implementing certain measures; and addressing the potential perpetrators, their possible actions and criminal behaviour, the trade-offs which occur in the food supply chain that motivate such activity, still remains complex. These heuristic factors have led, in this study, to the consideration of 'pinch-points' where crime could occur as a result of capability, opportunity, motivation, rationalisation and supply chain pressure. Pinch-points can be addressed using the Food Crime Countermeasures Framework (FCCF) conceptualised in this paper. We argue that conventional anti-fraud measures: detection, deterrence and prevention are essential to support food fraud risk assessments, as are continuous interventions and response strategies. The implementation of countermeasures that initially drive prevention and deterrence and where required, detection, intervention and response form the basis of our approach. This paper focuses on the United Kingdom (UK) however it should recognised that food crime is a global issue.

[1] Author for correspondence: Tel: +44(0)1772 894567; E-mail: jmsoon@uclan.ac.uk.

Keywords: continuous interventions; countermeasures; fraud; vulnerability

Introduction

Whilst the topic of this paper is not generally the subject of criminological discourse it is nevertheless a contemporary and patently problematic criminological issue which is currently manifesting at a practical level. It is thus important, from a crime prevention and reduction perspective to examine at this practical, operational level. Consequentially, this paper aims to contextualise and synthesise the specialist knowledge implicit within the literature of food crime with that of crime prevention and reduction and thus as a result broaden the focus of both literatures. Whilst this study implicitly refers to the United Kingdom (UK) it is a worldwide and a cross-national crime problem and the framework presented herein has utility too at a global level.

The overarching topic of this conceptual paper is that of 'pinch-points' because it is within context that food crime is operationalised. The term "pinch-point" has been used to variously across the supply chain, safe practice and policing literature to describe 1) physical points or locations (Makwasha and Turner, 2013); 2) the weakest necessary conditions for the problems to persist when considering problem orientated policing (Read and Tilley, 2000); 3) strategic points in the supply chain such as bottlenecks where there is sensitivity to disruption and/or limited capacity (Christopher and Peck, 2004); and 4) points of intervention (Weisel, 2003) such as where external pressure can be applied e.g. regulatory pressure or stimulus (Yakovleva and Flynn, 2004); or where pressure can be applied to disrupt criminal activity (Chon, 2016). Pinch points can also occur as a result of supply chain pressure

(Manning *et al,* 2017). Wolf and Hermanson (2004) argue that pressure is one element of the “fraud diamond” model, the other three elements being capability, opportunity and motivation. Indeed, trading in an environment where there are differentiated global standards for animal welfare, environmental protection and worker welfare standards can lead to pinch points. Manning *et al,* (2017) argue that the existing model of the two-dimensional fraud diamond is actually three dimensional and multifaceted when the socio-economic dynamics of supply chain pressure should also be considered.

In summary, a pinch-point is the location at which intervention might be expected to have the longest term of action and the widest impact (Read and Tilley, 2000) and in the context of food crime the point where interventions take place that will have the longest and widest impact on mitigating illicit behaviour. In terms of types of crime associated with the food chain this paper is considering i**nter-food supply chain crime** i.e. criminal activity that occurs between one discrete food supply chain and another, the legal and the illicit. Conversely, **intra food supply chain criminal activity** is the criminal activity that occurs between actors within an otherwise seemingly legitimate food supply chain. To provide clarity the following definitions from Closs and McGarrell (2004, p. 8) are used:-

- A *supply chain* is the combination of organisations and service providers that manage the raw material sourcing, manufacturing, and delivery of goods from the source of the commodities to the ultimate users.
- *Supply chain management* is the inter- and intra- organisational coordination of the sourcing, production, inventory management,

transportation, and storage functions with the objective of meeting the service requirements of consumers or users at the minimum cost.

Farms are just one element of the supply chain that encompasses multiple actors and stakeholders. Indeed, farm crime can be considered in terms of criminal typology such as the urban marauder (Smith, 2010) exploiting often weak levels of security and police activity in rural areas, organised criminal gangs (OCGs) that may involve a network of insider groups (such as farmers) as well as external actors who can pass on the illicit goods into wider markets and destinations (McElwee *et al*, 2017). Also of interest here is the farm as a defensible and thus safe space (Newman, 1972; Mawby, 2017). Traditionally, in the UK, farmers have been lax in engaging in crime prevention and crime reduction initiatives, albeit this is changing with the advent of the 'Fortress Farm' Concept' (NFU Mutual, 2017). The fortress farm concept suggests that as countryside criminals increase their activity on farms the farmers as a result feel under siege and are turning their existing farmyards into protected fortresses in an effort to safeguard their property. Thus, the context in which farm, and wider food supply chain, crime is operationalised has an impact on the 'pinch-points' discussed herein.

This paper comprises of the following sections. In the first section we examine supply chain issues, including the importance of making trade-offs. Thereafter, we investigate the concept of 'pinch-points' before situating the concept within the food crime prevention literature. We then consider the issue of crime vulnerability and crime prevention weakspots. This leads us to consider how to design appropriate crime prevention strategies. The paper concludes with some relevant observations.

Appreciating the importance of supply chain issues

Prior to discussing the concept of 'pinch-points' it is necessary to begin by outlining the importance of developing an understanding of the supply chain perspective because it is within this context that food crime is operationalised. Illicit behaviour is a contemporary (but ancient) theme in food supply chains in terms of academic research, industry awareness, and in emergent food related organisational and supply chain literature. Illegal activity in food supply chains is not only a discrete process operating in parallel to legal activities and supply chains, but is also embedded within authorised, licensed and permitted processes that have particular elements of opacity (see Gregson and Crang, 2017; Manning *et al,* 2017). Since the global financial recession of 2007-08, McElwee *et al,* (2017) suggest that contemporary evidence from official reports and the media shows an increase in food related criminal activity including food adulteration, mislabelling of food, sheep theft, and trading in illegal halal meat. However, the strategic decision by individuals or groups to engage in informal, and criminal acts for financial gain is complex. It may be motivated by socio-political factors, such as the UK Government's austerity programme where the first fiscal and social measures were introduced in 2008. The impact of the austerity programme on the food supply chain, drove for some organisations the need to firstly be resilient, or in some cases to simply survive, and in some instances individuals and organisations focused on motives of profit maximisation and greed (Smith *et al,* 2017a).

The food supply chain is complex and involves both the farming sector and food industries, therefore adopting a holistic approach is essential to

125 combatting food supply chain crime. This paper makes a start by considering
126 the issue of 'pinch-points' that has been previously somewhat neglected by
127 criminologists in this context. Organisations within the chain do not sit in
128 isolation; they interact with external influences in their wider environment
129 (Winter *et al,* 2014). Supply chains are socio-economic networks with inter-
130 related strategies, activities, dynamic components (the products, processes
131 and technical knowledge employed) and structural elements such the key
132 actors involved including the retailer, farmer, manufacturers processor,
133 distributors and food service. Primary producers are the actors that provide raw
134 material, such as farms and aquaculture secondary producers (manufacturers
135 that enhance the value of raw materials, wholesalers, distributors) and tertiary
136 producers, retailers and food services (see Closs and McGarrell 2004; Borghesi
137 and Gaudenzi, 2013). Other factors include firstly the role and influence of
138 stakeholders such as investors, shareholders, insurers, certification bodies,
139 governments, policy makers and regulators, civil society, amongst others;
140 secondly the complexity of the relationships formed between stakeholders,
141 thirdly the climate of the relationships in terms of collaborative or conflicting
142 characteristics of association, and lastly the type of goals each actor develops
143 (Closs and McGarrell, 2004; Borghesi and Gaudenzi, 2013). This begs the
144 question as to the factors that have led to this reported rise in food related
145 criminal activity both at farm level, and across the wider supply chain and how
146 in some circumstances illicit behaviour is rationalised by perpetrators from
147 being the exception to becoming the norm. We investigate these factors which
148 are arguably influenced by multiple trade-offs within the food supply chain.

149 Trade-offs occur because in a given situation neither the decision-

maker, nor wider society can have everything they want so as a result they have to compromise in some way (Campbell and Kelly, 1994). A trade-off is a mediated form of decision-making or compromise, and this type of decision-making is ubiquitous at farm level when land is managed with multiple strategic and operational objectives (Klapwijk *et al,* 2014). Consumer trade-offs occur when they are willing to trade one attribute for another e.g. quality for price (Luce *et al,* 1999). Trade-offs occur at multiple levels including field, enterprise, farm, landscape or supply chain (Table 1).

Take in Table 1

Research on trade-offs especially with multiple attributes and/or collective decision-making has considered the trade-off between time and cost (Feng *et al,* 1997); time, cost and quality (Monghasemi *et al,* 2015); speed and accuracy (Häubl and Trifts 2000: Franks et al. 2003; Dane and Pratt, 2007); accuracy and effort (Johnson and Payne, 1985; Bettman *et al,* 1990; Häubl and Trifts, 2000; Boulis et al. 2003; Gigerenzer and Gaissnaier, 2011); accuracy and informativeness i.e. accepting errors in return for securing more informative judgments (Yaniv and Foster, 1995); cost and risk (Kerstholt, 1994); and finally benefit and harm (O'Connor *et al,* 2003).

In addition, time pressure is a frequent element of trade-offs. Time pressure is driven by deadlines when the time available may be perceived as too short to make a decision. Multiple studies have investigated this phenomenon (Huber and Kunz, 2007). Time pressure, may also lead to a negative emotional response (Maule *et al,* 2000) which then affects decision-making. Luce *et al,* (1999, p. 144) define emotional trade-off difficulty as "*the*

174 *level of subjective threat a decision-maker associates with an explicit trade-off*
175 *between two attributes*". Thus positive (benefit) and negative emotion (fear,
176 harm, anxiety, threat, challenge, concern, uncertainty) and specific emotional
177 goals (such as protecting self-esteem, maintaining a moral value or ideal) have
178 an impact on both cognitive appraisal and decision-making. Therefore, trade-
179 offs occur at occur multiple, complex and interwoven levels and the trade-off
180 between legality and illegality is only one of a number of decisions that supply
181 chain actors have to take.

182 Humans adapt their decision-making behaviour to a given situation, or
183 environment, often seeking to reduce the amount of associated cognitive effort
184 required to reach the decision (Shugan, 1980; Häubl and Trifts 2000). This can
185 occur as a conscious response or as an unconscious cognitive strategy. Thus
186 arguably decision-making is a situated event influenced by a number of factors.
187 Prendergast (2002) suggests that the trade–off of risk versus incentive is
188 influenced by how risk is determined e.g. risk as measured by volatility or
189 variance of returns by the executive, whereas for farmers it is the variance of
190 profits or variance of yield in a given crop cycle.

191 In this context a *food crime* threat can be considered to be an agent that
192 arises from fraud, or perpetrators taking advantage of the market opportunities
193 to substitute, or deceive, as a result of weather events, harvest failure etc. that
194 can cause loss or harm to individuals and/or organisations. Profit maximisation
195 in the agricultural sector is contextualised by characteristics of constant
196 uncertainty and risk of failure due to weather, animal disease etc. and many
197 farming organisations have limited opportunities in terms of growth orientation

198 and business expansion (Smith *et al,* 2017b). We now turn to examine these
199 pinch-points in the supply chain that give rise to the environment where crime
200 could occur.

201 **Appreciating the importance of pinch-points in the supply chain.**

202 To achieve a greater understanding of the topic it is helpful to map these
203 pinch-points. As a process, pinch-point mapping involves identifying potential
204 bottlenecks and threats and manipulating and managing those points to ensure
205 effective control of resources in order to meet demand (Pil and Holweg, 2006).
206 Moreto and Clarke (2013) in their research on transnational illegal markets in
207 endangered species highlight that crime is situational and by directing
208 preventive measures at pinch-points this will deliver the best results in reducing
209 the potential for criminal activity. Furthermore, different crimes will have
210 different pinch-points.

211 Borghesi and Gaudenzi (2013) considered four types of supply chain risk:
212 1) market risk; 2) process risk; 3) supplier and environmental risk; and 4) the
213 risks associated with transparency and information visibility. For a retailer, the
214 degree of risk associated with a given supply chain actor is mediated by
215 whether the individual or business of interest has either a given monopoly in
216 terms of the product or service they supply i.e. they are non-substitutable or
217 alternatively they can be easily substituted e.g. farmers all providing the same
218 commodity. Traditional supply chain responses to managing and mitigating risk
219 include using insurance, greater information sharing or outsourcing risk to other
220 supply chain actors (Olson and Wu, 2011). Therefore, organisations can be
221 driven by their shareholder or insurer demands to quantify, manage and where

possible mitigate their risk profile. As a result, retailers, manufacturers or food service may seek to adopt a systems based approach to manage, mitigate or outsource risk.

Within this market context, there are multiple pressure factors that can drive illicit activity in food supply chains including rapid development of systems, logistics and technology, asymmetry in information flow, data swamping and opacity; market competition and resource scarcity, inadequate policy and market governance, lack of regulatory and market sanctions, and ultimately low probability of discovery (Charlebois *et al,* 2016; Manning *et al,* 2016; Manning, 2016; Marvin *et al,* 2016; Manning *et al,* 2017). This pressure can create a series of pinch-points at informal interfaces; formal and visible interfaces; and invisible interface(s) where differentiation in stakeholder approaches to supply chain risk, organisational goals and objectives leads to trade-offs and thus give rise to illicit behaviour. Taking a transactional approach and simply developing formal risk prevention strategies (countermeasures or preventive measures) is a welcome start but not enough to address the challenge of illicit behaviour and thus address the pressures and opportunities. Countermeasures are intended to reduce criminal opportunity in food supply chains (Spink *et al*, 2015). The implementation of countermeasures will not only have a preventive aspect in terms of preventing an incident and also making it more unlikely in the first place, but should an incident occur appropriate countermeasures will lessen too the impact of a given incident (Mitenus *et al,* 2014). Capability, motivation, rationalisation, derived value propositions, and regulatory and market incentives for illicit behaviour also need to be considered when developing crime prevention strategies (Manning *et al,* 2016; Manning *et al,* 2017).

The actualisation of this pressure on capability, opportunity and motivation dynamics can be seen through the lens of recent global food scandals such as the 2013 European horsemeat scandal (Smith and McElwee, 2017); the 2017 meat fraud scandal in Brazil (Manning *et al,* 2017), and the 2017 fipronil in eggs and composite products scandal in Europe (Kowalska *et al,* 2018). The lack of early and harmonised regulatory intervention in the fipronil scandal resulted in an incident affecting 56 countries (RASFF Portal, 2018; RASFF 2018; Kowalska *et al,* 2018). A number of contextual factors impact on criminal behaviour such as pressure, resource allocation and ownership, greed, economic inferiority, need and power relations.

Situating pinch-points in the food crime prevention literature.

Supply chain power is driven by the degree of power localisation or conversely distribution and each actor's relative control of or access to resources and capital assets. Thus the risk of illicit behaviour is situational and is framed by power structures and other socio-economic factors. Successful modes of food crime in terms of the degree of financial gain, or their impact in the case of food defense (ideological food crime such as terrorism focused on the food supply chain), reflect on the quality of execution and at what point, or even if, detection actually occurs (Manning *et al,* 2017). The use of a pre-requisite programme to minimise, and where possible eliminate, the likelihood of an *unintentional* food safety incident is well established in the food supply chain through the hazard analysis critical control point (HACCP) approach. The alternative, i.e. the development of a countermeasures programme to minimise,

or where possible eliminate, the likelihood of a food crime threat is less well determined.

In the wake of the 2013 Horsemeat Scandal, the Elliott Review determined that a national food crime prevention framework was essential to prevent a future food crime incident (Elliott Review, 2014). Preventive measures, deterrence and/or a lack of motivation to conduct food crime will also have influence. Countermeasures that address food crime vulnerability can be grouped into four categories: detection, deterrence and prevention and disruption (Spink *et al,* 2015; Spink *et al*, 2016; Soon and Manning, 2017; van Ruth *et al,* 2017). *Detection measures* can identify the activities associated with food crime, whilst *deterrence* includes the measures that focus on a specific type of perpetrator and their activities. Deterrence can be described as 1) the inhibition of opportunity and perpetrator activity as a result of concern over the personal consequences to themselves as a result of taking an action or the maintenance of appropriate preventive measures, or 2) countermeasures that discourage their activity (e.g. concern that the attack will fail). *Prevention* in this context concerns the resources employed to minimise the potential for a food crime incident to occur and ensure disruption mechanisms to address any activity if it occurs. Kirby and Penna (2010) describe prevention as those interventions that stop an incident especially where they change a process or an environment in “a sustainable manner”. In contrast Kirby and Penna (2010, p. 205) define disruption as, “a more flexible, transitory, and dynamic tactic, which can be used more generally to make the environment hostile … [breaking up] the offender’s networks, lifestyle and routines”. Disruption tactics often align

295 to a prevention framework, thus serving as a deterrent through inhibiting
296 opportunity and reducing motivation to commit a crime (Kirby and Nailer, 2013).
297 Spink *et al,* (2017) recommend that in order to address the root cause of
298 food crime, in this instance fraud, food science and technology should
299 encompass social science, business and understanding of criminology. We
300 concur with this holistic approach using learning from a range of disciplines. To
301 further develop the countermeasures approach advocated by Elliott, Manning
302 and Soon (2016) compared and contrasted six existing food crime risk
303 assessment (FCRA) models in terms of their aims, mechanisms of operation
304 and practicalities of use. The risk assessment models were: threat analysis
305 critical control point (TACCP), vulnerability assessment and critical control point
306 (VACCP), the CARVER+SHOCK tool, the food protection risk matrix (Spink and
307 Moyer, 2011), and the United States Pharmacopeial (USP) preventive food
308 fraud management system. These operate at manufacturing and wider supply
309 chain level rather than being farm focused. Additional models are being
310 developed for food fraud vulnerability self-assessment including the SSAFE
311 model (van Ruth *et al,* 2017).
312 The ability to quantify the likelihood of a threat or vulnerability in a given
313 situation is influenced by the degree of adoption of countermeasures and their
314 effectiveness (Manning and Soon, 2016). Thus whilst FCRA is obviously of
315 value, the preventive benefit to organisations is limited. The output from FCRA
316 needs to be reviewed in line with any emerging or new threats otherwise the
317 risk assessment phase does not translate into an effective, and dynamic food
318 crime countermeasures framework (FCCF). The development of the FCCF is
319 essential to embed preventive measures, identify relevant sources of

intelligence on changing status of risk, detect illicit activity, and ensure timely and appropriate responsive action and a countermeasures' continuous improvement strategy. Therefore, three factors: detection, deterrence and prevention can be drawn together at regulatory, supply chain or individual business level to underpin a FCCF of integrated risk assessment and implementation of countermeasures that initially drive prevention and deterrence and where required, detection, intervention and response (Figure 1).

Take in Figure 1

Horizon scanning is a useful crime prevention tool. Roy *et al,* (2014), albeit not in a crime context, describe horizon scanning, as the systematic examination of future potential threats and opportunities, resulting in the prioritisation of threats and their effective management. Therefore, horizon scanning has the potential to act as an early warning system, initiating prompt discussion and then decision making about threat mitigation (Stanley *et al,* 2015 p. 553). Horizon scanning can be considered as a systematic way of considering evidence about future trends and scenarios in order to determine whether an organisation is adequately prepared for potential threats and has implemented, or can readily adopt, means for their appropriate countermeasure control. Effective horizon scanning for food crime is a foundation for a FCCF i.e. considering intelligence from a range of sources, be it economic, social or environmental, in order to effectively map possible criminal scenarios associated with the materials and products that the organisation procures, produces and sells, in order to accurately identify the potential threat, the

controls required and the mechanisms for updating such assessments if the evidence (intelligence) changes in the future.

During the mapping process weak areas, pinch-points or *hotspots* that are vulnerable to food crime at specific stages in food supply chains or networks can be determined. Detection, mapping and prevention activities can only be developed to address known issues or activities, making TACCP and VACCP of limited value with regard to emerging crime risk or entrepreneurial, enterprising, situational crime risk that is reactive, responsive and specific to an organisation, the products it produces and the associated supply chain (Soon and Manning, 2017; McElwee *et al,* 2017; Smith, 2017).

Van Ruth *et al,* (2017) considered food supply chain vulnerability to fraud and based their conceptualisation on the elements of opportunity (suitable target in terms of time, space and technical opportunities), motivation (the economic drivers, supply and pricing, value added product attributes where the potential to substitute an inferior product has the potential for a higher financial gain, economic environment and financial strains and culture and behaviour including business strategy and business culture) and the control measures (technical and managerial measures) linking their work to the routine activity theory developed by Cohen and Felson (1979).

Guardians are the individuals operating at national, supply chain or individual business levels (Spink *et al,* 2015) that have the knowledge, skills and understanding to implement a FCCF. Although guardians do not have to have a specific intent to watch over food products and services, they can act as guardians whilst carrying out their roles as managers or handlers (Hollis and Wilson, 2014). However, vulnerability can still occur even in the presence of a

capable guardian. This is where guardianship activity can be further enhanced by monitoring activities. The combination of available / visible guardians who are also monitoring the food products / process throughout the supply chain could provide a stronger deterrent effect (Reynald, 2009; Hollis and Wilson, 2014). Those individuals or teams developing FCCF need to recognise that the adoption of universal, general countermeasures based on historic threats as a 'catch all approach' to preventing and where required managing food crime is of limited value in addressing illicit behaviour that is caused by supply chain pressure. This is because the drivers of illicit behaviour and associated opportunity, rationalisation, capability and motivation, and derived value proposition are situational and transitory.

Situational crime risk and the means to predict its occurrence has been explored within criminology and contemporary food literature (Perline and Goldschmidt, 2004; McGloin *et al,* 2011; Manning and Soon, 2016). Situational crime risk factors include factors such as supply chain pressure, power asymmetry, type of corporate culture, the work environment and can have a multiple, compounding impact (Perline and Goldschmidt, 2004: Carson and Bull, 2003). Situational crime risk can be mitigated by strengthening environmental resilience (Clapton, 2014) especially by increasing the associated personal risks and difficulties associated with the crime and alternatively reducing the potential personal rewards of committing a crime (Clarke, 1995; Spink and Moyer, 2011).

The concept of crime prevention through environmental design is nothing new as the design of physical space has long been identified as being important in understanding and mitigating criminal behaviour (Newman, 1972).

Newman proposed that defensible space can be created when the physical space is structured in a way that reinforces the social structure that defends itself i.e. a farm or factory design could in itself help or hinder the social culture of the organisation in which people work and their psychological engagement with the space itself. This idea of defensible space is developed by van Ruth *et al,* (2017) into a concept of hard controls (physical and technical countermeasures) and soft controls which reflect the managerial controls that are in place. Appropriate countermeasures that are based on the concept of defensible space can be adopted in a preventive approach to crime in the food supply chain. Here we take this further to consider Newman's four themes of defensible space and these have been adapted in this conceptual research to considerations of a food supply chain environment: van Ruth *et al,* (2017) differentiate between external environment that consists of three levels 1) the direct supplier and customers; 2) the wider supply chain and industry network and 3) the international and national environment as opposed to the internal environment within the business. The four elements discussed here are territoriality, surveillance, image and milieu or juxtaposition:

- **Territoriality** – creates a sense of legitimate and illegitimate access to space i.e. identifying the legitimate allocation of space to those who are approved to work in the area and those who should not have access. Food industry protocols that address territoriality will assure that appropriate people are in a given space (production line, factory), wear colour coded protective clothing by location as this will create a visual territoriality that should prove a deterrent to illicit individuals entering that space who would be readily identified if they are not in appropriate clothing. Whilst territoriality

can be addressed by protocols in processing, storage and defined spaces such as farmyard areas, it proves more problematic at the field level where in the UK access often cannot be limited or prevented. Further if the perpetrators of crime are not outsiders or strangers, but are instead members of the community such as other farmers and/or professional rural offenders with legitimate reasons for access to a given location then legitimacy of access will have less influence on crime prevention (Mawby, 2017). Therefore this option to mitigate food crime can only be used in certain situations.

- **Surveillance** – designing the physical space in a way that assists legitimate users to observe the behaviours of both employees and visitors e.g. temporary workers, service engineers, contract cleaners etc. Again this approach is of value in a bounded work environment where territoriality and surveillance can combine, but harder to implement at the field level;
- **Image –** a sense that the physical space is well cared for and developing preventive measures that reduce the visual appearance that areas of the factory, farm, distribution centre or manufacturing site are remote, little used, or not regularly visited; and
- **Milieu or juxtaposition** – which, in the context of a food supply chain, describes the image, natural surveillance and territoriality of other businesses that interface with the organisation's space. This element reflects that other businesses in the supply chain may either not be addressing defensive space or may undertake opaque practices or lack transparency.

443 The example given here is one of defensive space in the physical context. The
444 other area of defensive space is more ethereal, such as data storage, data
445 exchange and cyber-related space. *Cybersecurity* can be described as the
446 countermeasures taken to protect a computer system and associated storage
447 clouds or individual appliance against an intentional malicious target attack
448 and/or unauthorised access and unintentional or accidental access.
449 Cybersecurity countermeasures include, but are not limited to, developing
450 cybersecurity policies and procedures, undertaking focused FCRA, adopting
451 training and awareness sessions for staff commensurate with an individual staff
452 member's responsibilities and developing soft or hard controls such as specific
453 software, firewalls, technologies etc. that can protect the organisation's cyber
454 environment and their electronic assets (Manning, forthcoming).

455 However, preventive environmental design to mitigate food crime risk is of
456 limited benefit if there is high-level insider complicity i.e. the involvement of the
457 business owner, management or employees in criminal activity in illegal
458 practices such as covert operations by running out of hours processing known
459 only to a select few (McElwee *et al,* 2017). Therefore, consideration of the
460 impact of the processing environment and the wider supply chain environment
461 is of value, but it cannot address all potential threats and is not as a result a
462 zero risk approach. However the theory of defensive space does lend itself to
463 adoption within an overarching FCCF.

464 In this respect, the concept of hurdles is of interest. Spink *et al*, (2015) define
465 *hurdles* in the context of food crime prevention approaches as the transactional,
466 formal system components that reduce opportunity for food crime by either
467 assisting detection or proving to be a deterrent. These would include on-line

468 monitoring and verification activities in the wider supply chain such as audits
469 and product sampling. Verification is discussed in more detail later in the paper.
470 Thus a *hurdle gap* can be described as a vulnerability to food crime where such
471 mitigation activities are not in place, or alternatively are in place, but are not
472 effective.
473
474 **Determining crime vulnerability and identifying crime prevention**
475 **weakspots**
476 Food criminals are clandestine, stealthy, and actively seek to avoid
477 detection (Spink, 2011). According to the Centre for the Protection of National
478 Infrastructure (CPNI, 2013), the majority of insider criminal activity in
479 organisations was carried out by permanent staff (88%), with only 7% of cases
480 involving contractors and 5% involving agency or temporary staff. Individuals
481 who had worked for their organisation for less than 5 years represented 60% of
482 cases and 49% of cases were by perpetrators aged between 31 and 45. More
483 males (82%) were involved in insider activity compared to females (18%).
484 These data were derived from 120 UK-based insider cases from both public
485 and private organisations from a range of industry sectors, not just food, where
486 financial gain was the single most common primary motivation (47%), ideology
487 (20%), desire for recognition (14%) and loyalty to friends, family or country
488 (14%). This literature and other sources lends itself to categorising food criminal
489 according to type (see Spink and Moyer, 2013; Manning *et al,* 2016; PAS, 96:
490 2017) and by inference developing appropriate preventive strategies.
491 Crime vulnerability is the extent to which an individual, organisation, supply
492 chain or national food system is at risk from, or susceptible to, attack, emotional

injury or physical harm, or damage from intentional illicit activity (Manning and Soon, 2016). Vulnerability can be assessed, using input from legal, intelligence, medical, scientific, economic, and political sources, to determine the scientific, economic, political, and social circumstances of a country in order to quantify the degree of threat and to set priorities for resources (Manning *et al,* 2005; WHO, 2002). Vulnerability ranking is not static and needs to be routinely reassessed to ensure that the ranking and prioritisation of crime risk remains appropriate and that suitable countermeasure(s) continue to be in place. McElwee *et al,* (2017) argue that in order to mitigate the potential for food crime in the supply chain two approaches can be followed: firstly to design food supply chains with built in risk-tolerance to crime and secondly to have appropriate strategies in place to contain the damage once an undesirable event has been identified. The magnitude of food crime risk (and to whom) will depend on the likelihood and severity of each type of incident and the degree of implementation of preventive and mitigation measures which can also be affected by the efficacy of guardians and hurdles (Spink *et al*, 2015). Thus as previously outlined in this paper there is no silver bullet of solutions to address food crime instead holistic, situation-specific product and process crime prevention strategies need to be adopted.

Designing appropriate crime prevention strategies

Regulators seek to reduce illegal activities either though punitive command and control measures, prosecution and detection systems or alternatively via preventative or deterrence measures such as awareness education and enterprise support (Smith *et al,* 2017b). Alternatively, market orientated or

supply chain approaches need to drive a crime prevention strategy based on reduced opacity and more transparency and access to information in the supply chain (the milieu). Supplier monitoring protocols need to include not only product related procurement activities but also ethical codes of conduct, integrity screening and whistleblowing protocols (van Ruth *et al,* 2017), standard reference checks, financial status checks, and consideration of the supplier's surge capacity and flexibility i.e. the ability to deliver increased quantities at short notice, if required (Beil, 2009). A financial status check can be incorporated into a suppliers' ranking and performance weighting and the scoring system that can highlight and reflect financial risk associated with a given supply base. This data will support FCRA that focuses on identifying the suppliers who could be subject to the supply chain pressures described earlier in this paper e.g. failed harvest, volatility in commodity price (wheat, milk, meat) etc. and as a result be more likely to undertake illicit activities. These "high-risk" suppliers can then be tracked and monitored. Price is one of the most important factors used in supplier selection, but it is critical to ensure that the objectivity of assessing product integrity and food crime risk is not lost in a purely risk: financial reward; or time versus accuracy trade-off.

Forensic accounting has been adopted as a food crime countermeasure especially to identify "false" suppliers (Power, 2013). Traceability tests and second party and third party supply chain audits will provide more information for focused forensic accounting and combined audits can be developed (Figure 2).

Take in Figure 2

Indeed, it was a recommendation of the Elliott Review (2014) that the UK government should "*support the work of standards owners in developing additional audit modules for food fraud prevention and detection incorporating forensic accountancy and mass balance checks.*" Traceability protocols adopt as a minimum the regulatory one step backward and one step forward tracking and trace principle (EU Regulation No. 178/2002) or market protocols can require traceability throughout from field to fork and the reverse too in a given supply chain. However, with multiple ingredients used to make composite products, and lengthy and complex food supply chains traceability can prove difficult in practice. Additionally, if an individual business within the supply chain deliberately and unanimously decides to behave illicitly, they can choose to circumvent orthodox supply chain traceability countermeasures, controls and monitoring. Therefore the value of developing a traceability countermeasures is the promotion of food integrity and developing an open transparent supply network. Procedural controls for traceability in themselves are not enough to ensure consistent compliance and prevent the opportunity for illicit activity. Further actions are needed including an effective verification (or surveillance) programme that ensures that the controls are in place and adequate.

The process of food production involves discrete production stages from farm to fork i.e. during growing, harvesting / slaughtering / catching of primary products, primary processing, secondary processing of food / food ingredients, packaging, labelling, storage and dispatch. These are all pinch-points where food crime activities could occur. At the manufacturing stage specifically, countermeasures need to be adopted to address the process vulnerabilities that can provide opportunity for food crime earlier in the supply chain.

During processing, itself potential deliberate contamination of food products or tampering with processes can be minimised via limited accessibility through engineering design (hard controls) and consideration as to the accessibility of production equipment and where needed re-engineering of equipment to prevent access e.g. covered conveyors, use of sight glasses, zoning (place) and creating a buddy-system to limit lone workers at high-risk processes such as use of expensive ingredients, or for recipe use where such information is deemed confidential. Tracer ingredients can be added to high value food so that potential counterfeit product can be readily identified in production and post packing. Further supply chain preventive countermeasures include numbered and tamper-proof seals on delivery vehicles and bulk storage silos, stock control measures such as computerised fill level equipment which relay the information back to central computerised systems, reduced electronic access to specific physical zones which are deemed high-risk via fingerprint technology, codes and passwords (PAS 96, 2017) password protection of computer terminals and electronic process management systems etc.

Appropriate assessment measures that demonstrate whether the FCCF is effective include substitution profit assessments, suppliers' ranking and ongoing performance monitoring, risk rating of likelihood of perpetrators to conduct activities, assessments to determine the likelihood of detection, severity or impact of practices, consideration of the effectiveness of preventive countermeasures and other factors that influence the risk of food crime such as history of occurrences, seasonality, and market prices. The formal FCCF systems, being visible and auditable, provide objective evidence to internal and external stakeholders of the organisation's commitment to combatting food

592 crime (Power, 2013). However this approach does not, according to Power,
593 build the soft knowledge required in terms of inspector skills to interpret audit
594 results. This means that a new type of balanced score card of soft, culture-
595 based risk factors also needs to be developed so that it can be effectively
596 verified. This development is worthy of further study and empirical research.
597 Assessing the efficacy of the FCCF encompasses both the technical areas
598 of responsibility within the food supply chain as equally as the administrative
599 areas of responsibility, so food auditors (food crime / fraud assessors) need to
600 work hand in hand with appropriately trained accountants, purchase ledger
601 administrators etc. The consistency of records and documentation can be
602 assessed via processes such as forensic accounting, and mass balance testing
603 for discrete batches allows unusual and inappropriate trends to be identified.
604 Market knowledge is essential to undertake this assessment effectively
605 especially because as described in this paper the risk is situational and
606 dynamic.
607 Verification through documentation review and classical food supply chain
608 auditing provides the food crime auditor with a range of evidence or audit
609 observations, which can be both qualitative, e.g. interviews, observations and
610 records or quantitative and based on measurement and test. System failure can
611 occur through people (human failure), process failure and place (i.e. design)
612 that provides opportunity for perpetrators to commit food crime. Therefore
613 verification activities need to include all of these areas in their scope.
614 The work of Newman has been introduced here and combined with the
615 literature from food supply and food crime risk identification and mitigation in a
616 novel approach. The need to address pinch-points and seek to prevent criminal

activity occurring requires the translation of the theory of defensive space from a previously urban-centric setting to one that reflects rural crime prevention too. Crime in the food supply chain is not victimless, as the cost of such criminal activity is ultimately met by food consumers. Further food consumers are being misled, misinformed and cheated when such criminal activity occurs. Mawby (2017) argues that crime prevention need to focus on locations where crime most commonly occurs, defined here as pinch-points, rather than exclusively on the circumstances that influence offending. It is important to state that defensive space is posited here not just in terms of localised guardians and physical hurdles, but for the food supply chain as a whole in terms of symbolic hurdles and cyber-based hurdles rather than how the theory has historically been used in wider criminological literature. For example further research work could be undertaken to develop a food supply chain based “secured by design” (SBD) approach to identify pinch-points and then a strategy of combined activities to prevent crime from occurring.

Conclusion

This conceptual paper has developed our collective knowledge on how an understanding of pinch-points and the FCCF presented advances our understanding of the holistic nature of contemporary crime prevention techniques used in the food supply chain. Conventional anti-fraud measures: such as detection, deterrence and prevention are essential to support FCRA, as are continuous interventions and response strategies. The implementation of countermeasures that initially drive prevention and deterrence and where required, detection, intervention and response form the basis of our approach.

Pinch-points are not dissimilar to vulnerability points. Identification of pinch-points and applying intervention strategies within the food supply chain – will provide positive impact in reducing food crime. One way to address the pinch-points is via the FCCF. In addition to the conventional deterrence, detection and prevention methods, the FCCF emphasizes a circular or a feedback mechanism to ensure continuous interventions are successfully implemented. The countermeasures cover a range of potential pinch points and vulnerabilities or can be targeted measures that act against unique risks and perpetrators. The situational aspects of crime, often driven by trade-offs, in the food supply chain means that holistic mechanisms need to be developed that address both social aspects of rationalisation and also motivational economic aspects of opportunity and capability and the potential for such crimes to go undiscovered.

References

Beil, D. 2009. *Supplier selection*. Available at: http://www-personal.umich.edu/~dbeil/Supplier_Selection_Beil-EORMS.pdf. accessed 2 January 2018.

Bettman, J.R., Johnson, E.J. and Payne, J.W. (1990) A componential analysis of cognitive effort in choice. *Organ. Behavior Human Decision Processes.*Vol. 45, pp 111–139.

Borghesi, A. and Gaudenzi, B. (2013) Operational risk and supply chain risk management. In *Risk Management* (pp. 117-137). Springer Milan.

Boulis, A., Ganeriwal, S. and Srivastava, M.B. (2003) Aggregation in sensor networks: an energy–accuracy trade-off. *Ad hoc networks*, Vol. 1, No. 2, pp 317-331.

Campbell, D.E. and Kelly, J.S. (1994) Trade-off theory. *The American Economic Review*, Vol. 84, No. 2, pp 422-426.

Carson, S. and Bull, R. (2003), *Handbook of Psychology in Legal Contexts*, John Wiley & Sons.

678 Charlebois, S., Schwab, A. Henn, R. and Huck, C.W. (2016) Food fraud: An
679 exploratory study for measuring consumer perception towards mislabeled
680 food products and influence on self- authentication intentions. *Trends in Food*
681 *Science & Technology*, Vol. 50, pp 211-218.

682 Chon, K.H.S. (2016) Cybercrime precursors: towards a model of offender
683 resources. Available at: https://openresearch-
684 repository.anu.edu.au/handle/1885/107344 accessed 2 January 2018
685
686 Cohen, L.E. and Felson, M. (1979) Social change and crime rate trends: A
687 routine activity approach. *American Sociological Association*, Vol. 44, pp 588-
688 608.
689
690 Christopher, M. and Peck, H. (2004) Building the resilient supply chain,
691 *International Journal of Logistics Management*, Vol. 15, No. 2, pp 1-13.

692 Clapton, W. (2014) *Risk and Hierarchy in International Society: Liberal*
693 *Interventions in the Post-Cold War Era*. Palsgrave Macmillan
694
695 Clarke, R.V. (1995) Situational Crime Prevention, Crime and Justice Vol. 19,
696 Building a Safer Society: *Strategic Approaches to Crime Prevention* (1995),
697 pp 91-150
698
699 Closs, D.J. and McGarrell, E.F. (2004) *Enhancing security throughout the*
700 *supply chain*. Washington, DC: IBM Center for the Business of Government.
701 Available at: https://www-
702 03.ibm.com/procurement/proweb.nsf/objectdocswebview/filesupply+chain+se
703 curity+white+paper+and+assessment+guide+april+2004/$file/supply+chain+s
704 ecurity+white+paper+and+assessment+guide+april+2004.pdf (accessed on 2
705 January 2018)
706
707 CPNI Centre for the Protection of National Infrastructure. (2013). *CPNI insider*
708 *data collection study: Report of main findings*. Available at:
709 http://www.cpni.gov.uk/Documents/Publications/2013/2013003-
710 insider_data_collection_study.pdf. accessed 2 January 2018
711
712 Dane, E. and Pratt, M.G. (2007) Exploring intuition and its role in managerial
713 decision making. *Academy of management review*, Vol. *32,* No. 1, pp33-54.
714
715 Elliott Review. (2014). *Elliott Review into the integrity and assurance of food*
716 *supply networks – Final report A national food crime prevention framework*.
717 HM Government, July 2014 London.
718
719 EC 178/2002. 2002. Regulation (EC) No 178/2002 of the European
720 Parliament and of the Council of 28 January 2002 laying down the general
721 principles and requirements of food law, establishing the European Food
722 Safety Authority and laying down procedures in matters of food safety. Official
723 Journal of the European Communities L31/1: 1-24.
724

Feng, C.W., Liu, L. and Burns, S.A. (1997) Using genetic algorithms to solve construction time-cost trade-off problems. *Journal of computing in civil engineering*, Vol. 11, No. 3, pp184-189.

Franks, N.R., Dornhaus, A. Fitzsimmons, J.P. and Stevens, M. (2003) Speed versus accuracy in collective decision making. *Proceedings of the Royal Society of London B: Biological Sciences*, Vol. 270, No. 1532, pp 2457-2463.

Gigerenzer, G. and Gaissmaier, W. (2011) Heuristic decision making. *Annual review of psychology*, Vol. *62*, pp 451-482.

Gregson, N. and Crang, M. (2017) Illicit economies: customary illegality, moral economies and circulation. *Transactions of the Institute of British Geographers*, Vol. *42,* No. 2, pp 206-219.

Häubl, G. and Trifts, V. (2000). Consumer decision making in online shopping environments: The effects of interactive decision aids. *Marketing science*, Vol. 19, No. 1, pp 4-21

Hollis, M.E. and Wilson, J.M. (2014) Who are the guardians in product counterfeiting? A theoretical application of routine activities theory. *Crime Prevention and Community Safety*, Vol. 16, No. 3, pp 169-188.

Huber, O. and Kunz, U. (2007) Time pressure in risky decision-making: effect on risk defusing. *Psychology Science*, Vol. 49, No. 4, pp 415.

Jack. L. (2015) *Food fraud awareness and detection in your business*. NSF Food Crime Conference. Available at: http://www.nsf-food-conf.eu/assets/6_food_fraud_awareness_and_detection_ljack.pdf. accessed 2 January 2018.

Johnson, E.J. and Payne, J,W. (1985) Effort and accuracy in choice. *Management Sci. Vol.* 31, pp 394–414.

Kerstholt, J. (1994) The effect of time pressure on decision-making behaviour in a dynamic task environment. *Acta Psychologica*, Vol. *86, No. 1*, pp 89-104.

Kirby, S. and Nailer, L. (2013) Reducing the offending of a UK organized crime group using an opportunity-reducing framework—a three year case study. *Trends in organized crime*, Vol. *16*, No. 4, pp 397-412.

Kirby, S. and Penna, S. (2010) Policing mobile criminality : towards a situational crime prevention approach to organised crime in K Bullock, RV Clarke & N Tilley.

Klapwijk, C.J., van Wijk, M.T. Rosenstock, T.S. Van Asten, P.J.A. Thornton, P.K. and Giller, K.E. (2014) Analysis of trade-offs in agricultural systems: current status and way forward. *Current Opinion in Environmental Sustainability*, Vol. *6*, pp110-115.

775 Kowalska, A., Soon, J.M. and Manning, L., 2018. A study on adulteration in
776 cereals and bakery products from Poland including a review of definitions.
777 *Food Control*, Vol. 92, pp 348-356
778
779 Luce, M.F., Payne, J.W. and Bettman, J.R. (1999) Emotional trade-off
780 difficulty and choice. *Journal of Marketing Research*, Vol. 36, No.2, pp143-
781 159.
782
783 Makwasha, T. and Turner, B. (2013) Evaluating the use of rural-urban
784 gateway treatments in New Zealand. *Journal of the Australasian College of*
785 *Road Safety*, Vol. *24*, No.4, pp14.
786
787 Manning, L. (forthcoming) Institute of Food Science and Technology Guide to
788 Good Manufacturing Practice 7th Edition – Manning, L. Eds. ISBN-
789
790 Manning, L., Soon. J.M. de Aguiar, L.K. Eastham, J.F. and Higashi, S.Y.
791 (2017) *Pressure: driving illicit behaviour in the food supply chain* 12th
792 Research Workshop on Institutions and Organisations (12th RWIO) Brazil 10-
793 11 July 2017
794
795 Manning L. (2016) Food Fraud, policy and food chain, *Current Opinions in*
796 *Food Science*, Vol. 10, pp 16-21.

797 Manning, L. and Soon, J.M. (2016). Food safety, food fraud and food defense:
798 a fast evolving literature, *Journal of Food Science*, Vol. 81, No. 4, R823–R834

799 Manning, L., Smith, R. and Soon, J.M. (2016) Developing an Organizational
800 Typology of Criminals in the Meat Supply Chain, *Food Policy*, Vol. 59, pp 44-
801 54.

802 Manning L., Baines R.N. and Chadd S.A. (2005) Deliberate contamination of
803 the food supply chain, *British Food Journal,* Vol. 107, No. 4, pp 225–45.

804 Marvin, H.J., Bouzembrak, Y. Janssen, E.M. van der Fels-Klerx, H.J. van
805 Asselt, E.D. and Kleter, G.A. (2016) A holistic approach to food safety risks:
806 Food fraud as an example. *Food Research International*, Vol. 89, pp 463-470.

807 Maule, A.J., Hockey, G.R.J. and Bdzola, L. (2000). Effects of time-pressure
808 on decision-making under uncertainty: changes in affective state and
809 information processing strategy. *Acta psychologica*, Vol. *104,* No. 3, pp 283-
810 301.
811
812 Mawby, R.I. (2017) '*Defensible Space'*, in Oxford Research Encyclopedia of
813 Criminology and Criminal Justice. Henry Pontell. New York: Oxford University
814 Press (forthcoming).
815
816 McElwee, G., Smith, R. and Lever, J. (2017). Illegal activity in the UK halal
817 (sheep) supply chain: Towards greater understanding. *Food Policy*, Vol. *69*,
818 pp166-175.
819

McGloin, J.M., Sullivan, C.J. and Kennedy, L.W. (2011) *When Crime Appears: The role of emergence*. Routledge

Mitenius, N., Kennedy, S.P. and Busta, F.F. (2014) *Chapter 35 – Food defense, p. 937-958. In Y. Motarjemi and H. Lelieveld (ed.), Food safety management: A practical guide for the food industry*, Academic Press, Massachusetts.

Monghasemi, S., Nikoo, M.R. Fasaee, M.A.K. and Adamowski, J. (2015). A novel multi criteria decision making model for optimizing time–cost–quality trade-off problems in construction projects. *Expert systems with applications*, Vol. *42,* No. 6, pp 3089-3104.

Moreto, W.D. and Clarke, R.V. (2013) 11 Script analysis of the transnational illegal market in endangered species. *Cognition and Crime: Offender Decision Making and Script Analyses*, p.209.

Newman, O. (1972) *Defensible space: people and design in a violent city*. Macmillan, New York.

NFU Mutual (2017) Rural Crime Now. Rural Crime Report 2017. Available at: https://www.nfuonline.com/nfu-online/news/nfu-mutual-rural-crime-report-2017/ (Accessed on 21 May 2018)

NSF (2014) *Final report risk modelling of food fraud motivation – NSF Fraud Protection Model intelligent risk model scoping project.* Available at: https://www.food.gov.uk/sites/default/files/NSF%20Final%20report.pdf. accessed 2 January 2018

O'Connor, A.M., Légaré, F. and Stacey, D. (2003) Risk communication in practice: the contribution of decision aids. *BMJ: British Medical Journal*, Vol. *327, No.* 7417, pp. 736.

Olson, D.L. and Wu, D. (2011) Risk management models for supply chain: a scenario analysis of outsourcing to China. *Supply Chain Management: An International Journal*, Vol. *16* No. 6, pp 401-408.

PAS 96. (2017) *Guide to protecting and defending food and drink from deliberate attack*. BSI, London

Perline, I.H. and Goldschmidt, J. (2004) *The Psychology and Law of Workplace Violence: A Handbook for Mental Health Professionals and Employers*, Charles C Thomas Publisher

Pil, F.K. and Holweg, M. (2006) Evolving from value chain to value grid. *MIT Sloan management review*, Vol. *47*, No. 4, pp 72.

Power, M. (2013) The apparatus of fraud risk. *Account. Org. Soc.* Vol. 38, pp 525-543.

Prendergast, C. (2002) The tenuous trade-off between risk and incentives. *Journal of political Economy*, Vol. *110*, No. 5, pp 1071-1102.

RASFF. Portal (2018) The Rapid Alert System for Food and Feed. Available at: https://ec.europa.eu/food/sites/food/files/safety/docs/rasff. (accessed 2 January 2018)

RASFF (2018) The Rapid Alert System for Food and Feed. Conclusions from the Ministerial Conference on the follow up of the fipronil incident. Brussels, 26 September 2017 Available at: https://ec.europa.eu/food/sites/food/files/safety/docs/rasff_fipronil-incident_conclusions_201709.pdf (accessed 2 January 2018)

Read, T. and Tilley, N. (2000). Not rocket science. *Problem-solving and crime reduction*. ISBN 1-84082-494-8

Reynald, D.M. (2009) Guardianship in action: Developing a new tool for measurement. *Crime Prevention and Community Safety*, Vol. 1, No. 1, pp 1-20.

Roy, H.E., Peyton, J. Aldridge, D.C. Bantock, T. Blackburn, T.M. Britton, R. Clark, P. Cook, E. Dehnen-Schmutz, K. Dines, T. and Dobson, M. (2014) Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain. *Global Change Biology*, Vol. *20,* No. 12, pp 3859-3871.

Sarkis, J., Gonzalez-Torre, P. and Adenso-Diaz, B. (2010) Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. *Journal of Operations Management*, Vol. *28,* No. 2, pp 163-176.

Shugan, S.M. (1980) The cost of thinking. *Journal of consumer Research*, Vol. 7, No. 2, pp 99-111.

Smith, R. (2017) Documenting entrepreneurial opportunism in action: A case study of sheep theft in the UK from a food supply chain perspective. *British Food Journal*. Vol. 119, No. 1, pp 105-121.

Smith, R., McElwee, G. and Somerville, P. (2017a) Illegal diversification strategies in the farming community from a UK perspective. *Journal of Rural Studies*, Vol. *53*, pp122-131.

Smith, R., Manning, L. and McElwee, G. (2017b) Critiquing the Inter-Disciplinary Literature on Food-Fraud, *International Journal of Rural Criminology*, Vol. 3, No. 2, pp 250 - 270

Smith, R. and McElwee, G. (2017) Illegal activity in the Horse Meat' Supply Chain: Understanding Food Fraud in the context of the 2013 Horsemeat Scandal, ISBE, Belfast, 8-9 November, 2017.

Smith, R. (2010), Policing the changing landscape of rural crime: a case study from Scotland, *International Journal of Police Science & Management,* Vol. 12 No. 3, pp. 373-387.

Soon, J.M. and Manning L. (2017) Whistleblowing as a countermeasure strategy against food crime, *British Food Journal,* Vol. 119, No. 12, pp 1-25

Spink, J., Moyer, D.C. and Whelan, P. (2016). The role of the public private partnership in Food Fraud prevention—includes implementing the strategy. *Current Opinion in Food Science*, Vol. 10, pp 68-75.

Spink, J., Moyer, D.C. Park, H. Wu, Y. Fersht, V. Shao, B. Hong, M. Paek, S.Y. and Edelev, D. (2015) Introduction to Food Fraud including translation and interpretation to Russian, Korean and Chinese languages. *Food Chemistry.* Vol. 189, pp 102-107.

Spink, J., Ortega, D.L. Chen, C. and Wu, F. (2017) Food fraud prevention shifts the food risk focus to vulnerability. *Trends in Food Science and Technology*, Vol. 62, pp 215-220.

Spink, J. and Moyer, D.C. (2013) Understanding and combating food fraud, *Food Technology,* Vol. 67, No. 1, pp 30-35.

Spink, J. and Moyer, D.C. (2011) Defining the public health threat of food fraud. *Journal of Food Science,* Vol. 76, No. 9, pp 157-163

Spink, J. (2011) The challenge of intellectual property enforcement for agriculture technology transfers, additives, raw materials, and finished goods against product fraud and counterfeiters. *J. Intellect. Prop. Rig.* Vol. 16, No. 2, pp 183-193.

Stanley, M.C., Beggs, J.R. Bassett, I.E. Burns, B.R. Dirks, K.N. Jones, D.N. Linklater, W.L. Macinnis-Ng, C. Simcock, R. Souter-Brown, G. and Trowsdale, S.A. (2015) Emerging threats in urban ecosystems: a horizon scanning exercise. *Frontiers in Ecology and the Environment*, Vol. *13, No. 10,* pp 553-560.

van Ruth, S.M., Huisman, W. and Luning, P.A. (2017) Food fraud vulnerability and its key factors. *Trends in Food Science & Technology*, Vol. *67*, pp 70-75.

Yaniv, I. and Foster, D.P. (1995) Graininess of judgment under uncertainty: An accuracy-informativeness trade-off. *Journal of Experimental Psychology: General*, Vol. 124, No. 4, pp 424.

Yakovleva, N. and Flynn, A. (2004) Innovation and sustainability in the food system: A case of chicken production and consumption in the UK. *Journal of Environmental Policy & Planning*, Vol. *6*, No (3-4), pp 227-250.

Weisel, D.L. (2003) The sequence of analysis in solving problems. *Crime prevention studies*, Vol. *15*, pp 115-146.

968
969 WHO. 2002. *Food safety issues: terrorist threats to food: guidance for*
970 *establishing and strengthening prevention and response systems 2002*.
971 Switzerland. ISBN 9241545844.

972 Winter, S., Berente, N. Howison, J. and Butler, B. (2014) Beyond the
973 organizational 'container': Conceptualizing 21st century sociotechnical
974 work. *Information and Organization*, Vol. *24*, No. 4, pp 250-269.
975
976 Wolfe, D.T. and Hermanson, D.R. (2004) The Fraud Diamond: Considering
977 the Four Elements of Fraud. *CPA Journal,* Vol. 74, No. 12, pp 38-42.
978

979 **Table 1. Types of Trade-off (Adapted from Klapwijk *et al,* 2014)**

Trade off	Examples
Field level	Production yields versus nitrate/phosphate leaching and water quality
Enterprise level (crop or animal)	Grain versus crop residue Milk versus meat production
Farm/agricultural system level	Cropping plans/enterprise mix Diversification Maximising short-term versus long-term return
Landscape level (agricultural system versus spatial, environmental or socio-cultural objectives	Land use and ecosystem services Water use
Supply chain	Specification versus food waste Cost versus risk

980

981

982

983

984
985

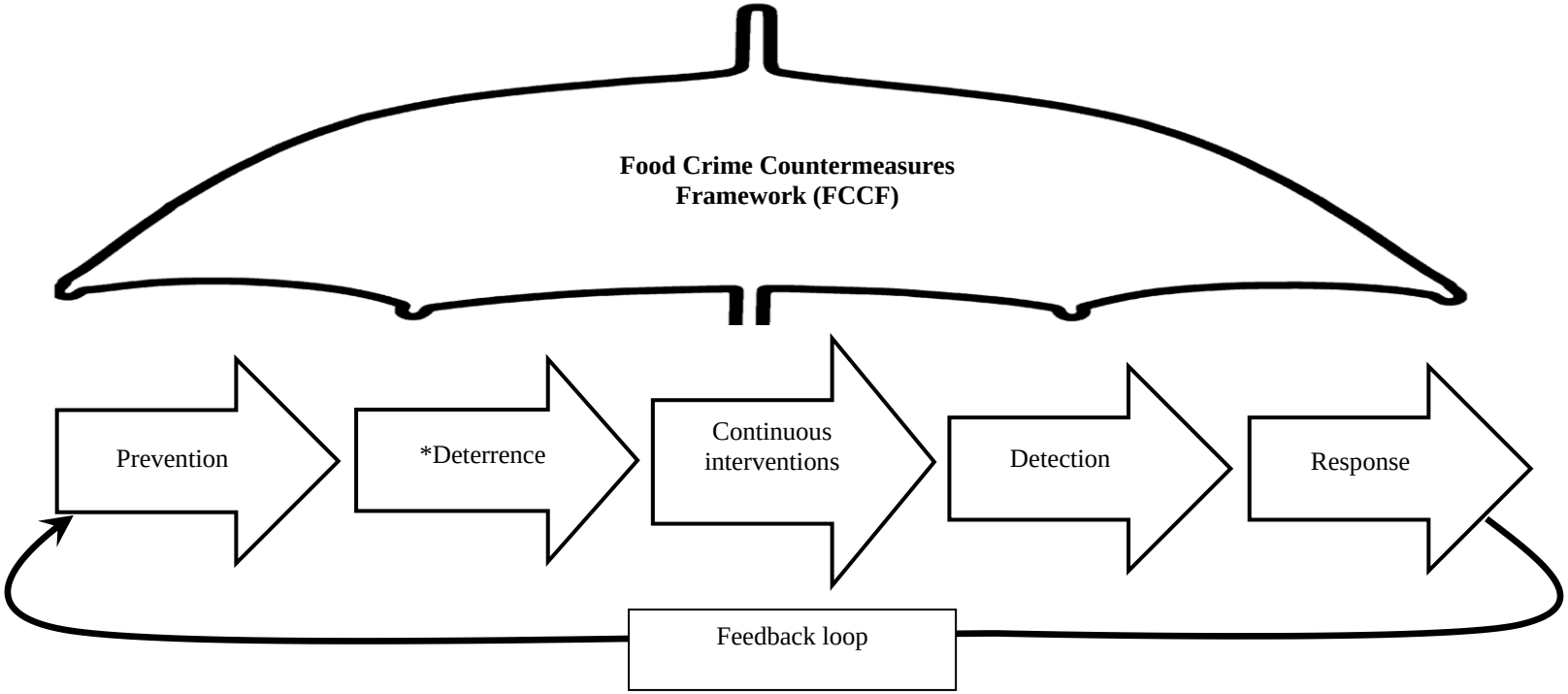

FIGURE 1. Steps in developing a food crime countermeasures framework (FCCF). *Via food crime risk assessment (FCRA), known threats may be prevented, deterred or detected. Via continuous interventions including horizon scanning, existing and emerging threats may be identified or detected and appropriate actions (response) can be taken.

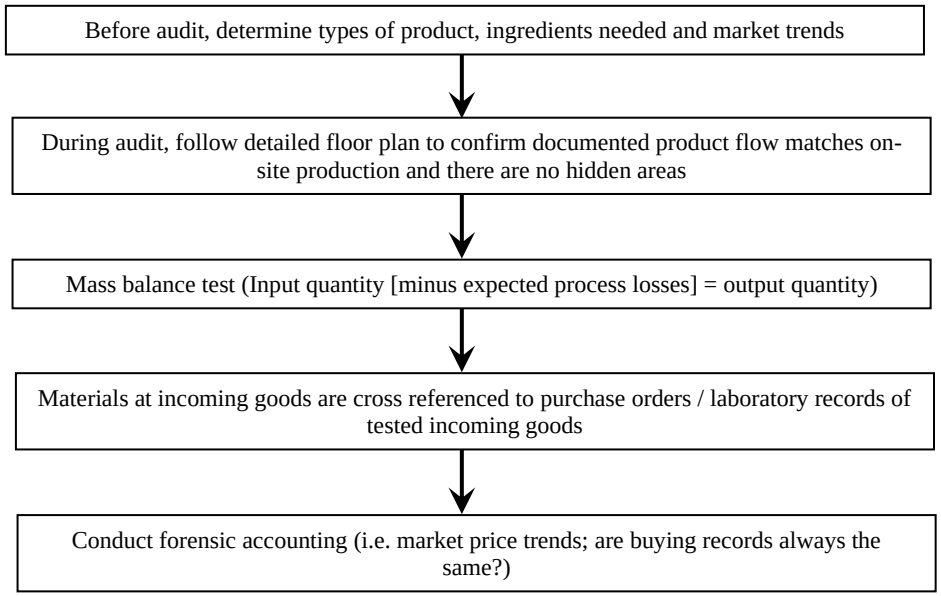

FIGURE 2. Forensic accounting and food crime prevention audits (adapted from Jack, 2015; NSF 2014)