The application of systematic accident analysis tools to investigate food safety incidents

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COMPREHENSIVE REVIEW

The application of systematic accident analysis tools to investigate food safety incidents

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Abstract

Effective food safety (FS) management relies on the understanding of the factors that contribute to FS incidents (FSIs) and the means for their mitigation and control. This review aims to explore the application of systematic accident analysis tools to both design FS management systems (FSMSs) as well as to investigate FSI to identify contributive and causative factors associated with FSI and the means for their elimination or control. The study has compared and contrasted the diverse characteristics of linear, epidemiological, and systematic accident analysis tools and hazard analysis critical control point (HACCP) and the types and depth of qualitative and quantitative analysis they promote. Systematic accident analysis tools, such as the Accident Map Model, the Functional Resonance Accident Model, or the Systems Theoretical Accident Model and Processes, are flexible systematic approaches to analyzing FSI within a socio-technical food system which is complex and continually evolving. They can be applied at organizational, supply chain, or wider food system levels. As with the application of HACCP principles, the process is time-consuming and requires skilled users to achieve the level of systematic analysis required to ensure effective validation and verification of FSMS and revalidation and reverification following an FSI. Effective revalidation and reverification are essential to prevent recurrent FSI and to inform new practices and processes for emergent FS concerns and the means for their control.

KEYWORDS
analysis, food safety, incident, revalidation, reverification

1 | INTRODUCTION

Effective food safety (FS) management comes from an understanding of the risks related to a potential FS incident (FSI) and determining the means for their control (Song et al., 2020), and hazard analysis critical control point (HACCP)-based FS management systems (FSMSs) have been considered a fundamental measure to mitigate FSI, especially foodborne disease (FBD) and for the effective management of FS (da Cunha et al., 2022).

International standards certification based on Codex Alimentarius HACCP principles (e.g., ISO 22000) are widely approved approaches for the effective development of FSMS with significant competitive advantages for food companies demonstrating compliance with such national and international standards. However, inadequate implementation of prerequisite programs (PRPs) and poor application of HACCP principles weaken the foundations of the FSMS increasing the potential for pathogen growth, cross-contamination, and improper food handling practices, all of which are determinant antecedents for FBD outbreaks (Casolani et al., 2018; Lee et al., 2021; Putri & Susanna, 2021; Yang et al., 2019). The failure to embed effective FS management practices within organizations can have a negative impact too on the overall organizational values and behaviors directed toward FS and the development of FSMS (Nyarugwe et al., 2020).

Despite having validated, implemented, verified, and audited FSMS, repeated food recalls, FSI, and FBD outbreaks have occurred and remain a significant concern for governments, health authorities, private business, and consumers (Faour-Klingbeil & Todd, 2020; Nayak & Waterson, 2019; Rustia et al., 2021). Notable instances of FBD incidents from a global perspective include outbreaks of *Listeria monocytogenes* linked to frozen vegetables (European Food Safety Authority, 2018; Koutsoumanis et al., 2020), *L. monocytogenes* (Maple Leaf Foods) (Howell & Miller, 2010), *Salmonella* in peanut products, Peanut Corporation of America (PCA) (Irlbeck et al., 2013), and pathogenic *Escherichia coli* at XL Foods Inc. (Curry, 2013 & Pennington, 2009), as reported and critiqued in the literature (Manning, 2017; Nayak & Waterson, 2017; Powell et al., 2011; Vashisht, 2018). These FBD incidents, and FSI more widely, demonstrate that there are underlying factors contributing to failures in FS practices within organizations often with tragic consequences to both consumers' public health and the organization (i.e., its ability to trade) itself (Nayak & Jespersen, 2022). This raises concerns about HACCP's reliability alone in developing and implementing a fully effective FSMS, mitigating the risk of FBD and FSI (Kafetzopoulos et al., 2013; Wallace, 2014) and in supporting revalidation and reverification processes following an incident. Zwietering et al. (2021) proposed that there is always a residual level of risk even if businesses are fully compliant with the requirements of their FSMS, that is, zero risk is unattainable.

The underlying factors contributing to potential failures in FS practices affect every activity along the global food supply chain. The complexity of individual human behaviors and their interactions with the events that take place can contribute to an incident which in other safety contexts would be described as an "accident." A systems-based approach to consider FBD outbreaks and wider FSI advocates a holistic perspective toward how "accidents" occur and the role of contributory factors associated with the incident (Wang et al., 2016; Waterson et al., 2017). Systems thinking is an approach that considers all the interrelated elements in a given environment and reflects on the system as an interconnected complex entity in the subsequent analysis (Horvat, 2019). Systems thinking as a perspective views a system as being made up of interrelated components that work together to achieve a common objective (Arnold & Wade, 2015; Dekkers, 2015). Therefore, using a systems-based approach helps practitioners to understand better how complex systems operate and the role that people play within that socio-technical system which links the humans, technological, and organizational aspects enabling them to work more productively and proactively (Nayak, 2018). The system is considered here as an open rather than a closed system where there are multiple factors of influence that can lead to an FSI.

In contrast, the traditional accident/incident analysis approaches used focus on analyzing an individual unit of a system (Salmon et al., 2014) and on causal rather than contributory factors. Systematic accident analysis is broadly accepted as better in identifying and understanding the potential complex interrelations and multiple contributory factors of an incident across systemic levels, when compared to more linear approaches and tools. A more common simplistic, linear, and often reductionist approach focuses attention on either human errors or technical aspects of the FSMS (Fan et al., 2015) and considers how an undesirable outcome such as an FSI happens in a system or organization (Karanikas et al., 2020; Newnam et al., 2017; Read et al., 2013). This reductionist analytical approach leads to the use of isolated cause-effect models or linear models trying to identify the single point of failure, that is, process, procedure or individual at fault, or apportioning blame on people who at the time of the accident were performing the operational activity or who were involved in some closely related primary tasks (Salmon et al., 2021). Cooke (2003) and Underwood and Waterson (2014) argued that individuals, procedures, or devices should not be considered a single point of failure or the main reason for an incident or outbreak in the context of FS, but instead should be assessed within the entirety of the socio-technical system. Socio-technical systems are the systems that involve a complex interaction among humans, materials, machines, and environmental aspects of the system (Emery & Trist, 1960, 1965), that is, they have interrelated technical and social subsystems. The scope of consideration of a socio-technical system can be within the boundary of a food organization or more widely as will be explored in this paper.

Translating accident analysis models based on systems thinking to FS is an approach that is receiving recent attention in the literature (da Cunha et al., 2022; Wiśniewska, 2023). In order to analyze complex FS-related issues and improve understanding of the underlying causes of a FSI, moving beyond direct causal analysis helps to identify how safety can be built more holistically into a given food system (Hamim et al., 2020a; Stefanova et al., 2015). In addition, these approaches can provide valuable insights into contributing factors and systemic failures where proactive interventions and measures can be applied to improve the existing FSMS. Specific systematic analysis of *L. monocytogenes, Salmonella*, and *E. coli* outbreaks in previous research suggests that a "human element" contributed to failure, regardless of specific management failures, technical deficiencies, and/or inadequate sanitization procedures (Fleetwood et al., 2019; Jespersen & Huffman, 2014; Nayak & Waterson, 2016, 2017, 2019). Thus, increasing academic and practice focus has considered human behavior and/or FS-culture, that is, the unseen central values prevailing in an organization toward FS (Griffith et al., 2010; Yiannas, 2008). Indeed, Griffith et al. (2010) suggested that assessing organizational FS-culture, as well as the FSMS itself, requires a more integrated approach rather than just considering traditional FS risk factors in isolation. However, FSI can also arise due to failures in the wider food supply chain rather than a discrete failure within one organization (Soon et al., 2020) highlighting that the adoption of an organizational FSMS and the promotion of a good FS-culture at the organizational level can face many challenges in a connected food supply chain and the wider complex food system. Therefore, the ability to identify the contributory factors that have led to an FBD outbreak, or wider FSI, is critical to provide more effective controls to mitigate the impact of an incident and to prevent the occurrence of further incidents in the future (Lee et al., 2021). This review aims to explore the application of systematic accident analysis tools to both design FSMS as well as to investigate FSI to identify contributive and causative factors of influence and the means for their elimination or control. The study has compared and contrasted the diverse characteristics of linear, epidemiological, and systematic accident analysis tools and HACCP and the types and depth of qualitative and quantitative analysis they promote. The research provides insight into the usage and the performance of systems-based approaches to identify the causal and contributory factors to FSI. The structure of the paper is as follows: Section 1 introduces the context of the research, and Section 2 explores and critiques the development of accident analysis tools, including sequential, epidemiological, and systematic accident analysis tools. Section 3 provides an overview of additional systems-based techniques being developed for the evaluation of FSI datasets and reflects on examples of where the systemic accident analysis tools described in the paper have been applied to FSI and FBD outbreaks in particular in order to critique the advantages and disadvantages of applying certain systemic accident analysis models in this context. Furthermore, the section evaluates the strengths and weaknesses of the selected tools with regard to FS management, with particular emphasis on revalidation and reverification of FS plans and FSMS following an incident. The concluding remarks and reflections (Section 4) provide conclusions, implications, and recommendations from the research. This research contributes to existing research by providing a review of how systems-based accident analysis tools can be applied in the FS context as well as by framing how these tools can inform revalidation processes to prevent the reoccurence of FDI or FBD outbreaks. These models also can utilize both qualitative and quantitative data bringing together a much more comprehensive approach to ensuring safe food supply.

2 | SYSTEMS-BASED ACCIDENT ANALYSIS

Modern food operating systems are comprised of a variety of components of a social, human, organizational, and technical nature which are an intrinsic part of their design and structure. The interactions of such components can produce emerging unsafe phenomena across the sociotechnical system of people and systems (Salmon et al., 2013; Stanton et al., 2012). Systems-based safety approaches were originally applied in high-profile industries such as aviation, healthcare, nuclear plant, coal, and oil mining (Altabbakh et al., 2014; Igene et al., 2022; Kee et al., 2017; Qiao et al., 2019; Salmon et al., 2010, 2012; Waterson et al., 2017). In these industry applications, system accident analysis has had significant success in improving accident investigation due to its ability to evaluate, analyze, and recognize patterns in the interdependencies and interactions that occur in the abovementioned high-profile industries (Dolansky et al., 2020; Goode et al., 2014).

The main focus of systems-based accident analysis methodology is on the actual accident, which is defined in the related safety literature as an unexpected and sudden event that leads to an undesired outcome such as loss, damage, injury, or ill-health (Wienen et al., 2017). Systems-based accident analysis views an accident as an independent or unplanned and sudden event resulting from an undesirable change in the existing environment or from unsafe behaviors of individuals involved in the event. Similarly, in the food context, poor operational behavior in terms of FS at any stage in the food chain can lead to an FSI, including an FBD outbreak. Furthermore, systems-based accident analysis methodology also considers the importance of interactions of multiple factors which further expand the apparent context of the accident itself (Cooke, 2003; Fu et al., 2017; Goode et al., 2016; Underwood & Waterson, 2014; Wienen et al., 2017). According to Rasmussen (1997), accidents are an inevitable part of any operating system; they can happen at any stage during routine work practices and can be caused by various actors working at different levels of the socio-technical system. The probability of an accident is also affected by the fact that any operating system is a set of multiple components that not only have an ultimate goal, precise purpose, or particular task but also interact with each other (Karanikas et al., 2020). Each approach considered in this section proposes a specific theory to provide insights into the errors or chain of events that can lead to an accident (Grabbe et al., 2020; Stefanova et al., 2015; Waterson et al., 2017; Yousefi et al., 2019). There are several classifications (types) of accident causation models and analysis approaches which are in general based on certain characteristics and the area of application. The three types of accident analysis tools considered in this review are sequential, epidemiological, and systemic analysis techniques (Al-Shanini et al., 2014; Fu et al., 2020; Ge et al., 2022; Grabbe et al., 2020; Jacobsson et al., 2009).

2.1 | Sequential accident analysis

The oldest accident analysis tools are the sequential accident models that describe an accident as a chain of events occurring in a particular time sequence (Grabbe et al., 2020). Models, tools, and techniques in the sequential classification can help to answer and understand the "who" and "why" of an FBD outbreak or FSI. This is an advantage in understanding the reasons for a given incident and can provide guidance for preventing them in the future (Yousefi et al., 2019). Examples of traditional sequential models include fault tree analysis and event tree analysis, which consider the causes leading to an accident as being a linear sequence of events (Delikhoon et al., 2022). Over time, these methods have been revised and developed, and this has relocated the emphasis and identification of failures from being individual faults that occur toward them being considered defects in the management system (Yousefi et al., 2019). For instance, the traditional root cause analysis (RCA) approach is a structured framework for safety investigation determining in detail the reasons and prerequisites that have led to the occurrence of an "accident" (Wangen et al., 2017). Having originally been used in the fields of psychology and systems engineering, the main goal of using RCA is to identify the primary "root" cause of hazards, events, or problems (Wu et al., 2008). In this approach, the identification of the root cause is the starting point of an investigation (Gangidi, 2019; Salisbury NHS Foundation Trust, 2018). Domino theory was proposed by Heinrich and further redefined by other researchers (Heinrich, 1931; Jacobson et al., 2009) and is now considered an example of the sequential models that are used. Domino theory is based on the assumption that an accident has a clear linear cause-and-effect event with five sequential causation factors: social environment, fault of person, unsafe act, accident, and injury, that is, a person has a key role in the actualization of an accident (Figure 1).

These types of sequential models seek to find a clear cause and can provide recommendations and suggest solutions for preventing the occurrence of adverse situations in the future (Meyers & VanGronigen, 2021). In general, their advantage lies in their simplicity, being able to apply the sequential steps of analysis of the incident as well as their applicability in multiple accident and incident situations. The successful development of these well-established sequential systems-based approach methods has led to their continued maturity and use (Wienen et al., 2017). However, Grabbe et al. (2020) argued that these sequential models are not always suitable nor very effective in the explanation of accidents when they occur in very complex socio-technical systems.

2.2 | Epidemiological accident analysis

In the epidemiological accident analysis approach, methodologies change the focus of the analysis undertaken from the emphasis being on human factors, such as the fault of the person in the Domino effect, to consideration of the organization and the management system (Grabbe et al., 2020; Waterson et al., 2017). In this context, the integration of human factors in terms of the accident is characterized as human behaviors and actions. Epidemiological accident models have their roots in the field of disease epidemiology (Qureshi, 2007) and try to explain accident causation using the analogy of scientific, systematic, and data-driven studies of the distribution (frequency, pattern) and determinants (causes, risk factors) of health-related states and events. An example of an epidemiological approach to accident analysis is the Haddon Matrix developed in 1970 by William Haddon, Jr. (Barnett et al., 2005). The Haddon matrix is a framework used in the field of public health and injury prevention to analyze accidents and injuries from an epidemiological perspective. This approach allows factors relating to human, medical, and environmental aspects to be considered before, during, and after an accident or injury event. The matrix has three dimensions: pre-event, event, and post-event. The approach helps to identify potential

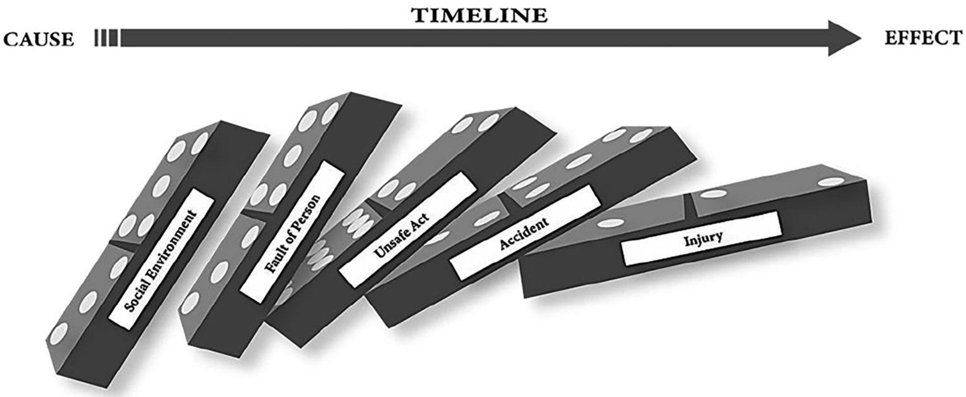

FIGURE 1 Heinrich's Domino model of accident causation. *Source*: Adapted from Peerally (2021).

interventions and strategies to prevent or mitigate injury by addressing each phase of the event. The matrix has been applied to different types of accidents, such as road traffic, industrial, and public health accidents (Deljavan et al., 2012). It provides a systematic way of analyzing the factors that contribute to accidents and injuries and guides the development of effective prevention interventions based on the identified risks and vulnerabilities at different stages.

The accident may be prevented from occurring if one barrier (in FS management often described as a hurdle) or element of the socio-technical system blocks the actualization of an FS hazard (Yousefi et al., 2019). The combination and interaction of different factors thus combine to create the conditions for the accident, or conversely the conditions to prevent the accident (Stefano et al., 2015; Zhang et al., 2018). An example of this accident prevention approach is the Swiss Cheese Model (SCM) that was proposed by James Reason in the early 1990s (Reason, 2007). The SCM is a type of graphical model (Figure 2) in which the barriers within the safety system that could prevent the incident are presented as slices of cheese and the holes in the slices indicate the failures, errors, or weakness in the organizational management system (Larouzee & Le Coze, 2020). Pictorially, when the accident trajectory occurs, the interaction of several factors or weaknesses is presented as one major hole across the whole system which is actualized when all the individual holes in every barrier align.

Recently, FS researchers have used the SCM to illustrate the barriers and weaknesses associated with individual behaviors in a food organization, outlining the importance of appropriate behaviors to the effective implementation of an FSMS (Wiśniewska 2023). In addition, da Cunha et al. (2022) proposed the SCM as a new perspective on FS management and explored the application of the SCM to determine how to manage FS risk and to develop organizational awareness about FS. A critique of the SCM would highlight that besides the emphasis on human factors and the identification of active and latent failures in a socio-technical FSMS, this model fails to represent the dynamics of a complex food system and how the factors of influence that could contribute to an incident are associated and interconnect. Therefore, as a model, it could be argued that the SCM does not fully capture the nonlinear interactions that can occur within an FSMS, an organization, the wider supply chain, and the totality of the food system (Thoroman et al., 2020; Waterson et al., 2015).

Effective preventive measures will either stop the holes from occurring in the first place in an FSMS or the FSMS will have suitable interventions planned that will close the holes should they occur. As a result, the interactions among latent conditions, active failures, and the often nonlinear interaction between stakeholders across the complex socio-technical food system, it could be argued, cannot be conveyed in the depth required with the SCM model. Further, there is a danger that the linear dynamics of the SCM model can oversimplify the nature of an incident. Moreover, latent conditions and active failures/errors may not be well characterized because they may be some distance from the locus of the actual incident, that is, they are actualized in a different socio-technical level of the food system. Therefore, in a preventive model, it would not necessarily be possible to identify the latent conditions and active failures and then create a suitable defense layer, indeed a series of defensive layers, through the use of the SCM approach alone.

Other models in the epidemiological accident analysis classification are based on the same principles established by Reason's SCM. As a result, they neither give a precise categorization of the factors of influence nor the latent conditions associated with the accident. In order to overcome these limitations, the model analysis approach was upgraded by including a classification scheme of failures (Shappell & Wiegmann, 2000). The Human Factors Analysis and Classification Scheme (HFACS) applies four levels of analysis and ranks the factors of interest as follows: (i)

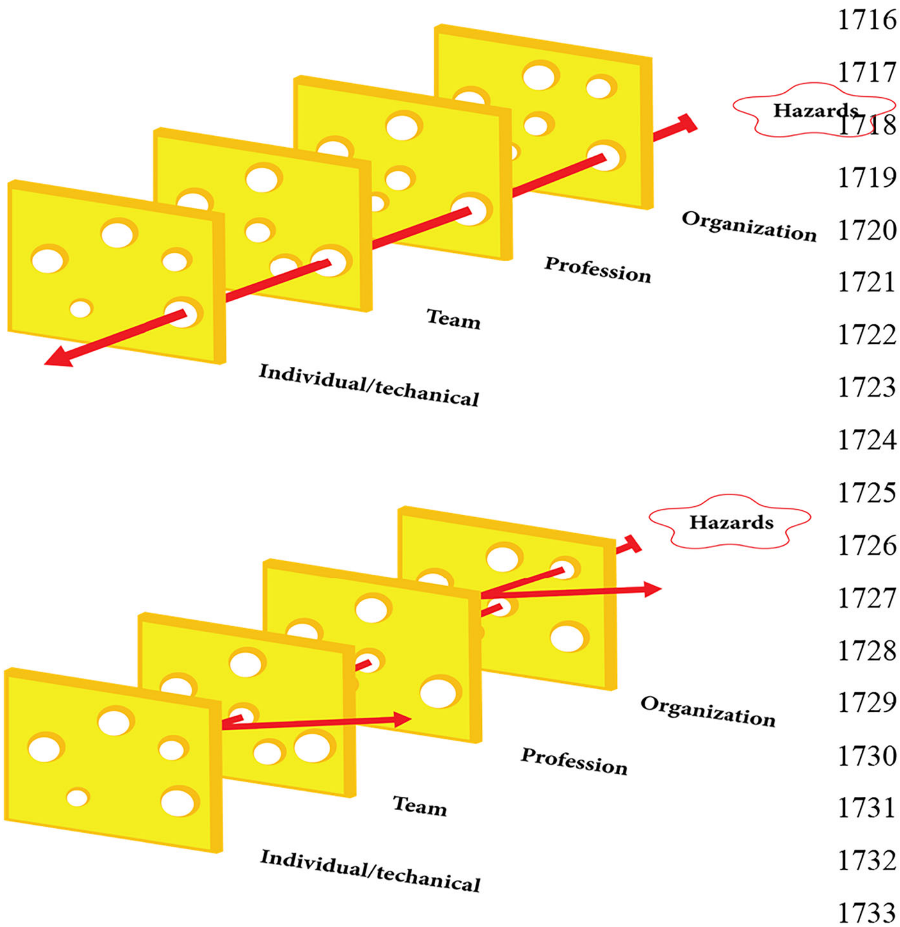

FIGURE 2 Reason's Swiss cheese epidemiological model. *Source*: Adapted from Peerally (2021).

dangerous acts; (ii) the preconditions for dangerous acts; (iii) dangerous supervision; and (iv) organizational influences (Figure 3). This classification is important because it assists the entire analysis process and supports the analyst themselves to classify the identified failures with more accuracy and clarity.

In this modified approach, the human factor is considered the main and most important reason in the operating system for an accident to occur (Hulme et al., 2019a; Li et al., 2019; Salmon & Lenné, 2009). According to Grabbe et al. (2020), the introduction of the human factor into the investigation and analysis of accidents greatly improves understanding and contributes to the application of the method in more complex accident scenarios. However, the HFACS has the same disadvantage as the SCM as it considers the causality of events or accidents as being linear. The links among different stages of the accident are still loosely addressed, and thus, the method does not fully represent the dynamics of the socio-technical system being analyzed (Hulme et al., 2019b). The evolution of accident analysis modeling has focused on the development of more robust models which have tried to overcome the limitation of linear accident analysis when investigating accidents within a dynamic socio-technical system (Leveson, 2012).

2.3 | Systemic accident analysis

A systemic approach considers an accident scenario as the result of a complex and interconnected network of components, namely, technical, human, organizational, and managerial factors (Delikhoon et al., 2022; Grabbe et al., 2020; Underwood & Waterson, 2014). Contemporary, more advanced systemic accident analysis models have been developed, improved, and used by many researchers (Fu et al., 2020; Grabbe et al., 2020; Thoroman et al., 2020; Waterson et al., 2017; Yousefi et al., 2019). The approaches considered in this section are the models using in the agri-food business and FS context such as the functional resonance accident model (FRAM), systems theoretic accident model and processes (STAMP), and Accident Map (AcciMap).

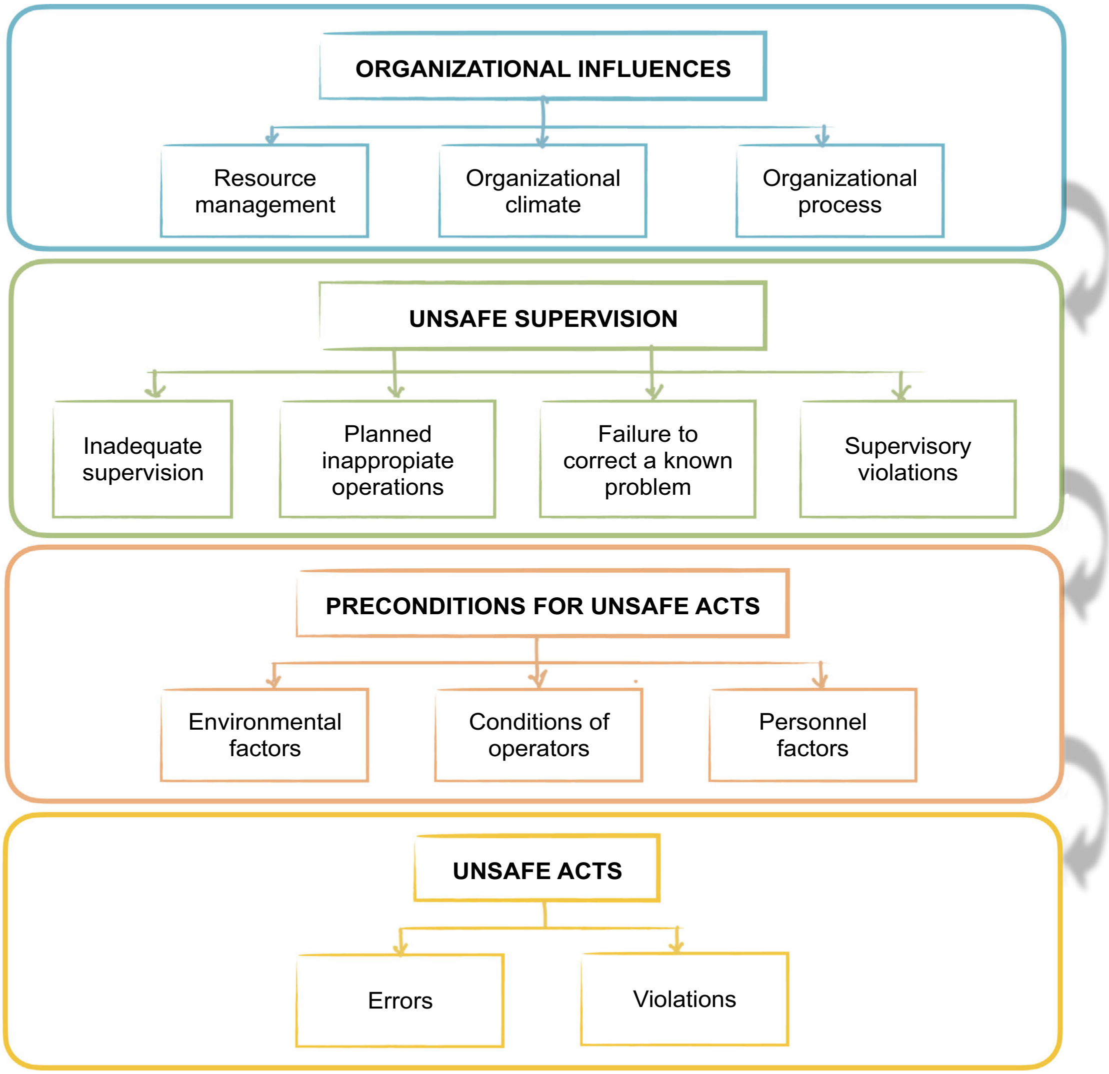

FIGURE 3 A detailed scheme from the Human factors analysis and classification systems (HFACS) model. *Source*: Adapted from Diller et al. (2014).

2.3.1 | The functional resonance accident model (FRAM)

In 2004, Hollnagel introduced The FRAM. The FRAM analysis is also a type of graphical model in which the basic unit is a two-dimensional hexagon shape. Operations are examined in detail according to six aspects (see Figure 4) which are the input, output, precondition, resources, time, and control which are placed on each of the vertices of the hexagon (Hollnagel, 2017; Lee & Chung, 2018).

The FRAM is a qualitative accident model that considers the nonlinear dynamics of events. It is based on the concept of normal performance and describes how functions of the system components may resonate and create hazards that can run out of control and lead to an accident (Herrera & Woltjer, 2010). The FRAM has been applied in the analysis of several investigations related to mid-air collisions (De Carvalho, 2011) and in cases of sepsis in healthcare facilities (Raben et al., 2018). Anvarifar et al. (2017) adapted the FRAM and used it for qualitative risk analysis in a program related to the multifunctional flood defenses situated in the Netherlands. The authors tried to represent the complexity of relationships between the functional components (individuals, devices, and organizational levels) in the socio-technical context. Nayak et al. (2022) used the FRAM to explore the compliance of actual events leading to the contamination of eggs with a banned pesticide, with defined hygiene standards and regulations in order to reconcile actual practices with policy directives. According to Huang et al. (2019), FRAM is a valuable tool for the assessment of industrial safety, mainly due to its socio-technical approach and the ability to provide a framework to examine system operations in detail.

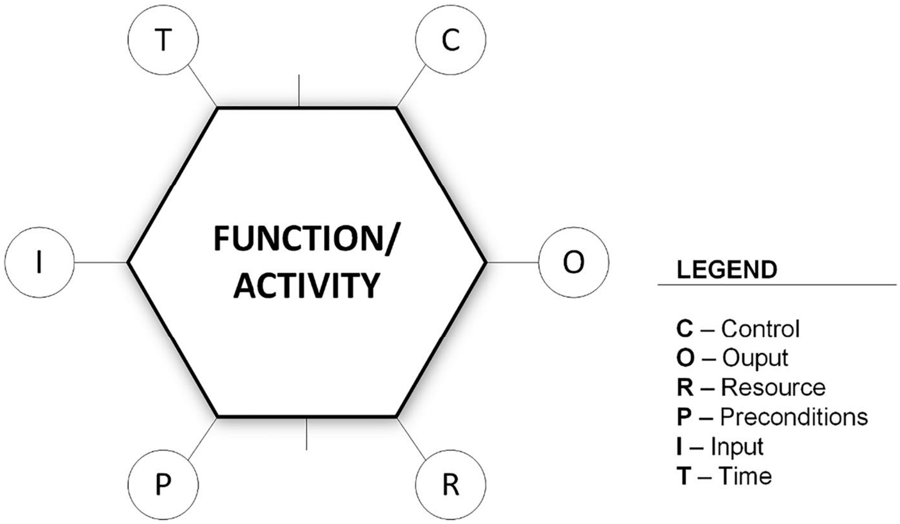

FIGURE 4 The geometry of the operational unit in the functional resonance analysis methods (functional resonance accident model [FRAM]). *Source*: Adapted from Tveiten (2013).

2.3.2 | Systems theoretic accident model and processes (STAMP)

Nancy Leveson (2004) proposed a STAMP approach. From the general theory of STAMP, two more methods have been developed by Leveson (2012). The systems theoretic process analysis is a hazard analysis technique. This method in a prospective way is used to identify hazards in the socio-technical system. The Causal Analysis using System Theory (CAST) is based on STAMP which is an accident analysis technique that assesses retrospectively and in-depth about the reason for an accident to happen (Helferich, 2011; Yousefi et al., 2019). The STAMP is an accident causation model that treats safety as a control problem (Figure 5).

Figure 5 includes both control and feedback loops in the different levels of the system (Leveson, 2004; Stanton et al., 2012). In this model, an accident is not considered a series of events; rather, it is viewed as the result of a lack of constraints implemented in the system's design and its operations (Leveson, 2004). The model has been applied to road safety in order to identify the fragile elements in the control structure of the road system (Salmon et al., 2016). STAMP has also been used to analyze a major railway accident in China and succeeded in revealing the causes (Ouyang et al., 2010; Song et al., 2012). Furthermore, the authors suggested measures for improvement in the system with the aim of preventing similar accidents in the future. However, Ferjencik (2011) considered STAMP analysis as laborious due to the extensive number of steps which are involved in the procedure that have to be undertaken. In this aspect, Leveson (2012) made a significant contribution toward a more simplified procedure by providing detailed guidance for the analysis, and thus, the reliability of the STAMP model has been significantly increased.

2.3.3 | Accident Map model (AcciMap)

Another notable systematic accident analysis tool is the AcciMap proposed by Rasmussen (Rasmussen, 1997; Svedung & Rasmussen, 2002) and includes a risk management framework that recognizes the importance of socio-technical factors in safety management processes as well as the socio-technical levels of the food system (Figure 6).

The AcciMap approach assesses the interactions of the events and the decisions that resulted in an accident and aims to detect the unexpected and uncontrolled relationships between the system's constituent parts (Branford et al., 2009; Igene et al., 2022; Stanton et al., 2012; Underwood & Waterson, 2013). The AcciMap uses a graphical representation for the system failures, decisions, and actions involved in the accident. It allocates them to six organizational levels which are presented as follows: (i) government policy and budgeting; (ii) regulatory bodies and associations; (iii) local area government planning and budgeting; (iv) technical and operational management; (v) physical processes and actor activities; and (vi) equipment and surroundings (Hulme et al., 2019; Newnam et al., 2017; Svedung & Rasmussen, 2002). AcciMap is one of the most popular approaches among the systemic accident analysis tools (Salmon et al., 2020; Underwood & Waterson, 2014) and has a wide application having been used to assist accident investigations and accident

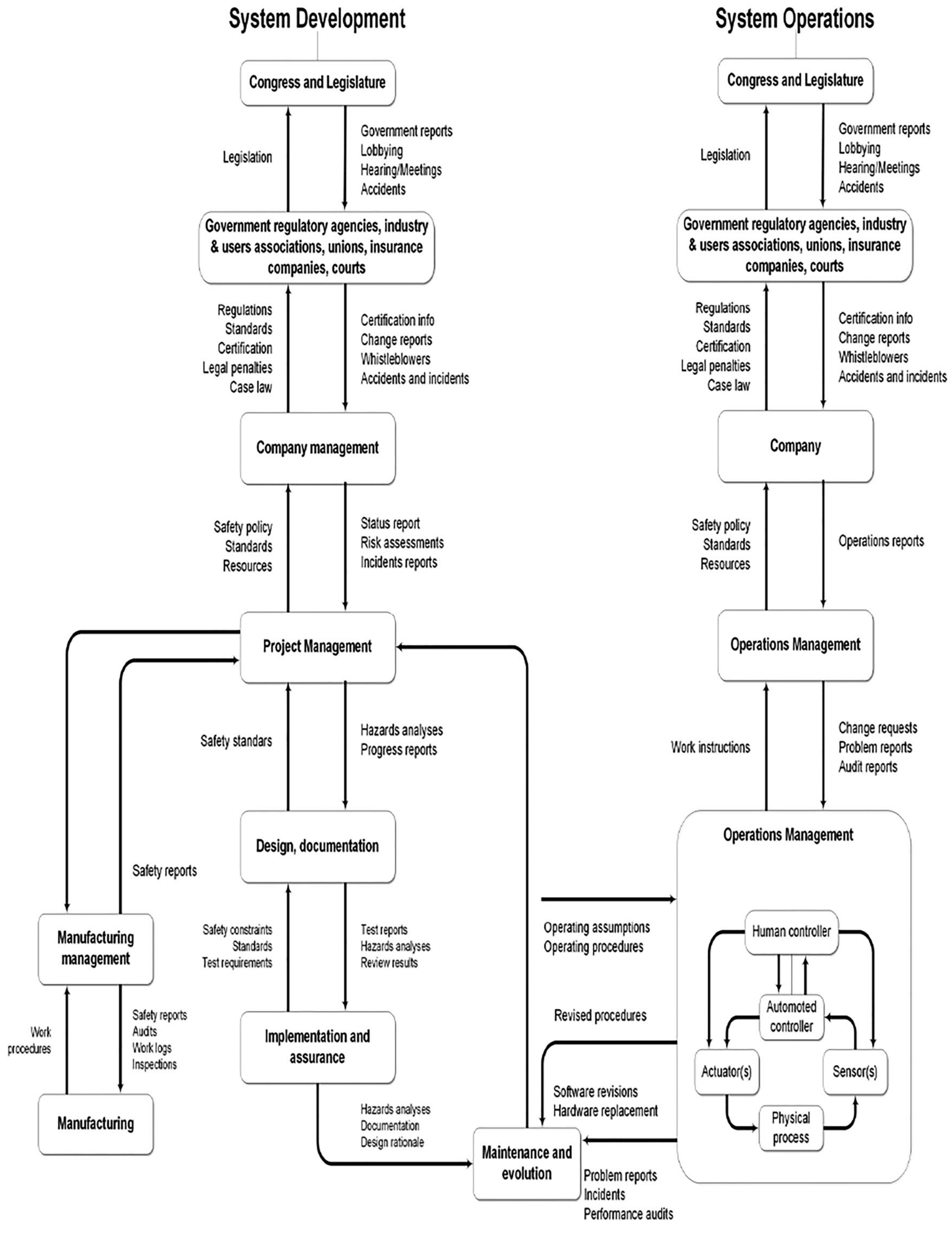

FIGURE 5 The hierarchy of control levels, examples of the adopted documents, and typical control loops in the systems theoretical accident model and processes (STAMP) model. *Source*: Adapted from Salmon et al. (2012).

analysis in a range of scenarios. The following is not an exhaustive list but presents examples of some of the areas of AcciMap application: FS (Diaz De Oleo et al., 2022; Nayak & Waterson, 2016); aviation (Branford, 2011; Thoroman et al., 2019, 2020); led outdoor activities (Salmon et al., 2017); maritime and ferry accidents (Jiang, 2016; Lee et al., 2017); mining (Stemn et al., 2020); oil and gas industry (Tabibzadeh & Meshkati, 2015); road traffic collisions with road users (e.g., pedestrian) and vehicles (Hamim et al., 2020a; Hamim et al. 2020b; Hamim et al.2022; Mcilroy et al., 2020; Read et al., 2013; Stanton & Salmon, 2020; Stefanova et al., 2022); and police armed response actions (Jenkins et al., 2010).

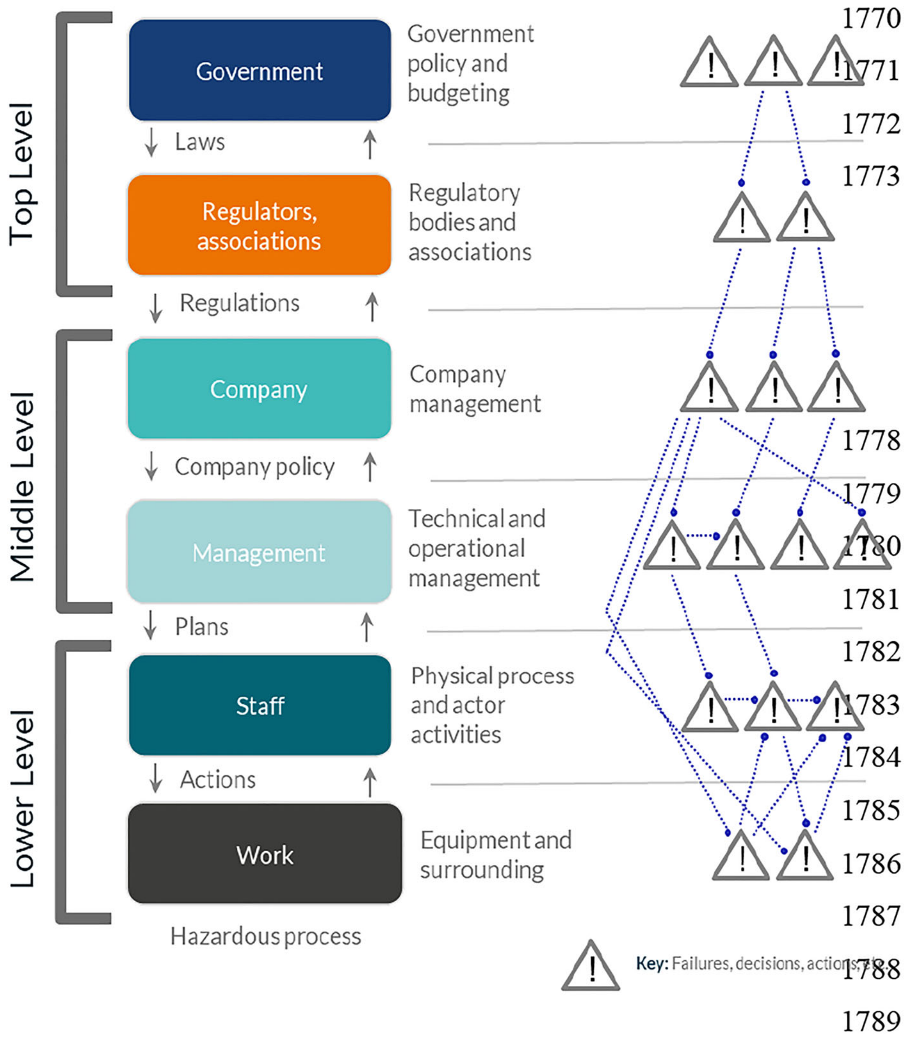

FIGURE 6 Representation of the levels, processes, and relationships throughout the complex socio-technical system according to AcciMap framework. *Source*: Adapted from Igene et al. (2022).

2.3.4 | Reflection

The above-referenced systemic accident analysis tools, STAMP, HFACS, FRAM, and AcciMap, are the most commonly cited for post-incident accident investigation and analysis research (Underwood & Waterson, 2013; Yousefi et al., 2019). The study by Delikhoon et al. (2022) on systemic accident analysis tools revealed that, from the 63 publications selected and reviewed, 25 articles applied AcciMap; and STAMP combined with other approaches was used and reported in 16 articles. FRAM was found in 22 studies and was also integrated with other methodologies. FRAM was mainly applied in the aviation domain. Each of these tools is described in the literature as models, on occasions, have been applied in other areas quite different from the original domain they were developed for. The general aim of all these approaches and their application in different situations has been toward the identification of contributory factors to an accident/incident to initiate improvement of safety procedures, better management systems, and the development of effective systematic analysis tools. In order to critique the advantages and disadvantages of applying certain systemic accident analysis models, the next section of the paper first provides an overview of additional systems-based techniques being developed for the evaluation of FSI datasets and second reflects on examples of where the systemic accident analysis tools described herein have been applied to FSI and FBD outbreaks in particular.

3 | THE APPLICATION OF SYSTEMATIC ANALYSIS APPROACHES IN THE FOOD SAFETY CONTEXT

Systemic accident analysis methodologies are expanding into diverse research areas. The literature shows an increased research interest in systems-based modeling

(Delikhoon et al., 2022; Yousefi et al., 2019). For instance, the 24Model which was introduced by Fu et al. (2005) is a systemic model that takes principles from previous methods and models. The 24Model uses a framework in which the accident is assessed at two main levels: (i) individual level and (ii) the organizational level. The model goes deeper by breaking down the systemic failures in four stages: (i) immediate cause; (ii) indirect cause; (iii) radical cause; and (iv) root cause. According to Fu et al. (2020), this model is suitable when big significant data analysis is performed on a certain type of accident. Review of the extant academic literature did not find a published article where the 24Model has been applied in a food context. Chen et al. (2022) compared and contrasted the 24Model and the SCM stating that SCM focuses on hazard identification especially at the design and implementation of a system and potentially is a static form of assessment, for example, of value in the design and implementation of an FSMS but does not inherently drive a continuous improvement process. Conversely, they argue that the 24Model is more focused on a Plan-Do-Check-Act cycle driving improved safety culture.

Here, it is important to state that the terms "causal factor," "associated factor," and "contributory factor" have all been used in previous studies to determine the factors of influence in an accident or incident following both qualitative and quantitative analysis (Diaz De Oleo et al., 2022). The term "causal factor" in the literature may not be used to describe a direct cause-and-effect influence, rather to describe instead factors that, either individually or in combination, were found often qualitatively to have influenced the shape and dimensions of the incident. In this section, for consistency, and to recognize the qualitative nature of some systematic accident analysis methodologies, the term "contributory factor" is used to more appropriately reflect the nature of the effect and the innate degree of rigor of the methodology(ies) employed (Diaz De Oleo et al., 2022).

System failures that lead to FBD outbreaks could be due to multiple and cascading contributing factors. New models are emerging based on a Complex Network Theory, where the network is presented graphically with a complex topological structure. In the analysis, the network could evolve to determine a certain network or graphical representation that captures the factors that might lead to an FSI (Luo et al., 2013). Guo et al. (2020) described the "behavioral risk chains of accidents" that can be considered within an accident causation network where the accident causal factors are presented as nodes and arrows used to depict the interrelationship between them. These contemporary systemic analysis approaches are combined with mathematical models (Fu et al., 2020), leading to a hybrid approach that differs from the previously described systemic analysis approaches which are primarily qualitative.

To analyze and to capture the complexity of these highly technological systems, more powerful incident "causation" investigations and analysis models are needed (Luo et al., 2013). Hybrid models that use qualitative extraction of causal factors combined with mathematical modeling of their interactions can improve the estimation accuracy in terms of risk prediction and the probability of occurrence, which are both important aspects to consider in preventing FSIs, as well as when analyzing incident data from regulatory and organizational datasets. Additionally, researchers have proposed hybrid systematic models using Bayesian Networks, where the Bayesian Network is supported by the use of big data (Jin et al., 2020; Malik et al., 2021; Unnevehr, 2021).

Bayesian Networks are "cause-effect prediction models belonging to the family of probabilistic graphical models, which combine principles from graph theory, probability theory, computer science and statistics" (Marvin & Bouzembrak, 2020, p. 1). The Bayesian Network approach has been considered an effective tool to predict, monitor, and control FS and food fraud issues in the food supply chain (Soon & Abdul Wahab, 2022; Soon et al., 2020; Wahyuni et al., 2020; Rezazade et al., 2022). Marvin et al. (2016, p. 463) proposed the use of Bayesian Networks as an approach to determine FS risk using large databases such as the EU Rapid Alert System for Food and Feed "taking into account the influence of multiple 'drivers' on food safety … to predict the increased likelihood of occurrence of safety incidents so as to be better prepared to prevent, mitigate and manage associated risks."

The Bayesian Network approach has also been used by the same research team to consider chemical hazards in fruit and vegetables (Bouzembrak & Marvin, 2019), hazard ranking of nanomaterials (Marvin et al., 2017); food fraud (Bouzembrak & Marvin, 2016); herbs and spices monitoring programs (Bouzembrak, Camenzuli et al., 2018); modeling of diarrhetic shellfish poisoning (Wang et al., 2022); and the dairy supply chain (Liu et al., 2022). The aim of these approaches is to use existing datasets to inform future monitoring, surveillance, and early warning systems in order to prevent or minimize the impact of FSI. A similar approach in less economically developed countries where historical data, databases, computing technology, infrastructure, and resource are limited has not yet been considered, despite the potential benefits and capability to model complex systems and integrate both qualitative and quantitative data, for example, through the use of text mining as a means to develop surveillance programs and early warning systems (Bouzembrak, Steen et al., 2018; Marvin et al., 2022). FBD outbreaks occur and can reoccur in less economically developed countries where there are existing limitations and barriers to the consistent implementation of FSMS and particularly HACCP-based systems (Diaz De Oleo et al., 2023; Garridogamarro et al., 2023; Rincon-Ballesteros et al., 2019).

Identifying the potential interrelations and multiple contributing factors can help to determine why FSI, and in particular FBD outbreaks, occur from a human, technical, or system perspective. In his book "*When Food Kills: BSE E. coli and Disaster Science*", Pennington (2003) issued substantial questions concerning the safety landscape within the realm of the food industry. The importance of considering human factors in analyzing FBD outbreaks was acknowledged, and there was a call for a more systems-based approach to FS management. In response to this appeal, Couturier and Levenson (2009) applied STAMP as an advanced approach that could support the redesigning and reengineering of the FS and risk management system in the United States (US). The authors suggested that STAMP was useful in the identification and understanding of existing flaws and interactions that contributed to FS issues in the US food industry. Nayak and Waterson (2019) applied STAMP to establish and propose a UK food system's safety control structure model. They concluded that systems analysis models, such as the STAMP model, offer the capacity to address the constraints of event chain models and examine the intricate interrelations among various components within the intricate and complex food system.

Helferich (2011) stated that the changes in the dimensions of the food supply chain from a national to an international-wide scale led to the emergence of new types and more complex FDI and FBD outbreaks. FBD outbreaks and their geographical spread have become the focus for many investigations. Often an epidemiological approach to detect and trace an FBD outbreak and its source(s) does not consider contributory factors at a system level, which is a drawback. Alternatively, incident investigation analysis has been applied using the STAMP and CAST models to assess the 2008 *Salmonella* outbreak associated with the PCA (Helferich, 2011). The model applied in this research provided additional information about the FBD outbreak and helped to determine which controls were ineffective in enforcing the implementation of the FSMS.

The AcciMap method has been used to review a range of FSIs within the academic literature. Table 1 presents several investigations where systemic models such as AcciMap were applied to analyze and understand the cause of a particular FSI.

AcciMap has been considered a more versatile and user-friendly accident/incident causation technique, useful for in-depth analysis, and suitable for complex socio-technical systems (Hamim, Hoque et al., 2020b; Hulme et al., 2019). In summary, systematic accident analysis of FSIs especially FBD outbreaks can uncover systemic failure at single or multiple points and the methodological process goes beyond simply identifying the visible and surface individual errors committed by front-line staff to considering more complex interactions across a range of socio-technical levels. In a wider context, graphically presenting a complete picture of the complex interactions and relationships of the contributing factors that have been identified across socio-technical levels is of value in developing a system-level understanding of an FSI and an appropriate corrective response.

Developing a system-level understanding of an FSI has the potential to enhance existing FSMS and facilitate the implementation of effective FS and broader operational controls. According to the assertions made by Waterson et al. (2015) and the findings presented in this research, it becomes evident that systems-based accident analysis tools are better suited to comprehend the intricate nature of interactions in the context of FBD outbreaks. This is due to their capability to effectively capture the interconnected factors that culminate in negative incidents, offering a more appropriate approach. Systems-based analysis of FSI and FBD outbreaks is beneficial for embedding learning from previous incidents, for example, what went wrong, or which control(s) were ineffective, providing valuable insight that can help the food industry going forward and enhance the controls applied to protect food products across systemic levels in global food supply chains.

FS researchers have argued the importance of the focused human element to achieve FS outcomes and these factors being incorporated into the FSMS and in consideration of FS-culture (Wiśniewska et al., 2019). Malik et al. (2021) proposed the development of a hazard analysis and risk-based preventive control that extends beyond the application of HACCP principles. Other authors advocate the use of risk assessment techniques as complementary tools to enhance and manage FS (Arvanitoyannis & Varzakas, 2009; Lee et al., 2021; Varzakas, 2015) and the risk of an FBD outbreak. However, a more socio-technical approach has been considered through systems-based approaches that could be used to evaluate FSI in a socio-technical system to reveal the contributory factors leading to an incident. Systems-based accident analysis approaches can be applied to develop an understanding of the relationship between FSI and FBD outbreaks and accepted HACCP adoption practices. Table 2 critically compares and contrasts the three main systems-based accident analysis approaches reviewed in this paper, namely, STAMP, FRAM, and AcciMap as well as compares them with HACCP, the primary hazard analysis tool used in the food industry across the world for the design, development, and implementation of an FSMS with the aim of preventing FSI and FBD outbreaks. HACCP is considered here in terms of

TABLE 1 Example of studies using systematic accident analysis (Accident Map [AcciMap]) to consider food safety incident (FSI) or foodborne disease (FBD).

References	Scope of the study
Cassano-Piche et al. (2009)	AcciMap was used to assess the 1986 Bovine Spongiform Encephalopathy (BSE) incident in the United Kingdom. The AcciMap and Conflict Map to visually represent the factors contributing to the epidemic. The aim was to assess the effectiveness of the framework in explaining accidents in complex socio-technical systems, particularly those related to food production and characterized the contributing factors associated with the animal disease/human disease epidemic. The results have implications for safety and risk management practices in the food industry
Woo and Vicente (2003)	AcciMap techniques were used to conduct a comparative analysis of two public health outbreaks originating in Canadian drinking water systems. The North Battleford Cryptosporidium parvum outbreak of April 2001 and the Walkerton *Escherichia coli* outbreak of May 2000. Within the context of complex socio-technical systems, the study seeks to understand how different factors at various levels contribute to these incidents. The systemic approach distinguishes between low-level physical and individual factors and high-level governmental and regulatory factors in the analysis. The findings will inform the design of more effective public policies to reduce risk in similar systems
Vicente and Christoffersen (2006)	The study used the report of the 2000 Walkerton water contamination incident (*E. coli*). The aim was to evaluate the usefulness of the AcciMap framework in explaining the contributing causes of the incident and to draw wider lessons for improving safety in complex socio-technical systems. This includes factors ranging from strictly physical elements to individual workers practices, local government and regulatory agencies oversight and enforcement, and broader policy decisions
Waterson (2009)	The research was focused on examining the key events and factors contributing to Clostridium difficile outbreaks within a specific NHS Trust in Kent, United Kingdom. It explored the contributing factors at different levels of the healthcare system and provides insights into the relationships between hospital and clinical management. The findings highlight the value of considering cross-level and whole-system issues in understanding infection outbreaks. The study's findings and approach have implications for the prevention hospital-related infections
Nayak and Waterson (2016)	AcciMap was used to uncover the systemic factors associated with two *E. coli* outbreaks of in the United Kingdom, one in 1996 and another in 2005. The contributing causes of these outbreaks were identified by examining human errors and organizational issues within food production process as well as understanding the immediate causes of the outbreaks and address problems within the system that may have existed before the outbreaks occurred. As a result, the study highlights the need for a systemic approach to food safety and the importance of addressing underlying problems in the system to prevent such outbreaks from occurring in the future
Diaz De Oleo et al. (2022)	The purpose of this study was to investigate three established norovirus incidents using the AcciMap incident analysis approach to determine its effectiveness in informing food safety policies the design. The research findings from the AcciMap analysis reveal common contributing factors such as poor inspections, lack of regular monitoring of quality of water supply, inadequate management of wastewater, and ineffective communication that led to each incident across the hierarchical levels within a socio-technical system. The value of the AcciMap approach is that it does not limit the analysis to individual components or specific types of incident, allowing for a more holistic and interconnected risk assessment
Thatcher et al. (2020)	The research includes a practical application of two of the tools (AcciMap and system theoretic accident mapping and processes) to a real problem within the transnational food integrity system. The study discusses the implications of the AcciMap analysis for understanding and addressing food fraud and related issues. It highlights the need for a comprehensive approach to address food fraud (the 2013 European horsemeat scandal) and its underlying causes within the food system, focusing on multiple levels of the system, from government to consumers. It was concluded that the needs for new methods or adaptations of existing methods are needed to better understand and address dynamic, adaptive systems in the context of sustainability, in order to meet the demands of complex, evolving systems

its ability to be used as a tool to design an FSMS as well as to retrospectively assess an existing HACCP plan and the associated FSMS at an organizational level in the event of the need for revalidation and reverification following an incident. However, the revalidation of the HACCP plan itself is limited as it may not, depending on the scope of the HACCP, address all levels of the socio-technical food system (see Figure 6). National FS plans would also need to follow a similar approach in the event of an FBD outbreak or the identification of a novel, emergent, FS hazard.

An existing FSMS is reviewed on an ongoing basis as defined within the FSMS. In terms of HACCP principles

TABLE 2 **Comparison of the advantages of** Accident Map **(AcciMap),** functional resonance accident model **(FRAM),** hazard analysis critical control point **(HACCP), and** systems theoretical accident model and processes (**STAMP) approaches for holistic incident analysis**.

Description of advantage of systematic tool	AcciMap	FRAM	HACCP	STAMP	Comments
Description of accidents within a single diagram	Yes	Yes	No	No	
Description of accidents in hierarchical level	Yes	No	No	Yes	
Proximal sequence of events and influences	Yes	Yes	No	Yes	Flow diagrams are developed through HACCP, but they tend to be rudimentary and are often generic
Simplicity of identifying the causes of accident	Yes	Yes	No	No	
Identification of contributing factors close to or far from the accident	Yes	Yes	No	Yes	The HACCP Plan would be revalidated following an incident but not explicitly through a sociotechnical lens
Provision of recommendations for the control structure	Yes	Yes	Yes	Yes	Recommendations via the revalidation of a HACCP plan may be linear, epidemiological as there is no explicit requirement for a systematic assessment
Description of events and actions	Yes	No	No	Yes	A HACCP Plan revalidation may not address all the levels of the socio-technical system as shown in Figure 6, i.e., analysis of top-level contributory factors may be absent
Description of components of system	No	Yes	No	Yes	
Providing enough information about system structure	No	No	No	No	
Taxonomy of errors or failures modes	No	Yes	No	Yes	
Focus on operators and functions	No	Yes	Yes	Yes	A HACCP plan revalidation may focus on operators and functions but may not consider all socio-technical levels
Considering the environmental conditions (equipment and surroundings)	Yes	Yes	Yes	Yes	
Identifying singular root causes for accidents	No	No	Yes	No	A HACCP Plan revalidation may conclude that there is a singular root cause for an FSI
Definition of system boundaries	Yes	No	Yes	Yes	The scope of the HACCP plan will define boundaries, but the boundary may be the organization itself so any analysis in this instance will be limited in terms of socio-technical levels covered
Include multiple feedback loop	No	No	No	Yes	The consideration of multiple feedback loops in a HACCP plan revalidation would depend on the skills of the HACCP team it is not an inherent element of the methodology
Providing a context to identify system safety improvements	Yes	Yes	Yes	Yes	
Identification of the control and feedback inadequacies	No	No	Yes	Yes	This aspect may only be considered for a HACCP plan revalidation in the context of the scope of the HACCP and the associated boundaries

(Continues)

TABLE 2 (Continued)

Description of advantage of systematic tool	AcciMap	FRAM	HACCP	STAMP	Comments
Empirical data are not required	Yes	Yes	No	Yes	Some empirical data would be required to revalidate a HACCP plan
Minimized level of system information is required for analysis	No	No	No	No	
Easier to be implemented	Yes	No	Yes	No	
Providing adequate guidance regarding the methodology	Yes	Yes	Yes	No	
Appropriate for use in a variety of contexts	Yes	Yes	Yes	Yes	
Ability to quantify the accident occurrence and yield probabilities	No	No	No	No	
Is not affected by analyst bias	No	No	No	No	
Easy to disseminate results to nonexperts	Yes	No	No	No	

Source: Adapted from Yousefi et al. (2019), Delikhoon et al. (2022), and Ma et al. (2022).

revalidation, this includes ensuring critical limits at critical control points and prerequisite programs are still valid, as well as the wider HACCP plan. Deviations from the planned activities within the HACCP plan or deviations in terms of the actual safety of food products may be identified during routine monitoring and verification activities. Appropriate corrective and preventive action will require interventions from the organization to ensure that food remains safe and FSMSs are effectively implemented. It is important to distinguish here between routine revalidation as part of an annual review of the HACCP system and revalidation following an FSI or FBD outbreak. Revalidation as part of annual review processes of the HACCP plan and the FSMS means obtaining evidence that the control measures are still capable of effectively managing FS (Dzwolak, 2019) alongside verification activities that ensure the controls are being implemented effectively and are complied with. The critical limit at a CCP, according to Codex Alimentarius is a criterion, observable or measurable, relating to a control measure at a CCP which separates acceptability from unacceptability of the food with regard to FS. Revalidation ensures that the critical limits that have been set are still appropriate, or in the event, they need to be amended, ensures that appropriate critical limits are set and they are valid, for example, specific temperature, time, or pH. Revalidation following an FSI is a much more focused process considering those control measures that relate specifically to the context of the FSI, for example, a pasteurizer failure, hygiene failure, or a loss of control in terms of metal contamination of a final product.

Although much has been written about FSMS verification in the literature, there is scant academic discourse with regard to the validation of FSMS and revalidation processes in the event of an FSI or FBD outbreak. In the early adoption of HACCP, validation was a focus of attention. Scott (2005, p. 497) defined validation as “the element of verification focused on collecting and evaluating scientific and technical information to determine whether the HACCP plan, when properly implemented, will effectively control the hazards.” Validation processes are informed by data drawn together not only within the business, but also externally, for example, if there is an FSI with a similar business. Product and process validation, and revalidation when required, is an essential aspect of designing appropriate, resilient FSMS that are capable of consistently producing safe food (Manning, 2013). Revalidation of HACCP plans and associated FSMSs reflects that over a period of time, a HACCP plan and associated FSMS will require updating or revision when there are significant changes to either regulatory, scientific, or technical information that underpins a HACCP plan, or there have been changes to products, operations, and/or processes. An example would be where a recent food fraud incident highlighted a realizable FS issue, for example, lead adulteration associated with cinnamon powder. On discovering this “new knowledge,” it would be reasonable to expect that an organization using cinnamon powder as an ingredient would revalidate their existing FS controls associated with that ingredient and include appropriate preventive measures within the HACCP plan. These specific actions need to be undertaken to ensure that the HACCP plan is appropriate and all potential, reasonable FS hazards are suitably controlled (Fortin, 2011; Sperber, 1998; Surak, 2015). Revalidation of analytical tests especially microbial tests is also important (On et al., 2013), and revalidation of quality assurance reference standards (Anderson & Cunningham, 2000) to ensure their efficacy. Revalidation is essential when failures are identified, or vulnerabilities or weaknesses arise in the FSMS, for example, through the identification of new information, improvement in scientific models, changes in risk characterization or identification of new hazards or characteristics of hazards which could, if not addressed, lead to an FSI (Scott, 2005). Revalidation of skills and knowledge has been a focus to assure human performance in medicine (Archer & de Bere, 2013), and in terms of the efficacy of cleaning systems over time in food settings in line with a revalidation policy (Schmitt & Moerman, 2016). Sharma et al. (2018) argued that revalidation is essential following certain "modifications" of a product or the process in which it is produced, specifically a change in ingredients and processing materials, to the source of ingredients and processing materials, for example, a new supplier, changes to packaging materials and changes to equipment or the plant/facility. However, the discourse on revalidation activities, particularly following an FSI, is tactical rather than systematic and does not reflect the approaches proposed in systematic accident analysis. Systems-based accident analysis tools have proven useful and are well-established approaches but have had little exposure in specific FS research and investigations, other than those examples described here in this paper. In particular, applying AcciMap, STAMP, and FRAM has played an important role in accident investigations and analysis to identify potential risk factors more generally and with particular focus on FS. All approaches share common characteristics such as their socio-technical nature as the underlying concept, the hierarchical and systemic structural approach, and the graphical representation. This is in contrast with the HACCP approach where the dual aspects of HACCP and building FS-culture are being integrated more commonly together. Common to all three systematic accident analysis approaches is that the analysis process traditionally follows a retrospective approach to examine the accident/incident and identify the contributory factors involved. From a socio-technical perspective, they examine the loss of control, aspects of safety, unexpected failures, and contributory factors identifying the vulnerabilities and weaknesses in the entire system, considering the exchange between the human, equipment, internal, and external organizational aspects and their interactions in a determined system (Belmonte et al., 2011; Qureshi, 2007). For instance, the focus of FRAM is on understanding how combinations of normal everyday performance variability can result in unforeseen outcomes (Hollnagel et al. 2014). It describes the relationships among factors based on their functional dependencies and examines the aggregation or coupling of variability in the system.

An example of where FRAM has been applied in the food sector is with regard to fipronil contamination of eggs (Nayak et al., 2022). The application of FRAM here considered contributory factors to the incident on farm, in the wider supply network, and associated with decisions taken by policymakers and regulators and the impact on consumers.

3.1 | Systems-based and hierarchical levels

Both STAMP and AcciMap employ a systemic and hierarchical approach to the analysis of complex events and systems. This makes them valuable tools in safety management and FSI. These systematic tools are appropriate to address complex system issues (Qiao et al., 2019). The hierarchical structure of some of the models, such as the AcciMap and STAMP, incorporate a multi-organizational layer's structure to depict the levels of the socio-technical system and the control structures within each level (Patriarca et al., 2022; Wang et al., 2016), allowing system-level identification of the causal scenario, contributory factors, flaws, and potential risks at each level (Karanikas & Roelen, 2019). The AcciMap framework typically features six explicit system levels in the model (government, regulatory, company, management, staff, equipment, and surroundings). Differences such as the stage of the food supply chain, for example, farm, manufacturer, resources available, and political factors associated with government are considered here. One limitation in these system levels in the context of applying this model to FSI is that it does not explicitly have a level that focuses on consumers and their role in perpetuating an FSI or FBD outbreak. However, it could be argued that the application of HACCP principles again does not have a phase that explicitly considers the non-compliant behavior of consumers.

However, researchers have shown some exceptions in studies applying a modified AcciMap in terms of the label or number in the system levels of the framework (Kee et al., 2017; Lee et al., 2017; Nayak & Waterson, 2016). Other studies looked at the "outcomes" level that included the proximal factors to an FBD outbreak (Diaz De Oleo et al., 2022; Nayak & Waterson, 2016). Furthermore, some studies have applied an expanded version of the original AcciMap hierarchical structure at the top system level, for example, including international committees and national committees (Hamim et al., 2020a; Stanton & Salmon, 2020). They conclude that it is necessary to recognize a high level from a system perspective, including international influences and contributory factors that operate above the government level, that is, the supranational level of global food policy. International standardization and harmonization of policy in the food system, often mediated by international committees, has accelerated complex changes at regional, national, and global levels, increasing the degree of influence of a range of stakeholders, including nongovernmental organizations together with governments and their regulatory bodies. Therefore, the extended AcciMap and its generic nature seem more flexible to consider the upper level of the socio-technical food system when trying to identify and address contributing factors from existing and transitioning international and national standards, such as Codex among others that influence the food system and food supply chains.

Similarly, to AcciMap, STAMP specifies the system levels for consideration (Igene et al., 2022) and largely adopts a systems-based view that considers all components in the socio-technical system (government level: including regulators and legislature). Therefore, the model has demonstrated good applicability to the international context (Salmon et al., 2016). Conversely, the system levels on the FRAM model have to be implied because the model itself does not consider upper levels in the system as other models. This too is true of HACCP principles which have been more routinely applied to the consideration of FS. This lack of implicit socio-technical systems within the FRAM approach has been considered an advantage through avoiding the hierarchy prominence of the system based on function making the analysis more concise, potentially important when there are high levels of uncertainty in the characterization of the levels, or the incident being considered (Bjerga et al., 2016). In addition, FRAM does not consider multiple contributing factors and actors (Stanton, 2019). The STAMP and FRAM approaches consider more closely the elements per process or function in their analysis, which differs from the AcciMap, which described the events and actions performed in the system (Igene & Ferguson, 2023).

3.2 | Models' analysis process and system behaviors

The approach to system behaviors varies between systems-based models. Not all models describe the process in detail, as seen in the AcciMap, where certain elements such as feedback availability and system goals are only partially described and implicitly addressed (Underwood & Waterson, 2013). Furthermore, the process and details are provided in the FRAM, and the STAMP goes beyond the mere description of events and causal factors to provide a full description of the reasons for unsafe control actions (Igene & Ferguson, 2023). In this context, models such as STAMP and FRAM are particularly explicit about the safety-related objectives that the system is trying to achieve. These objectives are outlined at different stages of the analysis, accompanied by the representation of feedback pathways. STAMP places particular emphasis on the critical role of feedback mechanisms in maintaining safety outcomes. In contrast, the feedback channel is not outlined in the AcciMap model and needs to be inferred in the FRAM model (Karanikas et al., 2020).

3.3 | Systems-based model incident communication

The use of graphical representations, such as maps or diagrams, to visually depict the contributory relationships and interdependencies between factors within the system is a key feature of these systematic models. The AcciMap model, for example, enables a comprehensive analysis of the entire FSI. It facilitates the identification of actions, causal links, and factors that contribute to FS problems, such as food contamination incidents, effectively capturing these elements and their interrelationships throughout the system (Igene & Ferguson, 2023). The benefits of the diagrams are that they provide a visual and improved understanding of the nuances of the FSI through its proximal sequence of events, interactions, and mapping of interconnected relationships. Furthermore, Underwood and Waterson (2013) highlighted that the AcciMap diagram provides a visually appealing and effective means of communicating complex incidents, including FSI, within socio-technical systems. In the FRAM model, an incident can be described in a single diagram, similar to the AcciMap. The FRAM diagram analyzes the different functions and the links between each function. In addition, design software can be used to design the diagrams, for example, FRAM and STAMP models can be designed and displayed using the FRAM Model Visualizer software for FRAM and the STAMP Workbench for STAMP. These tools not only facilitate the analysis construction process by providing step-by-step guidance to analysts but also help to effectively communicate the analysis results in an understandable way (Karanikas et al., 2020; Patriarca et al., 2022; Qiao et al., 2019). The system-based model utilizes diagrams and visualization tools to analyze and communicate findings, which can prove beneficial in FS risk communication, especially when used for internal risk communication. The diagrams and analyses reveal the FS aspect(s) that was not met. The designed tools allow for easy visualization and exchanging of data between managers, floor staff, and food handlers, as well as their views on associated risks and factors. This can enhance both risk management and risk assessment. Additionally, an FS training program could be developed based on these findings, as there is a specific emphasis on FS aspects in the critique of the FSI.

3.4 | Systems-based boundaries and feedback channels

Difficulty in identifying some factors that have led to FSMS failures, FSIs, or FBD outbreaks can arise from the fact that the latent conditions and active errors that have contributed to the accident are actually located quite some distance from the location of the incident, that is, where it is being actualized (Griggs, 2012). As a consequence, some latent conditions and active errors/failures remain unnoticed during revalidation processes, especially if a linear relationship was assumed and/or they sit outside the boundary defined for the HACCP Plan and FSMS. This means that the latent conditions remain as systemic weaknesses either in the FSMS, or within the external environment and they can eventually create a scenario where individuals commit mistakes or processes fail, sometimes repeatedly. Repeat accidents or incidents, what has been described as supply chain déjà-vu and a failure to learn from previous events, can be linked to high levels of overconfidence, complexity, and complacency in food organizations (Manning et al., 2021). Aligning the safety appraisal literature considered in this paper with the FS literature, Fotopoulos et al.'s (2009) work highlights latent constructs in terms of organizational characteristics (PRPs, equipment, and verification procedures) and human resource characteristics (employees' availability, commitment, training, and motivation) which are of major importance in implementing and verifying an effective socio-technical FSMS. The strengths and weaknesses of the three selected tools have been considered with regard to FS management, with particular emphasis on the revalidation and reverification of FS plans and FSMS following an incident. Systems-based accident analysis of FSIs can uncover systemic failures and go beyond simply identifying the visible and surface-level individual errors committed by the front-line staff or cause-and-effect explanations of an FSI or FBD outbreak (Nayak & Waterson, 2016). In a wider context, graphically presenting a complete picture of the multiple, interactions, and relationships between these factors across multiple socio-technical levels is of value not only in determining what happened and what contributed to the incident, but also in identifying how revalidation and reverification activities can add value to prevent future incidents of the same type from occurring in the future. The ability to consider complex global food networks in this way is of value, as well as the ability to use qualitative information as a source of evidence and this can especially support FSI and FBD outbreak investigation in developing countries where resources for epidemiological investigation are limited (Diaz De Oleo et al., 2022, 2023). Therefore, systemic accident analysis can improve the existing organizational FSMS and the FS-culture and support the application of optimum FS controls at organizational, supply chain, and food system levels especially in commercial and geopolitically sensitive situations.

4 | CONCLUDING THOUGHTS

Effective FS management relies on the understanding of the factors that contribute to FSI especially FBD outbreaks and the means for their mitigation and control. This review has explored the application of systems-based accident analysis tools to both the design of FSMS and the investigation of FSI and application of FSMS revalidation processes. The study has compared and contrasted the diverse characteristics of linear, epidemiological, and systematic accident analysis tools and HACCP and the types and depth of qualitative and quantitative analysis they promote. The application of linear accident analysis such as the SCM has been proposed to enhance the design of FSMS by improving the layers of defense for FS (da Cunha et al., 2022). However, this model, similar to other sequential and epidemiological models, fails to represent the nonlinear dynamics of a complex socio-technical food system and how these factors are associated with, and influence, FS outcomes. One SCM-based model of interest is the HFACS framework. Despite HFACS framework having been applied to multiple domains, adapting the framework to the public health domain remains a novel approach (Bickley & Torgler, 2021). This framework also has some limitations due to its aviation accident taxonomy-based nature, making it less appropriate when used outside the aviation domain (Fu et al., 2017).

Systems-based accident analysis tools, such as the AcciMap, FRAM, and STAMP, have been compared and contrasted. They are flexible systematic approaches to analyzing FSI within a socio-technical food system which is complex and continually evolving. They can also be applied at organizational, supply chain, or wider food system levels. As with the application of HACCP principles, the process for their use is time-consuming and requires skilled users to achieve optimum outcomes in their application. This would be a barrier to their application by small organizations that do not have the resources or capabilities required. Systemic accident analysis models such as AcciMap endeavor to describe the complex interrelationships and interdependencies among the different components in socio-technical food systems, for example, human factors and organizational aspects in a multi-leveled hierarchical framework. The systematic approaches have transitioned from the single, linear often reductionist approach of considering individuals and processes as a single point of failure in FSI and FBD outbreaks to developing systemic analysis models that simultaneously recognize the role of regulators, legislation, the presence and adoption of an FSMS and the maturity of FS-culture at the organizational level and collectively across the supply chain. Despite the diversity of models and approaches to evaluate and analyze FSI, some models are more widely proposed in the food science literature than others based primarily on their practicality of application. This research contributes to existing research by providing a review of how systems-based accident analysis tools can be applied in the FS context as well as framing how these tools can inform revalidation processes to prevent reoccurence of FSI or FBD outbreaks. These models also can utilize both qualitative and quantitative data bringing together a much more socio-technical approach to ensuring safe food supply.

AUTHOR CONTRIBUTIONS

Dileyni Díaz De Oleo: Conceptualization; investigation; writing—original draft; writing—review and editing; visualization. **Louise Manning**: Writing—review and editing; supervision. **Lynn McIntyre**: Writing—review and editing; supervision. **Nicola Randall**: Writing—review and editing; supervision. **Rounaq Nayak**: Writing—review and editing; supervision.

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CONFLICTS OF INTEREST STATEMENT

None.

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REFERENCES

Al-Shanini, A., Ahmad, A., & Khan, F. (2014). Accident modelling and analysis in process industries. *Journal of Loss Prevention in the Process Industries*, *32*, 319–334. https://doi.org/10.1016/j.jlp.2014.09.016

Altabbakh, H., Alkazimi, M. A., Murray, S., & Grantham, K. (2014). STAMP–Holistic system safety approach or just another risk model? *Journal of Loss Prevention in the Process Industries*, *32*, 109–119. https://doi.org/10.1016/j.jlp.2014.07.010

Anderson, D. L., & Cunningham, W. C. (2000). Revalidation and long-term stability of National Institute of Standards and Technology Standard Reference Materials 1566, 1567, 1568, and 1570. *Journal of AOAC International*, *83*(5), 1121–1134. https://doi.org/10.1093/jaoac/83.5.1121

Anvarifar, F., Voorendt, M. Z., Zevenbergen, C., & Thissen, W. (2017). An application of the functional resonance analysis method (FRAM) to risk analysis of multifunctional flood defences in the Netherlands. *Reliability Engineering & System Safety*, *158*, 130–141. https://doi.org/10.1016/j.ress.2016.10.004

Archer, J., & De Bere, S. R. (2013). The United Kingdom's experience with and future plans for revalidation. *Journal of Continuing Education in the Health Professions*, *33*(S1), S48–S53. https://doi.org/10.1002/chp.21206

Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. *Procedia Computer Science*, *44*, 669–678. https://doi.org/10.1016/j.procs.2015.03.050

Arvanitoyannis, I. S., & Varzakas, T. H. (2009). Application of failure mode and effect analysis (FMEA) and cause and effect analysis in conjunction with ISO 22000 to a snail's (Helix aspersa) processing plant; a case study. *Critical Reviews in Food Science and Nutrition*, *49*(7), 607–625. https://doi.org/10.1080/10408390802145294

Barnett, D. J., Balicer, R. D., Blodgett, D., Fews, A. L., Parker, C. L., & Links, J. M. (2005). The application of the Haddon matrix to public health readiness and response planning. *Environmental Health Perspectives*, *113*(5), 561. https://doi.org/10.1289/EHP.7491

Belmonte, F., Schön, W., Heurley, L., & Capel, R. (2011). Interdisciplinary safety analysis of complex socio-technological systems based on the functional resonance accident model: An application to railway traffic supervision. *Reliability Engineering & System Safety*, *96*(2), 237–249. https://doi.org/10.1016/j.ress.2010.09.006

Bickley, S. J., & Torgler, B. (2021). A systematic approach to public health—Novel application of the human factors analysis and classification system to public health and COVID-19. *Safety Science*, *140*, 105312. https://doi.org/10.1016/j.ssci.2021.105312

Bjerga, T., Aven, T., & Zio, E. (2016). Uncertainty treatment in risk analysis of complex systems: The cases of STAMP and FRAM. *Reliability Engineering & System Safety*, *156*, 203–209. https://doi.org/10.1016/j.ress.2016.08.004

Bouzembrak, Y., Camenzuli, L., Janssen, E., & Van Der Fels-Klerx, H. J. (2018). Application of Bayesian networks in the development of herbs and spices sampling monitoring system. *Food Control*, *83*, 38–44. https://doi.org/10.1016/j.foodcont.2017.04.019

Bouzembrak, Y., & Marvin, H. J. P. (2016). Prediction of food fraud type using data from Rapid Alert System for Food and Feed (RASFF) and Bayesian network modelling. *Food Control*, *61*, 180–187. https://doi.org/10.1016/j.foodcont.2015.09.026

Bouzembrak, Y., & Marvin, H. J. P. (2019). Impact of drivers of change, including climatic factors, on the occurrence of chemical food safety hazards in fruits and vegetables: A Bayesian network approach. *Food Control*, *97*, 67–76. https://doi.org/10.1016/j.foodcont.2018.10.021

Bouzembrak, Y., Steen, B., Neslo, R., Linge, J., Mojtahed, V., & Marvin, H. J. P. (2018). Development of food fraud media monitoring system based on text mining. *Food Control*, *93*, 283–296. https://doi.org/10.1016/j.foodcont.2018.06.003

Branford, K. (2011). Seeing the big picture of mishaps. *Aviation Psychology and Applied Human Factors*, *1*(1), 31–37. https://doi.org/10.1027/2192-0923/a00005

Branford, K., Hopkins, A., & Naikar, N. (2009). Guidelines for AcciMap analysis. in A. Hopkins (Ed.), *Learning from high reliability organisations* (pp. 193–212). CCH.

Casolani, N., Liberatore, L., & Psomas, E. (2018). Implementation of quality management system with ISO 22000 in Italian food companies. *Calitatea*, *19*(165), 125–131.

Cassano-Piche, A. L., Vicente, K. J., & Jamieson, G. A. (2009). A test of Rasmussen's risk management framework in the food safety domain: BSE in the UK. *Theoretical Issues in Ergonomics Science*, *10*(4), 283–304. https://doi.org/10.1080/14639220802059232

Chen, P., Fu, G., Wang, Y., Meng, H., & Lv, M. (2022). Accident causation models: A comparison of SCM and 24Model. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *237*, 810. https://doi.org/10.1177/1748006X221099094

Cooke, D. L. (2003). A system dynamics analysis of the Westray mine disaster. *System Dynamics Review: The Journal of the System Dynamics Society*, *19*(2), 139–166. https://doi.org/10.1002/sdr.268

Couturier, M., & Leveson, N. (2009). Re-engineering the United States food safety system. *Food Protection Trends*, *29*(9), 571–576.

Curry, B. (2013). *XL foods recall was product of preventable errors, review finds*. The Globe and Mail https://www.theglobeandmail.com/news/politics/xl-foods-recall-was-product-of-preventable-errors-review-finds/article12363508/

da Cunha, D. T., Hakim, M. P., Soon, J. M., & Stedefeldt, E. (2022). Swiss cheese model of food safety incidents: Preventing foodborne illness through multiple layers of defence. *Food Control*, *139*, 109053. https://doi.org/10.1016/j.foodcont.2022.109053

De Carvalho, P. V. R. (2011). The use of functional resonance analysis method (FRAM) in a mid-air collision to understand some characteristics of the air traffic management system resilience. *Reliability Engineering & System Safety*, *96*(11), 1482–1498. https://doi.org/10.1016/j.ress.2011.05.009

Dekkers, R. (2015). *Applied systems theory, applied systems theory*. Springer International Publishing, https://doi.org/10.1007/978-3-319-10846-9

Delikhoon, M., Zarei, E., Banda, O. V., Faridan, M., & Habibi, E. (2022). Systems thinking accident analysis models: A systematic review for sustainable safety management. *Sustainability*, *14*(10), 5869. https://doi.org/10.3390/su14105869

Deljavan, R., Sadeghi-Bazargani, H., Fouladi, N., Arshi, S., & Mohammadi, R. (2012). Application of Haddon's matrix in qualitative research methodology: An experience in burns epidemiology. *International Journal of General Medicine*, *5*, 621–627. https://doi.org/10.2147/IJGM.S34394

Díaz De Oleo, D., Mcintyre, L., Randall, N., Nayak, R., & Manning, L. (2022). A socio-technical approach to food safety incident analysis using the AcciMap model in the hospitality sector. *Food Control*, *136*, 108849. https://doi.org/10.1016/j.foodcont.2022.108849

Diaz De Oleo, D., Mcintyre, L., Randall, N., Nayak, R., & Manning, L. (2023). Systematic mapping of food safety outbreaks in the hospitality sector in the Dominican Republic. *British Food Journal*, *125*(2), 500–521. https://doi.org/10.1108/BFJ-10-2021-1146

Diller, T., Helmrich, G., Dunning, S., Cox, S., Buchanan, A., & Shappell, S. (2014). The human factors analysis classification system (HFACS) applied to health care. *American Journal of Medical Quality*, *29*(3), 181–190. https://doi.org/10.1177/1062860613491623

Dolansky, M. A., Moore, S. M., Palmieri, P. A., & Singh, M. K. (2020). Development and validation of the systems thinking scale. *Journal of General Internal Medicine*, *35*, 2314–2320. https://doi.org/10.1007/s11606-020-05830-1

Dzwolak, W. (2019). Assessment of HACCP plans in standardized food safety management systems: The case of small-sized polish food businesses. *Food Control*, *106*, 106716. https://doi.org/10.1016/j.foodcont.2019.106716

Emery, F. E., & Trist, E. L. (1965). The causal texture of organizational environments. *Human Relations*, *18*(1), 21–32.

Emery, F. Y. T., & Trist, E. (1960). Socio-technical systems. In *Management science models and techniques* (Vol. 2, pp. 83–97). Pergamon Press.

European Food Safety Authority. (2018). *Listeria monocytogenes*: Update on foodborne outbreak. EFSA. https://www.efsa.europa.eu/en/press/news/180703

Fan, Y., Li, Z., Pei, J., Li, H., & Sun, J. (2015). Applying systems thinking approach to accident analysis in China: Case study of "7.23" Yong-Tai-Wen High-Speed train accident. *Safety Science*, *76*, 190–201. https://doi.org/10.1016/j.ssci.2015.02.017

Faour-Klingbeil, D., & C D Todd, E. (2020). Prevention and control of foodborne diseases in Middle-East North African countries: Review of national control systems. *International Journal of Environmental Research and Public Health*, *17*(1), 70. https://doi.org/10.3390/ijerph17010070

Ferjencik, M. (2011). An integrated approach to the analysis of incident causes. *Safety Science*, *49*(6), 886–905. https://doi.org/10.1016/j.ssci.2011.02.005

Fleetwood, J., Rahman, S., Holland, D., Millson, D., Thomson, L., & Poppy, G. (2019). As clean as they look? Food hygiene inspection scores, microbiological contamination, and foodborne illness. *Food Control*, *96*, 76–86. https://doi.org/10.1016/j.foodcont.2018.08.034

Fortin, N. D. (2011). The United States FDA food safety modernization act: The key new requirements. *European Food and Feed Law Review*, *6*, 260–268. https://www.jstor.org/stable/24325240

Fotopoulos, C. V., Kafetzopoulos, D. P., & Psomas, E. L. (2009). Assessing the critical factors and their impact on the effective implementation of a food safety management system. *International Journal of Quality & Reliability Management*, *26*(9), 894–910. https://doi.org/10.1108/02656710910995082

Fu, G., Cao, J.-L., Zhou, L., & Xiang, Y.-C. (2017). Comparative study of HFACS and the 24Model accident causation models. *Petroleum Science*, *14*, 570–578. https://doi.org/10.1007/s12182-017-0171-4

Fu, G., Lu, B., & Chen, X. (2005). Behavior based model for organizational safety management. *China Safety Science Journal*, *15*(9), 21–27. https://doi.org/10.16265/j.cnki.issn1003-3033.2005.09.005

Fu, G., Xie, X., Jia, Q., Li, Z., Chen, P., & Ge, Y. (2020). The development history of accident causation models in the past 100 years: 24Model, a more modern accident causation model. *Process Safety and Environmental Protection*, *134*, 47–82. https://doi.org/10.1016/j.psep.2019.11.027

Gangidi, P. (2019). A systematic approach to root cause analysis using 3 × 5 why's technique. *International Journal of Lean Six Sigma*, *10*(1), 295–310. https://doi.org/10.1108/IJLSS-10-2017-0114/FULL/XML

Garridogamarro, E., Svanevik, C. S., Lundebye, A.-K., Sanden, M., D'agostino, E., Kjellevold, M., Pincus, L., & Pucher, J. (2023). Challenges in the implementation of food safety and quality assurance systems in small-scale fisheries. *Food Quality and Safety*, *7*, fyad007. https://doi.org/10.1093/fqsafe/fyad007

Ge, J., Zhang, Y., Xu, K., Li, J., Yao, X., Wu, C., Li, S., Yan, F., Zhang, J., & Xu, Q. (2022). A new accident causation theory based on systems thinking and its systemic accident analysis method of work systems. *Process Safety and Environmental Protection*, *158*, 644–660. https://doi.org/10.1016/j.psep.2021.12.036

Goode, N., Salmon, P. M., Lenné, M. G., & Hillard, P. (2014). Systems thinking applied to safety during manual handling tasks in the transport and storage industry. *Accident Analysis & Prevention*, *68*, 181–191. https://doi.org/10.1016/j.aap.2013.09.025

Goode, N., Salmon, P. M., Taylor, N. Z., Lenné, M. G., & Finch, C. F. (2016). Lost in translation: The validity of a systemic accident analysis method embedded in an incident reporting software tool. *Theoretical Issues in Ergonomics Science*, *17*(5–6), 483–506. https://doi.org/10.1080/1463922X.2016.1154230

Grabbe, N., Kellnberger, A., Aydin, B., & Bengler, K. (2020). Safety of automated driving: The need for a systems approach and application of the functional resonance analysis method. *Safety Science*, *126*, 104665. https://doi.org/10.1016/j.ssci.2020.104665

Griffith, C. J., Livesey, K. M., & Clayton, D. (2010). The assessment of food safety culture. *British Food Journal*, *112*(4), 439–456. https://doi.org/10.1108/00070701011034448

Griggs, F. J. (2012). A human factors analysis and classification system (HFACS) examination of commercial vessel accidents [Thesis, Naval Postgraduate School].

Guo, S., Zhou, X., Tang, B., & Gong, P. (2020). Exploring the behavioral risk chains of accidents using complex network theory in the construction industry. *Physica A: Statistical Mechanics and Its Applications*, *560*, 125012. https://doi.org/10.1016/j.physa.2020.125012

Hamim, O. F., Hasanat-E-Rabbi, S., Debnath, M., Hoque, M. S., Mcilroy, R. C., Plant, K. L., & Stanton, N. A. (2022). Taking a mixed-methods approach to collision investigation: AcciMap, STAMP-CAST and PCM. *Applied Ergonomics*, *100*, 103650. https://doi.org/10.1016/j.apergo.2021.103650

Hamim, O. F., Hoque, M. S., Mcilroy, R. C., Plant, K. L., & Stanton, N. A. (2020). Representing two road traffic collisions in one AcciMap: Highlighting the importance of emergency response and enforcement in a low-income country. *Ergonomics*, *63*(12), 1512–1524. https://doi.org/10.1080/00140139.2020.1807064

Hamim, O. F., Shamsul Hoque, M., Mcilroy, R. C., Plant, K. L., & Stanton, N. A. (2020). A sociotechnical approach to accident analysis in a low-income setting: Using AcciMaps to guide road safety recommendations in Bangladesh. *Safety Science*, *124*, 104589. https://doi.org/10.1016/j.ssci.2019.104589

Heinrich, H. W. (1931). *Industrial accident prevention; a scientific approach*. McGraw-Hill.

Helferich, J. D. (2011). *A systems approach to food accident analysis*. Massachusetts Institute of Technology.

Herrera, I. A., & Woltjer, R. (2010). Comparing a multi-linear (STEP) and systemic (FRAM) method for accident analysis. *Reliability Engineering & System Safety*, *95*(12), 1269–1275. https://doi.org/10.1016/j.ress.2010.06.003

Hollnagel, E. (2017). *FRAM: The functional resonance analysis method*. CRC Press, https://doi.org/10.1201/9781315255071

Hollnagel, E., Hounsgaard, J., & Colligan, L. (2014). *FRAM—The functional resonance analysis method—A handbook for the practical use of the method* (1st ed.). Southern Region of Denmark.

Horvat, A. (2019). *Systems thinking in managing the success of food products exploring the potential of a system dynamics approach CQ*. Wageningen University.

Howell, G. V. J., & Miller, R. (2010). Maple leaf foods: Crisis and containment case study. *Public Communication Review*, *1*(1), 47–56. https://doi.org/10.5130/pcr.v1i1.1297

Huang, W., Shuai, B., Zuo, B., Xu, Y., & Antwi, E. (2019). A systematic railway dangerous goods transportation system risk analysis approach: The 24 model. *Journal of Loss Prevention in the Process Industries*, *61*, 94–103. https://doi.org/10.1016/j.jlp.2019.05.021

Hulme, A., Stanton, N. A., Walker, G. H., Waterson, P., & Salmon, P. M. (2019a). Accident analysis in practice: A review of Human factors analysis and classification system (HFACS) applications in the peer reviewed academic literature. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 1849–1853. https://doi.org/10.1177/1071181319631086

Hulme, A., Stanton, N. A., Walker, G. H., Waterson, P., & Salmon, P. M. (2019b). What do applications of systems thinking accident analysis methods tell us about accident causation? A systematic review of applications between 1990 and 2018. *Safety Science*, *117*, 164–183. https://doi.org/10.1016/j.ssci.2019.04.016

Igene, O., & Ferguson, A. (2023). Application of systemic accident analysis (SAA) approaches in telemedicine/telehealth. In T.-C. Wang (Ed.), *Telehealth and telemedicine* (p. 8). IntechOpen.

Igene, O. O., Johnson, C. W., & Long, J. (2022). An evaluation of the formalised AcciMap approach for accident analysis in healthcare. *Cognition, Technology & Work*, *24*, 161–181. https://doi.org/10.1007/s10111-021-00669-w

Irlbeck, E., Jennings, J. F., Meyers, C., Gibson, C., & Chambers, T. (2013). A case study of the crisis communications used in the 2009 *Salmonella* outbreak in peanut products. *Journal of Applied Communications*, *97*(4), 3. https://doi.org/10.4148/1051-0834.1125

Jacobsson, A., Sales, J., & Mushtaq, F. (2009). A sequential method to identify underlying causes from industrial accidents reported to the MARS database. *Journal of Loss Prevention in the Process Industries*, *22*(2), 197–203. https://doi.org/10.1016/j.jlp.2008.12.009

Jenkins, D. P., Salmon, P. M., Stanton, N. A., & Walker, G. H. (2010). A systemic approach to accident analysis: A case study of the Stockwell shooting. *Ergonomics*, *53*(1), 1–17. https://doi.org/10.1080/00140130903311625

Jespersen, L., & Huffman, R. (2014). Building food safety into the company culture: A look at maple leaf foods. *Perspectives in Public Health*, *134*(4), 200–205. https://doi.org/10.1177/1757913914532620

Jiang, Y. (2016). *An application of AcciMap to identify and analyse the causes of the Eastern Star and Sewol casualties*. World Maritime University.

Jin, C., Bouzembrak, Y., Zhou, J., Liang, Q., Van Den Bulk, L. M., Gavai, A., Liu, N., Van Den Heuvel, L. J., Hoenderdaal, W., & Marvin, H. J. P. (2020). Big data in food safety—A review. *Current Opinion in Food Science*, *36*, 24–32. https://doi.org/10.1016/j.cofs.2020.11.006

Kafetzopoulos, D. P., Psomas, E. L., & Kafetzopoulos, P. D. (2013). Measuring the effectiveness of the HACCP food safety management system. *Food Control*, *33*(2), 505–513. https://doi.org/10.1016/j.foodcont.2013.03.044

Karanikas, N., Popovich, A., Steele, S., Horswill, N., Laddrak, V., & Roberts, T. (2020). Symbiotic types of systems thinking with systematic management in occupational health & safety. *Safety Science*, *128*, 104752. https://doi.org/10.1016/j.ssci.2020.104752

Karanikas, N., & Roelen, A. (2019). The concept towards a standard safety model (STASAM v. 0). In *MATEC Web of Conferences* (Vol. *273*, p. 02001). EDP Sciences.

Kee, D., Jun, G. T., Waterson, P., & Haslam, R. (2017). A systemic analysis of South Korea Sewol ferry accident–Striking a balance between learning and accountability. *Applied Ergonomics*, *59*, 504–516. https://doi.org/10.1016/j.apergo.2016.07.014

Koutsoumanis, K., Alvarez-Ordóñez, A., Bolton, D., Bover-Cid, S., Chemaly, M., Davies, R., De Cesare, A., Herman, L., Hilbert, F., Lindqvist, R., Nauta, M., Peixe, L., Ru, G., Simmons, M., Skandamis, P., Suffredini, E., Jordan, K., Sampers, I., Wagner, M., … Allende, A. (2020). The public health risk posed by *Listeria monocytogenes* in frozen fruit and vegetables including herbs, blanched during processing. *EFSA Journal*, *18*(4), 1–102. https://doi.org/10.2903/J.EFSA.2020.6092

Larouzee, J., & Le Coze, J.-C. (2020). Good and bad reasons: The Swiss cheese model and its critics. *Safety Science*, *126*, 104660. https://doi.org/10.1016/j.ssci.2020.104660

Lee, J., & Chung, H. (2018). A new methodology for accident analysis with human and system interaction based on FRAM: Case studies in maritime domain. *Safety Science*, *109*, 57–66. https://doi.org/10.1016/j.ssci.2018.05.011

Lee, J. C., Daraba, A., Voidarou, C., Rozos, G., Enshasy, H. A. E., & Varzakas, T. (2021). Implementation of food safety management systems along with other management tools (HAZOP, FMEA, Ishikawa, Pareto). The case study of *Listeria monocytogenes* and correlation with microbiological criteria. *Foods*, *10*(9), 2169. https://doi.org/10.3390/foods10092169

Lee, S., Moh, Y. B., Tabibzadeh, M., & Meshkati, N. (2017). Applying the AcciMap methodology to investigate the tragic Sewol ferry accident in South Korea. *Applied Ergonomics*, *59*, 517–525. https://doi.org/10.1016/j.apergo.2016.07.013

Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, *42*(4), 237–270. https://doi.org/10.1016/S0925-7535(03)00047-X

Leveson, N. (2012). *Engineering a safer world: Systems thinking applied to safety*. The MIT Press.

Li, C., Tang, T., Chatzimichailidou, M. M., Jun, G. T., & Waterson, P. (2019). A hybrid human and organisational analysis method for railway accidents based on STAMP-HFACS and human information processing. *Applied Ergonomics*, *79*, 122–142. https://doi.org/10.1016/j.apergo.2018.12.011

Liu, N., Bouzembrak, Y., Van Den Bulk, L. M., Gavai, A., Van Den Heuvel, L. J., & Marvin, H. J. P. (2022). Automated food safety early warning system in the dairy supply chain using machine learning. *Food Control*, *136*, 108872. https://doi.org/10.1016/j.foodcont.2022.108872

Luo, Z., Li, K., Ma, X., & Zhou, J. (2013). A new accident analysis method based on complex network and cascading failure. *Discrete Dynamics in Nature and Society*, *2013*, 1–9. https://doi.org/10.1155/2013/437428

Ma, Q., Wan, M., Shao, J., Zhong, M., Guo, Y., & Wang, W. (2022). Six-hierarchy model of accident analysis and its application in coal mine accidents. *Journal of Safety Science and Resilience*, *3*(1), 61–71. https://doi.org/10.1016/j.jnlssr.2021.10.004

Malik, S., Krishnaswamy, K., & Mustapha, A. (2021). Hazard analysis and risk-based preventive controls (HARPC): Current food safety and quality standards for complementary foods. *Foods*, *10*(9), 2199. https://doi.org/10.3390/foods10092199

Manning, L. (2013). Development of a food safety verification risk model. *British Food Journal*, *115*(4), 575–589. https://doi.org/10.1108/00070701311317856

Manning, L. (2017). The influence of organizational subcultures on food safety management. *Journal of Marketing Channels*, *24*(3–4), 180–189. https://doi.org/10.1080/1046669X.2017.1393235

Manning, L., Morris, W., & Birchmore, I. (2021). Organisational forgetting: The food safety risk associated with unintentional knowledge loss. *Trends in Food Science & Technology*, *118*, 242–251. https://doi.org/10.1016/j.tifs.2021.08.028

Marvin, H. J., Bouzembrak, Y., Janssen, E. M., van der Zande, M., Murphy, F., Sheehan, B., Mullins, M., & Bouwmeester, H. (2017). Application of Bayesian networks for hazard ranking of nanomaterials to support human health risk assessment. *Nanotoxicology*, *97*(1), 67–76. https://doi.org/10.1016/j.foodcont.2018.10.021

Marvin, H. J. P., & Bouzembrak, Y. (2020). A system approach towards prediction of food safety hazards: Impact of climate and agrichemical use on the occurrence of food safety hazards. *Agricultural Systems*, *178*, 102760. https://doi.org/10.1016/j.agsy.2019.102760

Marvin, H. J. P., Bouzembrak, Y., Janssen, E. M., Van Der Fels- Klerx, H. J., Van Asselt, E. D., & Kleter, G. A. (2016). A holistic approach to food safety risks: Food fraud as an example. *Food Research International*, *89*, 463–470. https://doi.org/10.1016/j.foodres.2016.08.028

Marvin, H. J. P., Hoenderdaal, W., Gavai, A. K., Mu, W., Van Den Bulk, L. M., Liu, N., Frasso, G., Ozen, N., Elliott, C., Manning, L., & Bouzembrak, Y. (2022). Global media as an early warning tool for food fraud; an assessment of MedISys-FF. *Food Control*, *137*, 108961. https://doi.org/10.1016/j.foodcont.2022.108961

Mcilroy, R. C., Plant, K. L., & Stanton, N. A. (2020). "Identifying the higher-order factors of a motorcycle collision: An AcciMap analysis". In *Contemporary ergonomics and human factors* (pp. 1–5). CIEHF. https://publications.ergonomics.org.uk/uploads/Identifying-the-higher-order-factors-of-a-motorcycle-collision-An-Accimap-analysis.pdf

Meyers, C. V., & Vangronigen, B. A. (2021). Planning for what? An analysis of root cause quality and content in school improvement plans. *Journal of Educational Administration*, *59*(4), 437–453. https://doi.org/10.1108/JEA-07-2020-0156

Nayak, R. (2018). *Food safety culture: A systems approach*. Loughborough University.

Nayak, R., & Jespersen, L. (2022). Development of a framework to capture the maturity of food safety regulatory and enforcement agencies: Insights from a Delphi study. *Food Control*, *142*, 109220. https://doi.org/10.1016/J.FOODCONT.2022.109220

Nayak, R., Manning, L., & Waterson, P. (2022). Exploration of the fipronil in egg contamination incident in the Netherlands using the functional resonance analysis method. *Food Control*, *133*, 108605. https://doi.org/10.1016/j.foodcont.2021.108605

Nayak, R., & Waterson, P. (2016). 'When food kills': A socio-technical systems analysis of the UK Pennington 1996 and 2005 *E. coli* O157 outbreak reports. *Safety Science*, *86*, 36–47. https://doi.org/10.1016/j.ssci.2016.02.007

Nayak, R., & Waterson, P. (2017). The assessment of food safety culture: An investigation of current challenges, barriers and future opportunities within the food industry. *Food Control*, *73*, 1114–1123. https://doi.org/10.1016/j.foodcont.2016.10.061

Nayak, R., & Waterson, P. (2019). Global food safety as a complex adaptive system: Key concepts and future prospects. *Trends in Food Science & Technology*, *91*, 409–425. https://doi.org/10.1016/j.tifs.2019.07.040

Newnam, S., Goode, N., Salmon, P., & Stevenson, M. (2017). Reforming the road freight transportation system using systems thinking: An investigation of coronial inquests in Australia. *Accident*

Analysis & Prevention, *101*, 28–36. https://doi.org/10.1016/j.aap.2017.01.016

Nyarugwe, S. P., Linnemann, A. R., & Luning, P. A. (2020). Prevailing food safety culture in companies operating in a transition economy-does product riskiness matter? *Food Control*, *107*, 106803. https://doi.org/10.1016/j.foodcont.2019.106803

On, S. L., Brandt, S. M., Cornelius, A. J., Fusco, V., Quero, G. M., Maćkiw, E., Houf, K., Bilbao, A., Díaz, A. I., Benejat, L., & Megraud, F. (2013). PCR revisited: A case for revalidation of PCR assays for microorganisms using identification of *Campylobacter* species as an exemplar. *Quality Assurance and Safety of Crops & Foods*, *5*(1), 49–62. https://doi.org/10.3920/QAS2012.0158

Ouyang, M., Hong, L., Yu, M.-H., & Fei, Q. (2010). STAMP-based analysis on the railway accident and accident spreading: Taking the China–Jiaoji railway accident for example. *Safety Science*, *48*(5), 544–555. https://doi.org/10.1016/j.ssci.2010.01.002

Patriarca, R., Chatzimichailidou, M., Karanikas, N., & Di Gravio, G. (2022). The past and present of system-theoretic accident model and processes (STAMP) and its associated techniques: A scoping review. *Safety Science*, *146*, 105566. https://doi.org/10.1016/j.ssci.2021.105566

Peerally, M. F. (2021). *Improving risk controls following root cause analysis of serious incidents in healthcare*. University of Leicester. https://doi.org/10.25392/LEICESTER.DATA.15112434.V1

Pennington, H. (2009). *The public inquiry into the September 2005 outbreak of E. coli O157 in South Wales*.

Pennington, T. H. (2003). *When food kills: BSE, E. coli, and disaster science*. Oxford University Press.

Powell, D. A., Jacob, C. J., & Chapman, B. J. (2011). Enhancing food safety culture to reduce rates of foodborne illness. *Food Control*, *22*(6), 817–822. https://doi.org/10.1016/j.foodcont.2010.12.009

Putri, M. S., & Susanna, D. (2021). Food safety knowledge, attitudes, and practices of food handlers at kitchen premises in the Port 'X' area, North Jakarta, Indonesia 2018. *Italian Journal of Food Safety*, *10*(4), 9215. https://doi.org/10.4081/ijfs.2021.9215

Qiao, W., Li, X., & Liu, Q. (2019). Systemic approaches to incident analysis in coal mines: Comparison of the STAMP, FRAM and "2–4" models. *Resources Policy*, *63*, 101453. https://doi.org/10.1016/j.resourpol.2019.101453

Qureshi, Z. H. (2007). A review of accident modelling approaches for complex socio-technical systems. In *Conferences in research and practice in information technology, 12th Australian workshop on safety related programmable systems (SCS'07)* (pp. 1–14). University of South Australia.

Raben, D. C., Viskum, B., Mikkelsen, K. L., Hounsgaard, J., Bogh, S. B., & Hollnagel, E. (2018). Application of a non-linear model to understand healthcare processes: Using the functional resonance analysis method on a case study of the early detection of sepsis. *Reliability Engineering & System Safety*, *177*, 1–11. https://doi.org/10.1016/j.ress.2018.04.023

Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. *Safety Science*, *27*(2–3), 183–213. https://doi.org/10.1016/S0925-7535(97)00052-0

Rasmussen, J., & Svedung, I. (2000). *Proactive risk management in a dynamic society* (1st ed.). Swedish Rescue Services Agency. ISBN: 91-7253-084-7. https://rib.msb.se/Filer/pdf/16252.pdf

Read, G. J. M., Salmon, P. M., & Lenné, M. G. (2013). Sounding the warning bells: The need for a systems approach to understanding behaviour at rail level crossings. *Applied Ergonomics*, *44*(5), 764–774. https://doi.org/10.1016/j.apergo.2013.01.007

Reason, J. (2007). *Managing the risks of organizational accidents* (1st ed.). Routledge.

Rezazade, F., Summers, J., & Lai Teik, D. O. (2022). A holistic approach to food fraud vulnerability assessment. *Food Control*, *131*, 108440. https://doi.org/10.1016/j.foodcont.2021.108440

Rincon-Ballesteros, L., Lannelongue, G., & González-Benito, J. (2019). Implementation of the BRC food safety management system in Latin American countries: Motivations and barriers. *Food Control*, *106*, 106715. https://doi.org/10.1016/j.foodcont.2019.106715

Rustia, A. S., Tan, M. A. P., Guiriba, D. N. S., Magtibay, F. P. S., Bondoc, I. R. J., & Mariano, C. B. D. (2021). Defining risk in food safety in the Philippines. *Current Research in Nutrition and Food Science Journal*, *9*(1), 233–257. https://doi.org/10.12944/CRNFSJ.9.1.23

Salisbury NHS Foundation Trust. (2018). *The principles of root cause analysis (RCA) investigation*. Salisbury NHS Foundation Trust.

Salmon, P., Hulme, A., Walker, G., Waterson, P., Berber, E., & Stanton, N. (2020). Something for everyone: A generic AcciMap contributory factor classification scheme. In *Contemporary ergonomics and human factors 2020*. Chartered Institute of Ergonomics and Human Factors. https://publications.ergonomics.org.uk/uploads/Something-for-everyone-A-generic-AcciMap-contributory-factor-classification-scheme.pdf

Salmon, P., Williamson, A., Lenné, M., Mitsopoulos-Rubens, E., & Rudin-Brown, C. M. (2010). Systems-based accident analysis in the led outdoor activity domain: Application and evaluation of a risk management framework. *Ergonomics*, *53*(8), 927–939. https://doi.org/10.1080/00140139.2010.489966

Salmon, P. M., Cornelissen, M., & Trotter, M. J. (2012). Systems-based accident analysis methods: A comparison of AcciMap, HFACS, and STAMP. *Safety Science*, *50*(4), 1158–1170. https://doi.org/10.1016/j.ssci.2011.11.009

Salmon, P. M., Coventon, L., & Read, G. J. (2021). *Understanding and preventing work-related violence in hospital settings: A systems thinking approach* (Final Report). University of the Sunshine Coast. https://www.safework.nsw.gov.au/__data/assets/pdf_file/0006/964716/understanding-and-preventing-work-related-violence-in-hospital-settings-a-systems-thinking-approach.pdf

Salmon, P. M., Goode, N., Archer, F., Spencer, C., Mcardle, D., & Mcclure, R. J. (2014). A systems approach to examining disaster response: Using AcciMap to describe the factors influencing bushfire response. *Safety Science*, *70*, 114–122. https://doi.org/10.1016/j.ssci.2014.05.003

Salmon, P. M., Goode, N., Taylor, N., Lenné, M. G., Dallat, C. E., & Finch, C. F. (2017). Rasmussen's legacy in the great outdoors: A new incident reporting and learning system for led outdoor activities. *Applied Ergonomics*, *59*, 637–648. https://doi.org/10.1016/j.apergo.2015.07.017

Salmon, P. M., & Lenné, M. G. (2009). Systems-based human factors analysis of road traffic accidents: Barriers and solutions. In *Proceedings of the 2009 Australasian Road Safety Research, Policing and Education Conference* (pp. 201–209). Australasian College of Road Safety.

Salmon, P. M., Read, G. J., Stanton, N. A., & Lenné, M. G. (2013). The crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings.

Accident Analysis & Prevention, *50*, 1278–1288. https://doi.org/10.1016/j.aap.2012.09.029

Salmon, P. M., Read, G. J., & Stevens, N. J. (2016). Who is in control of road safety? A STAMP control structure analysis of the road transport system in Queensland, Australia. *Accident Analysis & Prevention*, *96*, 140–151. https://doi.org/10.1016/j.aap.2016.05.025

Schmitt, R., & Moerman, F. (2016). Validating cleaning systems. In *Handbook of hygiene control in the food industry* (pp. 587–601). Woodhead Publishing.

Scott, V. N. (2005). How does industry validate elements of HACCP plans? *Food Control*, *16*(6), 497–503. https://doi.org/10.1016/j.foodcont.2003.11.013

Shappell, S., & Wiegmann, D. (2000). *The human factors analysis and classification system—HFACS*. Report. Federal Aviation Administration, Civil Aeromedical Institute. Oklahoma City, Oklahoma. DOT/FAA/AM-00/7 pp. 19. Retrieved from: https://commons.erau.edu/publication/737/ [Accessed 18 August 2023]

Sharma, S., Goyal, S., & Chauhan, K. (2018). A review on analytical method development and validation. *International Journal of Applied Pharmaceutics*, *10*(6), 8–15. https://doi.org/10.22159/ijap.2018v10i6.28279

Song, T., Zhong, D., & Zhong, H. (2012). A STAMP analysis on the China-Yongwen railway accident. In *Computer Safety, Reliability, and Security: 31st International Conference, SAFECOMP 2012, Magdeburg, Germany, September 25–28, 2012* (pp. 376–387). Springer.

Song, Y.-H., Yu, H.-Q., Tan, Y.-C., Lv, W., Fang, D.-H., & Liu, D. (2020). Similarity matching of food safety incidents in China: Aspects of rapid emergency response and food safety. *Food Control*, *115*, 107275. https://doi.org/10.1016/j.foodcont.2020.107275

Soon, J. M., & Abdul Wahab, I. R. (2022). A Bayesian approach to predict food fraud type and point of adulteration. *Foods*, *11*(3), 328. https://doi.org/10.3390/foods11030328

Soon, J. M., Brazier, A. K., & Wallace, C. A. (2020). Determining common contributory factors in food safety incidents–A review of global outbreaks and recalls 2008–2018. *Trends in Food Science & Technology*, *97*, 76–87. https://doi.org/10.1016/j.tifs.2019.12.030

Sperber, W. H. (1998). Auditing and verification of food safety and HACCP. *Food Control*, *9*(2–3), 157–162. https://doi.org/10.1016/S0956-7135(97)00068-6

Stanton, N. (2019). *Models and methods for collision analysis: A guide for policymakers and practitioners*. TRB Publications. https://www.racfoundation.org/wp-content/uploads/Models_and_methods_for_collision_analysis_Stanton_March_2019.pdf

Stanton, N. A., Rafferty, L. A., & Blane, A. (2012). Human factors analysis of accidents in system of systems. *Journal of Battlefield Technology*, *15*(2), 23–30.

Stanton, N. A., & Salmon, P. M. (2020). Actor map and AcciMap: Analysis of the Uber collision with a pedestrian in Arizona, USA. In *Contemporary ergonomics and human factors* (pp. 1–4). CIEHF. https://publications.ergonomics.org.uk/uploads/Actor-Map-and-AcciMap-Analysis-of-the-Uber-collision-with-a-pedestrian-in-Arizona-USA.pdf

Stefanova, T., Burkhardt, J. M., Filtness, A., Wullems, C., Rakotonirainy, A., & Delhomme, P. (2015). Systems-based approach to investigate unsafe pedestrian behaviour at level crossings. *Accident Analysis & Prevention*, *81*, 167–186. https://doi.org/10.1016/j.aap.2015.04.001

Stefanova, T., Parris, G., & Milne, T. (2022). Mapping the contributing factors associated with the Waterloo underground station accident (2020). In *Ergonomics & Human Factors* (Vol. 2022, pp. 1–3). CIEHF. https://publications.ergonomics.org.uk/uploads/3_97.pdf

Stemn, E., Hassall, M. E., & Bofinger, C. (2020). Systemic constraints to effective learning from incidents in the Ghanaian mining industry: A correspondence analysis and AcciMap approach. *Safety Science*, *123*, 104565. https://doi.org/10.1016/j.ssci.2019.104565

Surak, J. G. (2015). Developments in validation and verification methods for hazard analysis and critical control points (HACCP) and other food safety systems. In *Advances in microbial food safety* (pp. 238–254). Woodhead Publishing.

Svedung, I., & Rasmussen, J. (2002). Graphic representation of accident scenarios: Mapping system structure and the causation of accidents. *Safety Science*, *40*(5), 397–417. https://doi.org/10.1016/S0925-7535(00)00036-9

Tabibzadeh, M., & Meshkati, N. (2015). Applying the AcciMap methodology to investigate a major accident in offshore drilling: A systematic risk management framework for oil and gas industry. In *SPE Western Regional Meeting 2015: Old Horizons, New Horizons Through Enabling Technology* (pp. 347–361), Society of Petroleum Engineers. https://doi.org/10.2118/174020-MS

Thatcher, A., Nayak, R., & Waterson, P. (2020). Human factors and ergonomics systems-based tools for understanding and addressing global problems of the twenty-first century. *Ergonomics*, *63*(3), 367–387. https://doi.org/10.1080/00140139.2019.1646925

Thoroman, B., Goode, N., Salmon, P., & Wooley, M. (2019). What went right? An analysis of the protective factors in aviation near misses. *Ergonomics*, *62*(2), 192–203. https://doi.org/10.1080/00140139.2018.1472804

Thoroman, B., Salmon, P., & Goode, N. (2020). Applying AcciMap to test the common cause hypothesis using aviation near misses. *Applied Ergonomics*, *87*, 103110. https://doi.org/10.1016/j.apergo.2020.103110

Tveiten, C. K. (2013). Resilient planning of modification projects in high risk systems: The implications of using the functional resonance analysis method for risk assessments. In E. Albrechtsen & D. Besnard (Eds.), *Oil and gas, technology and humans* (1st ed., p. 169). CRC Press. https://doi.org/10.1201/9781315598741-11

Underwood, P., & Waterson, P. (2013). Systemic accident analysis: Examining the gap between research and practice. *Accident Analysis & Prevention*, *55*, 154–164. https://doi.org/10.1016/j.aap.2013.02.041

Underwood, P., & Waterson, P. (2014). Systems thinking, the Swiss cheese model and accident analysis: A comparative systemic analysis of the Grayrigg train derailment using the ATSB, AcciMap and STAMP models. *Accident Analysis & Prevention*, *68*, 75–94. https://doi.org/10.1016/j.aap.2013.07.027

Unnevehr, L. (2021). Addressing Food Safety Challenges in Rapidly Changing Food Systems. Paper presented at the virtual ICAE Conference Plenary Session on Agriculture, Food Systems, and Health, August 21, 2021. Virtual 313802, International Association of Agricultural Economists. https://doi.org/10.22004/ag.econ.313802

Varzakas, T. (2015). HACCP and ISO22000: Risk assessment in conjunction with other food safety tools such as FMEA, Ishikawa diagrams and pareto. In *Encyclopedia of food and health* (pp.

295–302). Elsevier Inc.. https://doi.org/10.1016/B978-0-12-384947-2.00320-2

Vashisht, A. K. (2018). *Food safety culture: An underlying cause for success and failures of food safety management systems*. NDSU. https://hdl.handle.net/10365/28134

Vicente, K. J., & Christoffersen, K. (2006). The Walkerton *E. coli* outbreak: A test of Rasmussen's framework for risk management in a dynamic society. *Theoretical Issues in Ergonomics Science*, *7*(02), 93–112. https://doi.org/10.1080/14639220500078153

Wahyuni, H. C., Vanany, I., Ciptomulyono, U., & Purnomo, J. D. T. (2020). Integrated risk to food safety and halal using a Bayesian network model. *Supply Chain Forum: An International Journal*, *21*(4), 260–273. https://doi.org/10.1080/16258312.2020.1763142

Wallace, C. A. (2014). HACCP-based food safety management systems: Great in theory but can we really make them work in practice? *Perspectives in Public Health*, *134*(4), 188. https://doi.org/10.1177/1757913914538731

Wang, X., Bouzembrak, Y., Marvin, H. J. P., Clarke, D., & Butler, F. (2022). Bayesian networks modeling of diarrhetic shellfish poisoning in *Mytilus edulis* harvested in Bantry Bay, Ireland. *Harmful Algae*, *112*, 102171. https://doi.org/10.1016/j.hal.2021.102171

Wang, Y., Zio, E., Zhang, S., & Yang, X. P. (2016). Some reflections on pre- and post- accident analysis for water transport: A case study of the Eastern Star accident. In L. Walls, M. Revie, & T. Bedford (Eds.), *Risk, Reliability and Safety: Innovating Theory and Practice: Proceedings of ESREL 2016* (pp. 127–133). Taylor & Francis Group.

Wangen, G., Hellesen, N., Torres, H., & Brækken, E. (2017). An empirical study of root-cause analysis in information security management. In *Proceedings of the SECURWARE. The Eleventh International Conference on Emerging Security Information, Systems and Technologies*. IARIA Press.

Waterson, P. (2009). A systems ergonomics analysis of the Maidstone and Tunbridge Wells infection outbreaks. *Ergonomics*, *52*(10), 1196–1205. https://doi.org/10.1080/00140130903045629

Waterson, P., Jenkins, D. P., Salmon, P. M., & Underwood, P. (2017). 'Remixing Rasmussen': The evolution of AcciMaps within systemic accident analysis. *Applied Ergonomics*, *59*, 483–503. https://doi.org/10.1016/j.apergo.2016.09.004

Waterson, P., Robertson, M. M., Cooke, N. J., Militello, L., Roth, E., & Stanton, N. A. (2015). Defining the methodological challenges and opportunities for an effective science of sociotechnical systems and safety. *Ergonomics*, *58*(4), 565–599. https://doi.org/10.1080/00140139.2015.1015622

Wienen, H. C., Bukhsh, F. A., Vriezekolk, E., & Wieringa, R. J. (2017). Accident analysis methods and models-a systematic literature review. In *WiPe Paper—Planning. Foresight and Risk Analysis Proceedings of the 15th ISCRAM Conference—Rochester, NY, USA May 2018*. https://idl.iscram.org/files/hanschristianaugustijnwienen/2018/2117_HansChristianAugustijnWienen_etal2018.pdf [Accessed 18 August 2023]

Wiśniewska, M. (2023). Just culture and the reporting of food safety incidents. *British Food Journal*, *125*(1), 302–317. https://doi.org/10.1108/BFJ-12-2021-1316

Wiśniewska, M., Czernyszewicz, E., & Kałuża, A. (2019). The assessment of food safety culture in small franchise restaurant in Poland: The case study. *British Food Journal*, *121*(10), 2365–2378. https://doi.org/10.1108/BFJ-03-2019-0152

Woo, D. M., & Vicente, K. J. (2003). Sociotechnical systems, risk management, and public health: Comparing the North Battleford and Walkerton outbreaks. *Reliability Engineering & System Safety*, *80*(3), 253–269. https://doi.org/10.1016/S0951-8320(03)00052-8

Wu, A. W. (2008). Effectiveness and efficiency of root cause analysis in medicine. *Jama*, *299*(6), 685–687. https://doi.org/10.1001/jama.299.6.685

Yang, Y., Wei, L., & Pei, J. (2019). Application of meta-analysis technique to assess effectiveness of HACCP-based FSM systems in Chinese SLDBs. *Food Control*, *96*, 291–298. https://doi.org/10.1016/j.foodcont.2018.09.013

Yiannas, F. (2008). *Food safety culture: Creating a behavior-based food safety management system (Food Microbiology and Food Safety)*. Springer Science & Business Media.

Yousefi, A., Rodriguez Hernandez, M., & Lopez Peña, V. (2019). Systemic accident analysis models: A comparison study between AcciMap, FRAM, and STAMP. *Process Safety Progress*, *38*(2), e12002. https://doi.org/10.1002/prs.12002

Zhang, Y., Jing, L., & Sun, C. (2018). Systems-based analysis of China-Tianjin port fire and explosion: A comparison of HFACS, AcciMap, and STAMP. *Journal of Failure Analysis and Prevention*, *18*, 1386–1400. https://doi.org/10.1007/s11668-018-0534-1

Zwietering, M. H., Garre, A., Wiedmann, M., & Buchanan, R. L. (2021). All food processes have a residual risk, some are small, some very small and some are extremely small: Zero risk does not exist. *Current Opinion in Food Science*, *39*, 83–92. https://doi.org/10.1016/j.cofs.2020.12.017

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