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Abstract

A theory-based systems approach, such as AcciMap accident analysis, has been widely used over the years in multiple safety critical sectors such as the nuclear, petrochemical, aviation and railway industries to provide a detailed understanding of complex systems and the chain of events contributing to accidents resulting from system failure. However, despite its advantages, the use of a systems approach in the food safety context has to date been limited. The purpose of this study was to investigate three established norovirus incidents using the AcciMap accident analysis approach to determine its efficacy at informing the design of food safety policies following a norovirus outbreak to prevent reoccurrence. This approach was found to be of value in analysing norovirus outbreaks. The findings of the AcciMap analysis reveal the norovirus outbreaks were not the outcome of a single causal incident, but a chain of events and interactions that involved governmental failure to control and enforce safety regulations and the impact on managerial and individual behaviours at a lower level in the system. The analysis identified the common contributory 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 using the AcciMap approach is that it does not constrain the analysis to individual components or particular types of incident allowing for a more holistic and interconnected risk assessment.

Keywords: Norovirus outbreak; food poisoning; incident analysis; AcciMaps; hospitality and tourism; food safety governance.

Highlights

- AcciMap is a systemic incident analysis method with application in multiple domains.
- AcciMap uses a graphical framework to show systemic failures at different levels of a socio-technical system.
- AcciMaps reveals multiple factors/conflicts in food safety management.
- AcciMaps can inform public policies and regulations to minimise food safety incidents.

1. Introduction

Viral gastroenteritis has a substantial impact on public health. Norovirus (NoV) is one of the most common causes of viral acute gastroenteritis (AGE) outbreaks worldwide (Chhabra et al., 2021; Greening et al., 2012; Parrón et al., 2020; Qin et al., 2016). In Japan, the United States (US) and Europe, NoV accounts for 50% of all food-related illness (Thébault et al., 2021). Moreover, the global socioeconomic burden from NoV is estimated to be around 4.2 billion US Dollars (USD) (equivalent to 3.0 billion pounds) in direct health-care costs, with an additional 60.3 billion USD annually in indirect costs (equivalent to 47.8 billion pounds) (Ford-Siltz et al., 2021). NoV is estimated to cause 685 million cases and 210,000 deaths worldwide every year (Cannon et al., 2021; Cates et al., 2020;) . Consequently, viral infections are a food safety hazard leading to international health threats due to their global occurrence in tourism settings mainly cruises and the hotel industry (Fisher et al., 2018; Misumi & Nishiura, 2021; Sharma et al., 2020). Moreover, hotels and restaurants are identified as being the riskiest settings (Gursoy, 2019; Mun, 2020; Okumus, 2021). For instance, Bozkurt et al., (2021) reviewed norovirus contamination in berries, finding that restaurants are among the most common setting for NoV outbreaks.

Food-related disease outbreaks such as swine flu, Ebola, the United Kingdom (UK) foot and mouth disease epidemic and avian influenza (H1N1) have negatively impacted the tourism industry across the world, leading to economic loss (Kim et al., 2020; Kurež & Prevolšek, 2015; Ruan et al., 2017). An example of this, was the Middle East respiratory syndrome (MERS) in the Republic of Korea in which dramatically decreased the influx of tourists, leading to an economic loss of USD$2.6 in tourism revenue (Joo et al., 2019). Overall, hospitality settings are a highly susceptible sector frequently affected by NoV infections as the virus can easily spread through contaminated food, water and person to person transmission in close contact (Giammanco et al., 2018). Therefore; a health-related crisis could have a negative impact on public health and socioeconomic systems. The recent COVID-19 pandemic is the perfect example of a global health threat disrupting all business sectors, including the hospitality industry, by the unpredicted closure of tourism facilities and borders, social distancing measures, lockdown and other restrictions to prevent the spread of Coronavirus (Gössling et al., 2020; Hu et al., 2021).

NoV has been described as a challenging pathogen due to attributes such as multiple transmission routes, environmental persistence, and low infectious dosage, which hinders efforts to detect early transmission, and control/prevent infection before it turns into a large outbreak (Barclay et al., 2014; DiCaprio et al., 2013; Esposito & Principi, 2020). It has been estimated that 18% of all sporadic and epidemic AGE cases are associated with NoV (Inns et al., 2017), which can easily spread in closed and semi-enclosed settings such as restaurants, hospitals, schools, healthcare facilities, tourist resorts and cruise ships (Alsved et al., 2020; Kreidieh et al., 2017; Leshem et al., 2016; Ong, 2013). Large NoV outbreaks have occurred via the environment, through contact with contaminated objects, hands or surfaces, and by the consumption of contaminated food or water (Hansen et al., 2020). For instance, sewage-contaminated water supplies containing NoV were implicated in large outbreaks in Sweden (Larsson et al., 2014). Contaminated raw food products, specifically leafy vegetables, fruits and seafood have also been implicated in globally-reported NoV outbreaks (Bozkurt et al., 2021; Elbashir et al., 2018). Environmental, direct person-to-person transmission and surface cross-contamination are frequent in hospitality settings such as cruise ships (Towers et al., 2018; Wikswo et al., 2011), and restaurants (Morgan et al., 2019).

Consequently, this sector which is specially affected by this public health issue have been implementing and developing safety control measures such as hand hygiene and cleaning and disinfection agent in enclosed settings to reduce the occurrence of infections and outbreaks

(CDC, 2011). However, these efforts to control and manage NoV outbreaks seem to remain ineffective (Doménech-Sánchez et al., 2020; Inns et al., 2017).

2. Review of literature

Effective food safety risk management comes from understanding the risk and hazards related to a food safety incident and the means for their control (Song et al., 2020). Government, organisations and private industry have mandated the adoption of hazard analysis and critical control point (HACCP). HACCP provides the means to enhance food safety and prevent foodborne illness through identify hazards e.g. chemical, biological, physical and set in place appropriate controls to effectively minimise risks (Lee et al., 2021; Rincon-Ballesteros et al., 2019). HACCP can be used as a tool for the effective development of Food Safety Management System (FSMS) with significant competitiveness advantages for the food companies through compliance with national and international standards (Kotsanopoulos & Arvanitoyannis, 2017; Manning et al., 2019; Yang et al., 2019). The need to create a single framework in the food sector and at the same time to achieve international recognition resulted in the development of the Food Safety Management Systems requirements within an International Standards Organisation (ISO) standard (ISO 22000, 2018). ISO 22000 is compatible with other ISO standards such as ISO 9001 (for quality management) and ISO 14001 (for environmental management) (Baurina & Amirova, 2021).

However, barriers to FSMS implementation are specific for each food business and are generally related to the lack of knowledge, staff and technical aspects, business demand, human factors, financial resources and the degree of adoption of pre-requisites of the HACCP system (Casolani et al., 2018; Lee et al., 2021; Yang et al., 2019). Despite existing preventive approaches food safety issues still remain a concern for government, health authorities, private business and consumers (Faour-Klingbeil & Todd, 2020; Nayak & Waterson, 2019; Rustia et al., 2021). However, given the complexity and nuances of the food safety/public health literature, there is a need for the development of a wide conceptual framework that combines the available knowledge, new analytical techniques, and a multidisciplinary integration of approaches which can be successfully used from both experts and practitioners (Zanin et al., 2017). Furthermore, different methodological approaches have been proposed to understand and mitigate food safety issues; for instance, the work of Griffith et al. (2010) stressed the human factors involved. Similarly, Nayak and Waterson (2019) and Pennington (2003) acknowledged the importance of human factors in analysing foodborne outbreaks and call for a more systems based approach to food safety. Moreover, inappropriate food safety performance according to can be enacted by individuals (Griffith et al., 2010), and such performance has a significant negative impact on the food safety culture in the entire organisation (Manning, 2017; Nyarugwe et al., 2020).

Therefore, some new, improved techniques and tools (models) which take into account the influence of human factors have been developed (Nayak & Waterson, 2017; Salmon et al., 2020; Underwood & Waterson, 2012). Among these improved models Root Cause Analysis (RCA), Failure Mode and Effect Analysis, Brainstorming, Pareto Analysis, 5-Whys, Fault Tree, Ishikawa Cause and Effect Analysis are widely used (Lee et al., 2021). As a example Root Cause Analysis (RCA) is mainly focused on understanding how and why the safety accident occurs (Wangen et al., 2017). However, most of the models mentioned above, usually failed to explain the complexity of non-linear interactions in a dynamic socio-technical system (Thoroman et al., 2020; Underwood & Waterson, 2013; Waterson et al., 2015).

In order to overcome some limitations of the existing models incident analysis aims to understand the underlying causes leading to a given failure [incident] by extending perceptions of a given situation beyond the direct causes. It also tries to identify how safety can be built more holistically into a given system (Hamim et al., 2020; Stefanova et al., 2015). A complex system involves operational interactions, and interrelationships with technical, human, social and management aspects in any organisation (Qureshi, 2008). The hospitality sector is an example of a complex system that encompasses the integration of hotel suppliers, officers from the ministry of public health, private businesses, local enterprises, managers and staff interacting with process, conditions and the effect of human factors (Dhir et al., 2020). This group participating individually, or collectively, across the socio-technical food system can influence the outcomes and safety performance of any given organisation. Indeed, the degree of stakeholder participation is a determinant of the ability to deliver on food safety/public health outcomes (Nayak & Waterson, 2016). System failure [incidents] may arise in complex socio-technical systems, as a result of a loss of control over a process or activity (Salmon et al., 2012). Therefore, a systems-based analytical approach, including consideration of both people's interaction with their environment and organisational aspects (e.g. leadership), emphasises stakeholder(s)' participation and influence at given system-levels and their role in the chain of events that can lead to a food safety/public health incident (Hamim et al., 2020; Song et al., 2020). The analysis of simultaneous interactions of multiple risk-contributing factors is of greater value in incident analysis than considering single factors in isolation (Stefanova et al., 2015). Moreover, the socio-technical system is comprised of a set of interrelated or interdependent elements and these can be analysed in order to reveal the contributory factors that could have been prevented and/or controlled to improve the safety output (safe food) in a complex system (Hamim et al., 2020). The use of such incident analysis approaches to assess NoV risk in hospitality settings is now considered.

2.1 Incident Investigation Models

Over the years, incident analysis approaches have been developed and used in different contexts and scenarios including public health, rail, aviation, mining, maritime and nuclear power plants (Hulme et al., 2019; Salmon et al., 2020). Each approach proposes a specific theory to provide insights into the errors or chain of events causing the accident (Grabbe et al., 2020; Stefanova et al., 2015; Waterson et al., 2017; Yousefi et al., 2019;). Accident analysis models can be classified into sequential, epidemiological and systematic models (Fu et al., 2020; Waterson et al., 2015). Sequential and epidemiological models fail to represent the dynamics of a system and how these factors are associated; therefore, they do not fully capture the nonlinear interactions that can contribute to a food safety incident (Thoroman et al., 2020; Underwood & Waterson, 2013). Alternatively, systemic models are based on systems theory and endeavour to describe the complex interrelationships and interdependencies between the different components in the systems (Yousefi et al., 2019). For instance, the analysis of high-profile accidents (e.g. Chernobyl) has employed systemic techniques to depict the contributory factors which triggered the accident, rather than focusing on a single element approach regarding human error or a conventional cause-effect approach, which is unable to depict the variety of causes [contributory factors] involved in an accident or their interplay (Salmon et al., 2020; Thoroman et al., 2020).

2.2 The AcciMap approach in foodborne incidents

An AcciMap is a systemic framework approach to consider foodborne disease incidents representing the actors (e.g. individuals and organisation) in the system allocated in six hierarchical levels. This theoretical framework proposed by Ramussen (1997) it is assumed and expected that each systemic level works together in the management of safety to control hazards by the mechanisms available on each level e.g. laws, regulations and protocols (Goode et al., 2017). This system hierarchy allows analysts to identify and summarise the contributory factors in an incident and follow the hierarchy structure downwards to visualise the events or failures that have emerged from the socio-technical interconnection and interaction at each level (Gao et al., 2016). Further, this enables analysts to understand how information, actions and decisions made at the top of the system affect the outputs at the lower levels and its systemic complexity (Lee et al., 2017; Underwood & Waterson, 2012).

AcciMap approaches have been used to investigate the bovine spongiform encephalopathy (BSE) incident in the UK with both human and animal food supply networks and to represent the contributing factors to the 1986 epidemic (Cassano-Piche et al., 2009). Researchers concluded that this study was successful in explaining how and why accidents occur in complex socio-technical systems. However, a downside of this method was that it did not anticipate the unsafe behaviour exhibited at a higher level in the system. The AcciMap model was used to conduct a comparative analysis of two public health outbreaks of *Cryptosporidium parvum* originating in Canadian drinking water systems (Woo & Vicente, 2003). It was found that the complex interaction among levels of a socio-technical system and contributory factors tended to be the same at higher levels and differed at the lower ones. Consequently the positioning of such factors has implications for the design of public policies to minimise risk in such complex sociotechnical systems. More recently, Nayak and Waterson (2016) applied AcciMap to uncover the systemic factors of influence in two outbreaks of *E. coli* O157 in the UK, one in 1996 and another in 2005 (Nayak & Waterson, 2016). Despite the considerable timeframe between outbreaks, it was found that some common as well as unique contributory factors were associated with the two outbreaks. Here, it is important to mention that the terms ‘causal’, ‘associated’ and ‘contributory’ have all been used in previous studies. The term ‘causal’ is not used to describe a direct cause and effect influence, but to describe factors that, either individually or in combination, were found to have influenced the incident. The method of the current study is not designed to be quantitative so the terms ‘causal’ and ‘associated’ have been replaced by the term ‘contributory’, which more appropriately reflects the nature of the effect and the innate degree of rigor of the methodology.

The application of AcciMap in incident analysis is based on the approach providing a 'big picture' analysis by identifying the sequences of events contributing to foodborne outbreaks and uncovering the potential root causes and their interactions both among, and across, the levels in a complex organisational system. There is limited literature on food safety incident analysis by a non-linear, systemic approach such as AcciMap. Hence, this paper will look at NoV incidents through a socio-technical perspective to identify contributory factors and events involved in NoV outbreaks in hospitality settings that have been published in the literature. The purpose of this study is to investigate three established norovirus incidents using the AcciMap accident analysis approach and to determine its efficacy at informing the design of food safety policies following a NoV outbreak to prevent reoccurrence.

3 Materials and methods

3.1 AcciMap Framework and methodology

AcciMap belongs to the group of systemic analysis causation models such as STAMP (Systems-theoretic accident model and processes), FRAM (Functional Resonance Analysis Method see Nayak et al., 2022) which are the most cited models in accident causation investigations (Yousefi et al., 2019). These models are largely used by organizations and researchers to explain accident causation in several fields of study and how the constant dynamic and stressors push the entire systems and actors involved from safe performance to errors (Salmon et al., 2020). However, AcciMap has been the one particularly applied to analyse foodborne outbreaks (Nayak & Waterson, 2016; Waterson, 2009; Woo & Vicente, 2003). Despite belonging to the group of systemic models, significant differences are still present in terms of the theoretical foundation, the methodological development of each type of model and the outcomes and conclusions obtained. In particular AcciMap use a specific framework which is comprised of six basic systemic levels which are shown in table 1.

Moreover, AcciMap considers other external factors that challenge food safety management across a system. Such external factors include the fast pace of technological development, competitiveness, market conditions, public and safety awareness, political climate, economic pressure, and globalisation (Lee et al., 2017; Salmon et al., 2012).

Take in Table 1

One of the major advantages of using the AcciMap is that it does not require a taxonomy of errors or failures modes in order to guide the safety analysis and thus allows identification of all factors without constraint (Hulme et al., 2021). Conversely, the lack of taxonomy can also be seen as an disavantage because the analysis would be entirely dependant upon the analyst(s)' expertise and judgement.

Another advantage of the AcciMap, and other similar approaches e.g. FRAM is the graphical representation of the incident (Nayak & Manning, 2021; Nayak et al., 2022). This enables analysts to understand how decisions made at the top of the system affect the outputs at the lower levels (Lee et al., 2017; Underwood & Waterson, 2012) and to identify the factors leading to failure (Hamim et al., 2020). Moreover, graphical representation acknowledges the actors involves at each level of the system and exposure the existing behaviours and responsibility as individuals and their systemic complexity (Nayak & Manning, 2021; Parnell et al., 2017). However, the downside of AcciMap analysis lies in its qualitative nature. An excellent guide for creating an AcciMap, building up the analytical skills and the theoretical knowledge of the analysis can be found in the detailed study by Branford et al., 2009). Some additional information and guidance about the nature of the analysis and AcciMap development is provided by other studies (Hamim et al., 2020; Nayak & Waterson, 2016; Salmon et al., 2020).

3.2 Study selection

A thorough review was undertaken to select the foodborne outbreak with the following inclusion criteria (1) NoV outbreaks; (2) different locations (national/international), (3) hospitality setting (e.g. all-inclusive hotels and resorts); (4) vehicles and modes of infection transmission (waterborne infection), and (5) sufficient publicly available information (e.g. published papers, reports). The reason to select NoV outbreaks was to provide safety measures in order to prevent future outbreak and current study focused on outbreaks related to two particular genogroups (GI and GII). These genogroups have been commonly associated to foodborne outbreaks in hotel premises affecting staff, guest and locals (Arvelo et al., 2012; Lee et al., 2015; Lu et al., 2020; Nguyen et al., 2017; Ong, 2013; Rico et al., 2020).

Taking into account Salmon et al.'s (2012) concerns that the effectiveness of AcciMap analysis could be limited if there is a lack of resources or insufficient information regarding the incident, the selected cases of NoV in the current study were well documented. This gives the opportunity to reaveal the strenght and advantages of the AcciMap over other techniques. Moreover, the selected NoV outbreaks had different cultural and socio-economical backgrounds which provided opportunity for more powerful AcciMap analysis in terms of the diverse human and organisational factors of influence.

3.3. AcciMap construction

In the current study, before the actual AcciMap analysis, two prelimanry steps were implemented following the procedure by Waterson (2009). During the first step data was collected, and information and details related to each of the incidents using articles and official reports. The second step established a time frame which provided a precise overview of the events and decision made by the actors involved during each outbreak. After these two preliminary steps, the AcciMap analysis was done independently for the three NoV outbreaks. For each outbreak, the AcciMap analysis followed a similar approach using the guidance of previous work (Branford et al., 2009; Hamim et al. 2020; Nayak & Waterson, 2016), and and the consecutive steps of procedure are shown in Figure 1.

Take in Figure 1

The AcciMap framework was drawn manually on a blank sheet and the contributory factors identified were placed at the bottom of the diagram in the sheet. A critical step in the AcciMap construction was to organise the gathered information (contributory factors) and allocated each factor in the corresponding level of the AcciMap (Brandford et al., 2009). At that stage, before analysis of the contributory factors and interconnections, the draft AcciMaps were reviewed by the second author, a socio-technical analyst with specific AcciMap expertise. Aside from the minor modifications related to the wording of the contributory factors in order to ensure accuracy of the AcciMap and provide clarity to the readers no further changes were made (Branford, 2007). The final step involved using Microsoft Visio (version 1808), to develop each AcciMap. Contributory factors were displayed in boxes and grouped at a particular level. The connections and links were displayed as arrows, which represent the interconnections between factors. A colour code was used for each level in order to highlight the interactions and range of each causal factor across the system.

The AcciMap approach analysed the multiple contributory factors of the three NoV outbreaks where similar elements such as aetiological outbreak agent, holiday setting, and transmission mode were considered to identify particular patterns of events that could compromise public health in hospitality settings. These patterns are identified in the results and discussion sections.

4 Results

The standarised AcciMap frameworks developed are shown in Figures 2 to 4. Each level in the framework has been depicted by separate colour code to first visualise the different contributing factors at each level and to highlight the impact of these factors across the

AcciMap. Following the connection across the levels will illustrate how the different elements are connected. The background to the three incidents is now considered in turn.

4.1. *Contributing factors NoV outbreak in Bermuda (1998).*

Brown et al. (2001) is the primary source for this case study. The Bermuda Department of Health was notified on 10th February 1998 that 14 foreign guests staying in a large resort hotel were affected by gastroenteritis. However, the onset of the outbreak began on 7th February with 401 suspected cases. Table 2 details the subsequent events and actions taken after the onset of the outbreak. The AcciMap (Figure 2) identifies 37 contributing factors from the analysis such as faecally contaminated water which led to the occurrence of this large NoV outbreak. The transmission route was identified, indicating two possible water contamination modes involving the cross-contamination of underground water with sewage and wastewater close to the terrace tank.

Take in Table 2 and Figure 2

Causal factors identified in the AcciMap at the top level indicated a low-risk assessment towards hazards in the hotel premises, moreover; the diagram shows the direct link of the contributory factor among factors across the levels. The approach highlights the ambiguity of water quality standards from the government and its regulatory body. Furthermore, failures were common to both drinking and wastewater systems by infrequent inspections and controls over the water supply sources and its treatments. Similarly, Woo and Vicente (2003) found that government ambiguity in monitoring and adopting compliance programmes compromised the ability of the health authorities to guarantee the quality and safety of the drinking water supply. At a lower-level, non-compliance with the hygiene and safety protocol was ignored and this, the poor maintenance of the water tank, and underestimation of government advice regarding chlorination guidelines to water supply, were contributing factors to the widespread faecal contamination that occurred. Moreover, irregular employee health check-ups were significant factors leading to the outbreak. In line with other research (Nayak & Waterson, 2016; Woo & Vicente, 2003), using the AcciMap approach was a useful method to determine the contributory factors at different socio-technical levels to understand in a wider scope of analysis how decisions made at the government level also influenced the decisions and performance at lower levels of the system.

4.2. *Contributing factors NoV outbreak in the Dominican Republic (2007)*

This section summarises the NoV outbreak in the Dominican Republic in July 2007, affecting 800 people over a two-week period (Doménech-Sánchez et al., 2011). Table 3 provides a timeline of the contributing events and actions undertaken from the onset of the incident. A total of 41 factors were identified and the sequence of events between all the levels in the system leading to the outbreak were identified (see Figure 3). By analysing the contributory factors from the high level 1 and the vertical integration across the multi-layer system down to the lower level 5, the numbers of actions contributing to the outbreak are evident.

Take in Table 3 and Figure 3

This second outbreak (see Figure 3) shows that events from the external level played a role in the Dominican Republic outbreak. Poor health and safety regulations (refer to second level) were significant factors in the outbreak's occurrence and magnitude. Moreover, conributing factors were related to the governmental managerial aspects and budget limitations. The current study found the government shortcomings such as a reduced and limited budget is a potential risk to safety management operations. Other studies for example, Nayak and Waterson (2016) and Vicente and Christoffersen (2006) analysed two different outbreaks using the AcciMap framework and found that both government and managerial aspects (budget cutbacks) played a contributory role.

The complex interaction of factors at all levels of the sociotechnical systems analysed were also found to be of importance by Hamim et al. (2020) and Woo and Vicente, (2003), who support the versatility of the AcciMap approach to comprehensively analyse and understand a complex system, regardless of the context in which it is applied (Gao et al., 2016; Hulme et al., 2021). Furthermore, this study supports the utility and validity of the approach due to its capacity to reveal the contributory factors in an incident and provide through the analysis of a given set of evidence (Branford, 2007; Branford, 2011; Salmon et al., 2012; Waterson et al., 2017).

Communication issues between the different organisational levels led to the failure to take the necessary measures to prevent the occurrence of events leading to the outbreak. In line with other research (Nayak & Waterson, 2016), this study identified lack of communication, poor safety behaviours and lack of knowledge regarding infectious disease. Dansai et al. (2021) states that effective communication between the decision maker, managers and front line staff is a key factor to improve the performance of food safety. Additionally, education and training is a valuable tool to ensure an effective food safety system management is in place to mitigate foodborne illness incidents in hotels (Gruenfeldova et al., 2019; Lee & Seo, 2020). Moreover, when organisations do not ensure sufficient awareness of appropriate training and assessment, employees tend to neglect food safety in the work environment, leading to weak control of food safety hazards and foodborne illness incidents to occur. Thus, to reduce the repeated food borne illness issues and incidents, regular, focused training should be provided (Kuo et al., 2020).

4.3. Contributing factors NoV outbreak in New Zealand (2012)

In the study carried out by Jack et al. (2013), 53 cases of AGE in a southern ski resort in New Zealand were reported in August 2012. On the 27th August, Public Health South was notified that 11 diners became ill between 24 and 48 hours after dinner on the 24th August. The timeline is provided in Table 3. The AcciMap analysis from this outbreak identified 39 contributory factors across the entire system (Figure 4), depicting all possible factors of influence in the waterborne outbreak. It is evident that systemic failure in the organisational management of water and wastewater systems occurred.

Take in Table 4 and Figure 4

The AcciMap (Figure 4) depicts systemic deficiencies from the local regulator (refer to second level) which were related to local public health governance and the unregulated procedures toward water supply management and the lack of proactiveness to comply with corrective actions from previous public health inspections. Other factors prevailing were the irregularity of inspection from the environmental health officers (EHOs) and the communication issues which led to the inadequate safety practices being adopted by local regulators such as overlooking past microbiologically related events. In addition, poor risk management led to a failure to safeguard proper treatment of the water drinking supply and wastewater system.

5 Discussion

The AcciMap has previously been employed to analyse several foodborne outbreaks (Nayak & Waterson, 2016; Waterson, 2009; Woo & Vicente, 2003). However, to our knowledge, this study is the first which use AcciMap incident analysis in hospitality settings to investigate the contributory factors in three NoV outbreaks. Studies integrating human factor error analysis in food safety management system are limited (Walsh & Leva, 2019). Food systemic analysis, such AcciMap, considers the interactions of human and organisational factors in a system. An advantage of this AcciMap is that it provides a broad view of the external/internal organisational contributory factors involved in each outbreak. Moreover, the study identified socio-cultural factors and linked them to other factors across the socio-technical levels. Thus, it shows the complexity and inter-relationship of the contributory factors between levels (Waterson et al., 2017). AcciMap analysis difer from other incident analysis models such as cause-effect, epidemiological, sequential models due to it supersedes binary or linear analysis and considers the hierarchical interaction and feedback loops that can occur. Further, this moves the discourse away from culpability and direct cause analysis to bringing together all possible contributing factors of influence in the system hierarchy (Nayak & Manning, 2021). Table 5 provides a summary of systemic failures in which regardless of the particular context of the three outbreaks it has their differences and similarities AcciMap analysis goes further by providing a wider scope of how decisions made by the actors at any level might affect the outcomes of the incidents in the system.

Take in Table 5

Common failures among outbreaks identified weak management, lack of authority, irregular monitoring activities and enforcement, communication issues and poor safety behaviours/knowledge towards food safety as the factors leading to the occurrence of the incident. These factors are all aspects that would be addressed by a food safety management system aligned with ISO 22000. Moreover, stakeholders' practices in each level of the socio-technical system show that the prevailing weak food safety culture has affected the performance of the embedded food safety management system and contributed to NoV outbreaks (Nyarugwe et al., 2020). The AcciMap approach identified unique failures in each outbreak that were also related to technical operational management.

Food safety culture within an organisation is influenced by the external business environment; furthermore, this is shaped by the food safety governance structures at all levels of a socio-technical system (Manning, 2017; Nyarugwe et al., 2020). Food Safety Culture Assessment has become increasingly relevant (see ISO 22000:2018) to identify the likelihood of an outbreak by assessing the attitudes and actions of managers/staff and to identify areas for improvement (Griffith et al., 2010). In this regard, the AcciMap approach can benefit the processs of hazard risk analysis and be used in combination with food safety culture assessment to provide in more in-depth of the systemic failure affecting the socio-technical system. Moreover, using AcciMap provides the ability to compile specific recommendations for each responsible stakeholder in the system to specifically impelemtn presentive meaures to improve the food safety management system at each level and across all levels (Branford et al., 2009).

6 Conclusion

The AcciMap analysis carried out in this research demonstrates how a systems approach can comprehensively elucidate the factors and decisions made which may contribute to a NoV outbreak. The findings indicate that further food safety governance strategies need to be implemented at government, regulatory and management levels to shape the knowledge, attitudes and practices of all actors involved in a more practical and comprehensive way. Findings from this paper can inform and improve public health management and practices in hospitality settings; therefore, it has practical implications for organisations to prevent similar failures in the future by taking appropriate precautionary and reactive measures.

Further studies should focus on quantifying the interaction amongst contributory factors and determine the dominant contributory factors in the system or across multiple foodborne disease outbreaks. This research could then inform decision support tools that could be used at the lower levels of the system to better improve public health outcomes especially for NoV outbreaks in the hospitality sector.

Declaration of Interests

None

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Tables

Table 1. Main systematic levels of AcciMap framework

Level	Measures and control at the system level
Government	Laws and legislations developed to control public health concerns the hazardous procedures.
Regulatory	Legislation is converted into industry rules and regulationsfor a given health concern. Regulatory bodies can be further divided into sub-levels: (a) National and (b) Local regulators
Company	The rules and regulations are integrated into the company rules and policies
Management level	Staff activities and roles are specified and overseen with a reference to the company level rules and policies
Staff	The work force that follows the rules set about by the company and implemented by their managers
Equipment and surroundings	The company's rules and policies apply based on the government level regulations (Branford et al., 2009).

Table 2. Timeline of a NoV outbreak affecting 448 people in a hotel in Bermuda in 1998.

Date	Events
7 February	Outbreak onset of 401 suspected cases.
10 February	Bermuda Department of Health (BDOH) was notified of gastrointestinal illness among 14 foreign guests.
14 February	It was reported that many of the bathrooms were out of service. Flooded areas and an odour of faeces near a restaurant were detectable. Valentine's day functions held at the hotel.
15 February	Peak in number of cases with similar symptoms.
16 and 19 February	Widespread faecal contamination within the hotel's distribution system and from the terrace tank.
21 February	The hotel was closed.
23 February	The BDOH invited a team from the Caribbean Epidemiology Centre (CAREC) to assist with an investigation.

Table 3. Timeline for NoV outbreak affecting 800 people in a single resort in the Dominican Republic resort in 2007.

Date	Events
27 July	Onset of the outbreak.
August	Ongoing outbreak reported. On the first day of the outbreak, seven people were affected by diarrhoea and explosive vomiting in public areas. In the following days, sanitary and safety measures were taken to remove high-risk food from the menu, treatment of recreational and potable water, cleaning and disinfection of hotel premises.
3 and 6 August	New cases with a similar clinical picture continuously arose by 100 cases per day after two new guest arrivals.
7 August	The number of cases dropped after new entrants into the resort were cancelled Swab surface samples were collected from objects and common areas in the hotel. Airplanes were used to transport some tourists to and from the Dominican Republic on different dates when a severe gastroenteritis case was diagnosed.
12 August	The last case was reported.

Table 4. Timeline for NoV outbreak affecting 53 people in a busy tourist location in New Zealand in 2012.

Date	Events
18 August	Sporadic acute gastroenteritis cases reported from locals/hotel staff.
24 August	Hotel guests and local patrons become ill after dining/drinking tap water at the hotel.
27 August	The public health office was notified of 11 diners ill with gastroenteritis. Local authorities inspected the water system supply.
29 August	Leftover food samples were collected.
6 September	Inspection of the hotel kitchen was conducted, and strict cleaning procedures were implemented. Chlorination levels were tested from the kitchen tap and other water supplies.
13-14 September	Environmental water samples were taken from the neighboring resort (local river surface, surface water stream).

Table 5. Summary common casual factors from the analysis of the three NoV outbreaks

System level	Common factors	Unique factors
1. Government	Inadequate/poor surveillance system Limited health and safety regulations	Poorly define government responsibility Limited regulations sewage/ wastewater system Unregulated drinking water supply sources
2. Regulatory bodies	Inadequately trained EHO Irregular inspections Communications issues	Weak enforcement local health regulations Neglect of risk of food safety hazards
3. Organisational Workplace	Poor safety management systems Infrequent inspection of water supply sources Overestimation of sickness policy Issues in communication	Limited water treatment resources No established outbreak control protocols Delayed to amend corrective actions
4. Physical individual events, Process and conditions	Deficient hygiene procedure Lack of protocol compliance	Non preventive control measure were in place to mitigate food safety hazards
5. Outcomes	Norovirus infections Widespread/faecal contamination Waterborne transmission Cross-contamination Hotel closure	

Figures

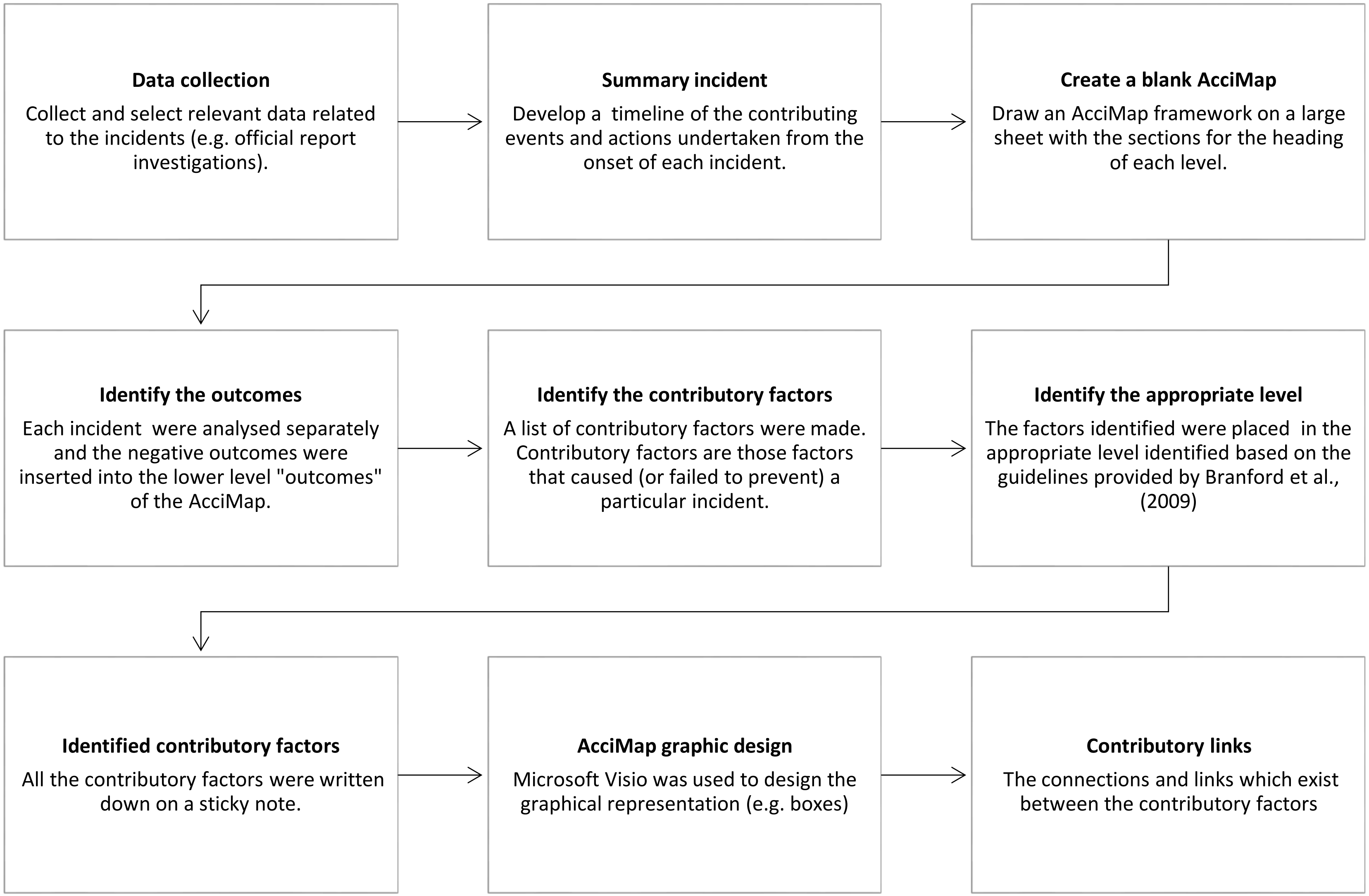

Figure 1. Flowchart illustrating the steps used to construct the AcciMap.

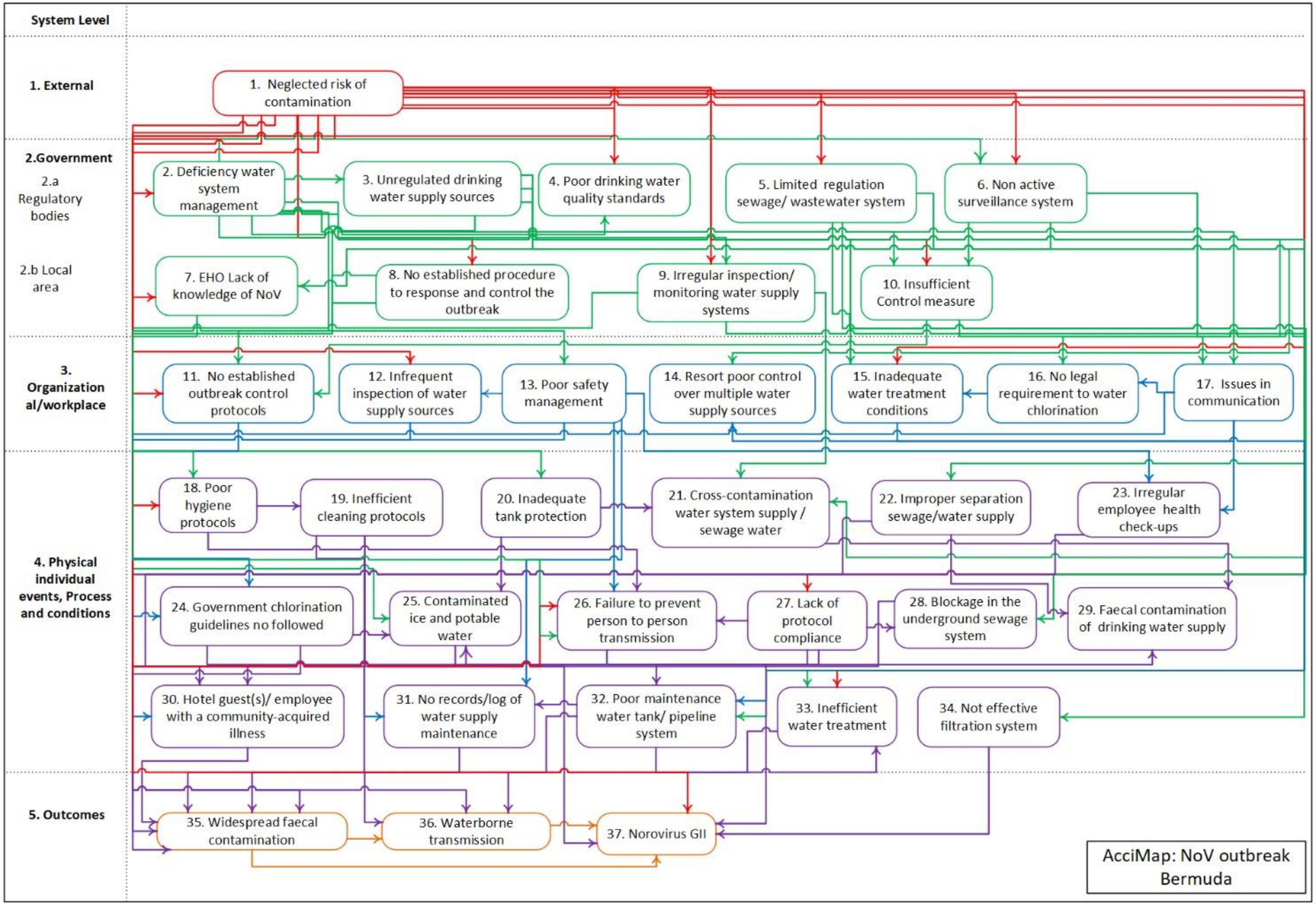

Figure 2. AcciMap diagram of the 1998 norovirus outbreak in Bermuda.

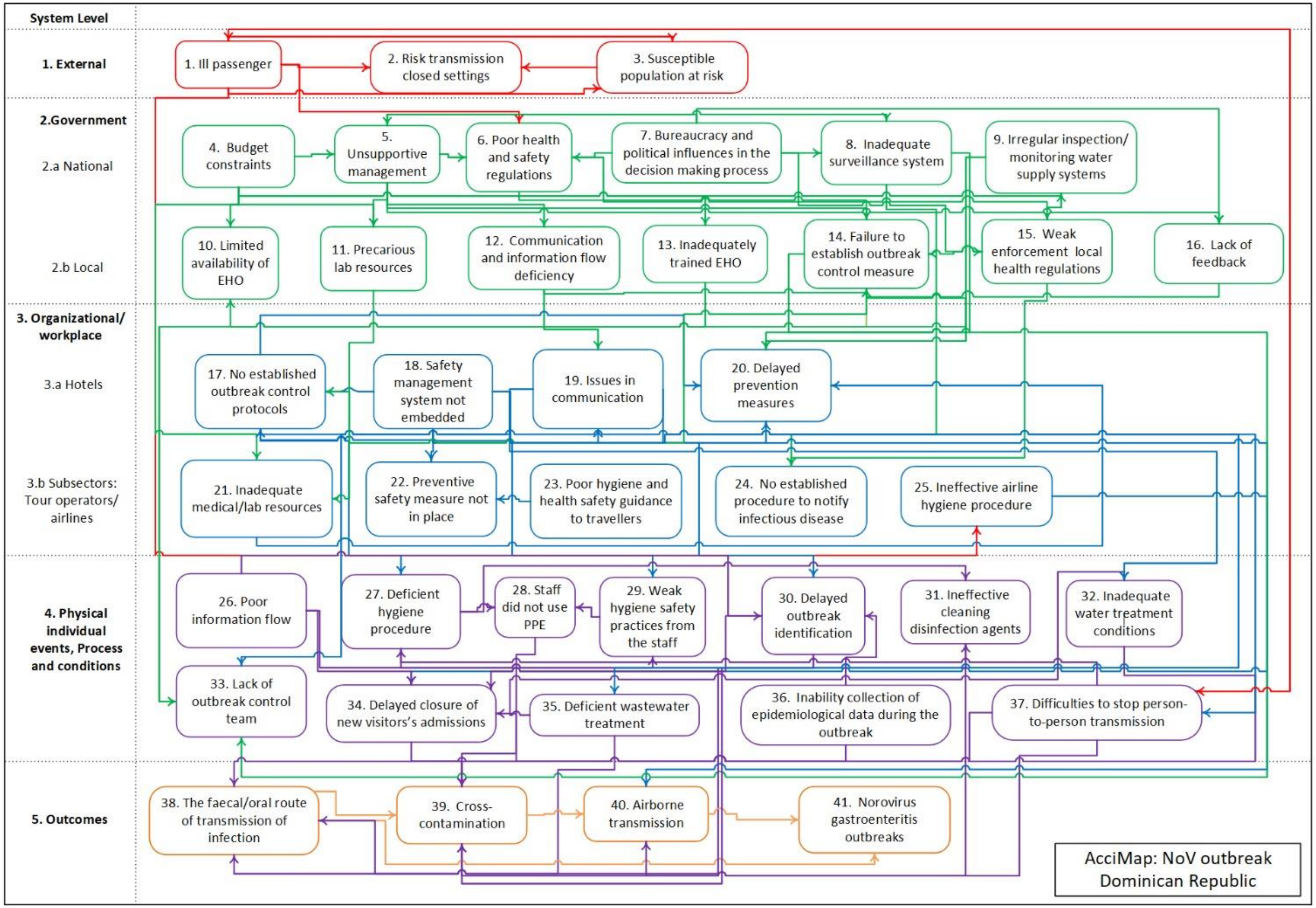

Figure 3. AcciMap diagram of the 2007 norovirus outbreak in Dominican Republic.

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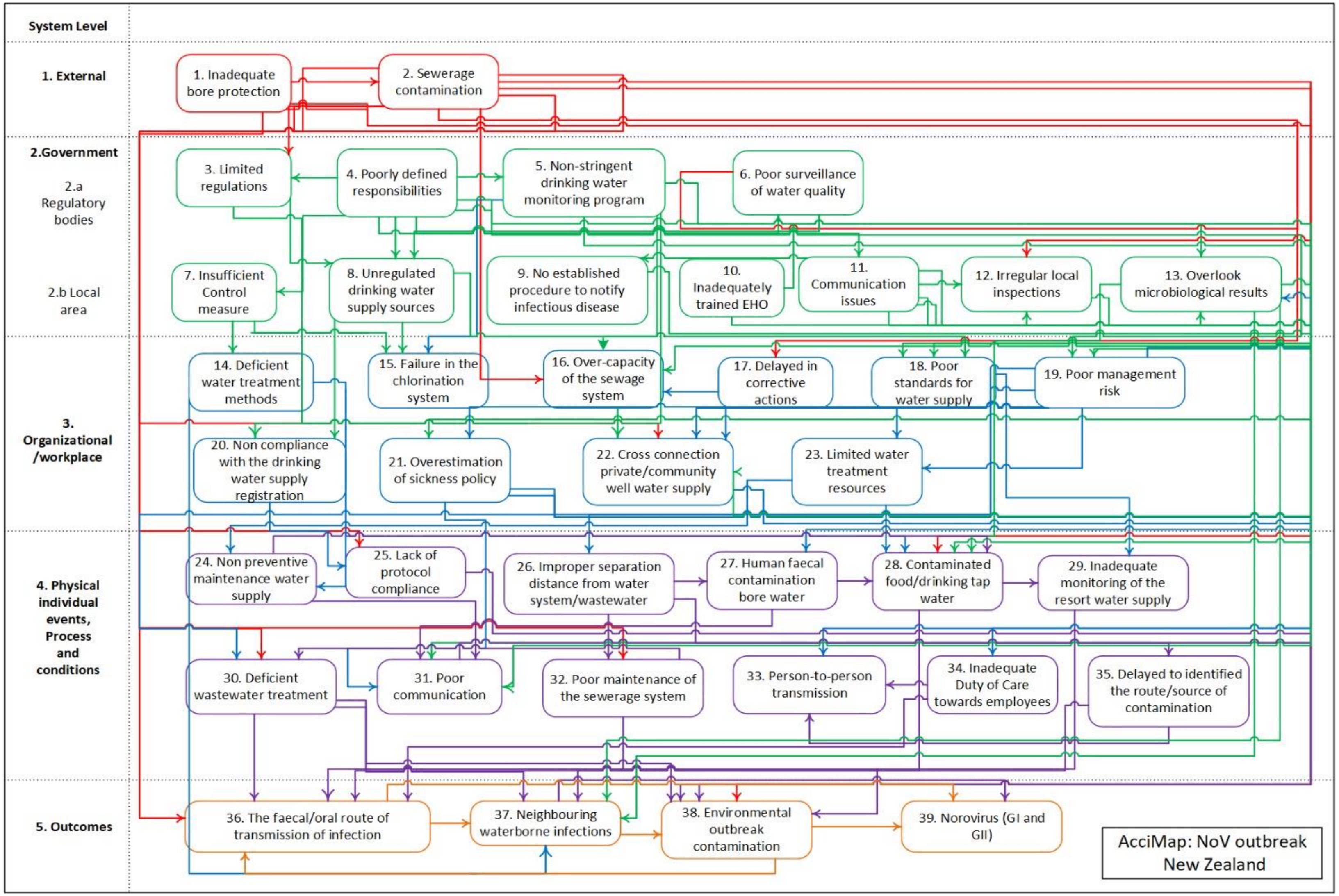

2 Figure 4. AcciMap diagram of the 2012 norovirus outbreak in New Zealand.