In Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society
(pp. 386-390). Santa Monica, CA. Human Factors and Ergonomics Society

A SOCIOTECHNICAL SYSTEMS ANALYSIS OF THE BSE EPIDEMIC IN THE UK THROUGH CASE STUDY

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In 1986, Bovine Spongiform Encephalopathy (BSE) was identified in the United Kingdom. Millions of BSE-infected cows and were slaughtered and over 150 people contracted variant-Creutzfeldt Jakob Disease (vCJD), an inevitably fatal human form of BSE. The purpose of this study was to test the ability of Rasmussen's (1997) risk management framework to explain how and why BSE (and later vCJD) entered the human and animal food supply from 1986 to 1996. This study represents the first test of the ability of Rasmussen's framework to explain how and why accidents occur in the food production domain. Using a case study methodology, this study investigates how well the evidence of the case study supports the framework's seven predictions of how and why accidents occur in complex socio-technical systems. All seven of the predictions were supported by the evidence.

INTRODUCTION

In 1986, the beef production system in the United Kingdom (UK) became contaminated with Bovine Spongiform Encephalopathy (BSE). Ten years later, despite the efforts of regulators to protect against BSE's potential risks, over 160,000 infected cows had been slaughtered and ten young people had confirmed cases of the inevitably fatal disease variant Creutzfeldt-Jacob Disease (vCJD), the human form of BSE thought to be transmitted through the consumption of contaminated beef. As of 2006, approximately 150 people have died from vCJD in the UK (The National Creutzfeldt-Jacob Disease Surveillance Unit, 2006) and millions of cattle have been slaughtered.

Tragic incidents such as this provide valuable opportunities to understand and improve the safety of complex socio-technical systems. The purpose of this thesis was to test the ability of Rasmussen's (1997) risk management framework to explain how and why BSE (and vCJD) entered and continued to be transmitted through the human and animal food supply in the UK from 1986 to 1996. If the events that transpired during that ten-year period are accommodated by the framework and the properties of the framework are validated by the events that occurred, then the framework may prove useful for system re-design to prevent future accidents related to similar hazard sources in the food production domain. This study represents the first test of the utility of Rasmussen's risk management framework for explaining how and why accidents occur in the food production domain.

Rasmussen's (1997) risk management framework for complex socio-technical systems has two components: a structural hierarchy of the actors and organizations in a system (Figure 1), and the dynamic forces that can cause the system to change its behavior (Figure 2). The exact number of levels in the hierarchy and titles of each level can vary depending on the system being studied. Generally speaking, the bottom level of the hierarchy describes events related to the process being controlled. The next level describes activities of frontline staff. The following level describes the activities of people that manage or supervise the staff, and the level above describes the activities of the entire company or organization. The level second from the top describes the activities of the regulatory bodies, and finally, the top level describes the activities of the government, which determines public policy.

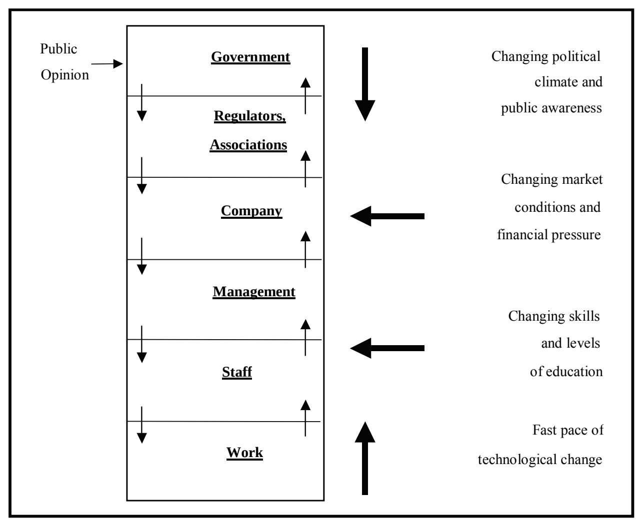

Figure 1: Structural hierarchy of actors in a complex socio-technical system. Adapted from Rasmussen (1997) and reprinted from Vicente (2002). Quality and Safety in Healthcare, 11, 302-304. With permission from the BMJ Publishing Group.

According to Rasmussen's (1997) framework, vertical integration across all levels of a complex socio-technical system is required for the system to function safely. That is, decisions made at the higher levels of the hierarchy need to be disseminated to the lowest levels of the hierarchy, and information about what is happening at the lower levels of the hierarchy needs to circulate to the higher levels, creating feedback loops. These feedback loops allow decisions made at the higher levels of the system to reflect the goals and capabilities of the lower levels.

Following this theory, safety is an emergent feature of a system and is impacted by the actions and decisions of individuals and organizations at multiple levels. System stability is difficult to achieve because external forces (Figure 1, right side) influence complex systems, especially in today's dynamic society where change is more frequent.

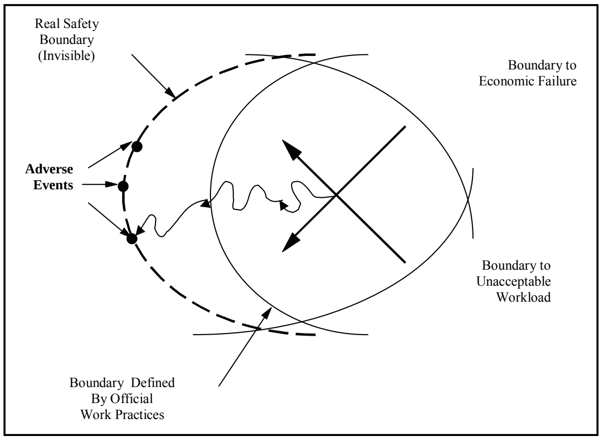

Figure 2: Dynamic forces and behavioral change Adapted from Rasmussen (1997) and reprinted from "The Human Factor: Revolutionizing the Way People Live With Technology", © Kim Vicente, 2003.

Figure 2 illustrates how two dynamic forces, financial and cognitive efficiency pressures, affect the behavior of a complex socio-technical system over time (Rasmussen, 1997). As these forces interact, people at all levels of the system adapt their work practices to allow operators to work with fewer resources. The changes in work practices may appropriately address the financial and efficiency goals imposed, but they often cause a system to migrate closer to the proscribed boundary of safety; one that is defined by official work practices. Over time, people migrate beyond this proscribed boundary of safety towards the "real" boundary of safety where accidents occur. This migration may take years; therefore, subsequent to a major disaster, the people involved often do not understand what has happened because their actions did not deviate greatly from those in the recent past.

What is distinctive about Rasmussen's risk management framework is that it advocates for the development of descriptive models of actual human behaviour so that an understanding of the behaviour shaping mechanisms that influence human decisions and actions can be gained. By understanding what shapes operator performance, particularly in ways that violate established defenses and diminish the margin between safe operation and accidents, efforts to improve safety can be appropriately targeted.

METHOD

A qualitative case study research method (Yin, 2003) was adopted. According to Yin, a case study has five components: questions, propositions, unit of analysis, logic linking data to the propositions, and criteria for interpreting the findings. The propositions are the seven predictions of Rasmussen's risk management framework (described later).The unit of analysis for this study is the release of BSE into the human and animal food supply. The logic linking data to the propositions is provided by the framework's tools – the AcciMap (Figure 3) and the Conflict Map (Figure 4) – which help to highlight patterns in the data as they relate to the seven predictions. Characteristics of these tools (e.g., boxes on the AcciMap, connections between boxes, annotations on the Conflict Map) provide the criteria for interpreting the findings.

Yin's (2003) case study methodology provides methods for enhancing a study's quality. Three different methods were used to enhance construct validity. The first was the use of multiple sources of evidence to allow for triangulation of the data. The Lord Phillips Report, used as the main data source, is over 5,000 pages in length. It represents data that has been triangulated from multiple sources including over 1,000 witness statements, 138 days of public oral evidence, and more than 3,000 government files. The second method was to establish a chain of evidence. The AcciMap provides an explicit means for establishing a chain of evidence linking the information in each box on the hierarchy to the release of the hazard source. The third method was the use of key informants to review the analysis. There were two key informants who participated in reviewing the results of this case study – Prof. Erik Millstone, professor of Science and Technology Policy at the University of Sussex in the UK and co-author of the chapter titled '*Mad cow disease' 1980s-2000: how reassurances undermine precaution* in the European Environment Report *Late lessons from early warnings: the precautionary principle 1896-2000* (Van Zwanenberg & Millstone, 2001) and Dr. Ron Rogers, Senior Scientific Advisor in the Bureau of Microbial Hazards at Health Canada.

RESULTS

The events that contributed to the release of BSE can be seen in the AcciMap (Figure 3). Factors from each level that strongly contributed to the critical event are presented in this section, followed by a discussion of how each of the framework's seven predictions are supported.

Factors Mapped onto the AcciMap

Equipment and Surroundings. Several of the factors at the bottom level of Figure 3 relate to the nature of BSE. BSE was an unknown entity until November 1986. Identifying this new disease in cows was difficult because on many farms there was a pattern of only a single cow in a herd being affected. This factor, combined with the similarities between BSE clinical symptoms and other cattle diseases, delayed the identification of index cases. Further delay was due to BSE's incubation period (five to six years), which made it difficult to identify cattle feed as the transmission source.

Certain cow tissues such as brain and spinal cord are known to have a high titre of the BSE agent in clinically infected cows. Ingestion of less than a gram of brain tissue from clinically affected animals is enough to transmit the disease to a calf. This degree of infectivity was not realized by the Ministry of Agriculture, Fisheries and Food (MAFF) until 1994. MAFF's ignorance early in the epidemic about what amount of highly infective tissue was required to transmit the disease meant that precautionary measures put in place to protect the public did not have the desired effect because they did not protect against small amounts of infected material entering the human and animal food supply.

The final factor that will be discussed at this level is the process of mechanical carcass splitting. The carcass would be split along the "mid-line of the spinal column although some veering from the mid-line would inevitably take place. Generally, the spinal cord was then removed, to improve the appearance of the meat, by drawing a thumb, knife or blunt hook down the length of the spinal canal. Most spinal cord was thrown into a receptacle to be sent for rendering, or washed to drains. A small amount would have remained stuck to the [vertebral] column and been passed on to mechanically recovered meat manufacture or for rendering" (Phillips et al., Vol. 13, p. 14). Mechanically recovered meat is incorporated into food products for human consumption. The small amount of potentially highly infectious spinal cord that occasionally remained attached was impossible to eliminate due to human operator limitations, even though those responsible for carcass splitting were highly skilled operators.

Physical Processes and Actor Activities. There are two main factors that will be discussed at this level. The first is the practice of feeding rendered animal protein to ruminants. This bears the most responsibility for how animals and humans were subjected to BSE. The practice of feeding ruminant materials to herbivores exposed them to infective risks for which they had not evolved defenses.

The second factor at this level is the cross-contamination that occurred between ruminant and non-ruminant feed. Shortly after the discovery of BSE, the Ruminant Feed Ban (RFB) was introduced, prohibiting the inclusion of ruminant protein in ruminant feed. This was thought to stop the flow of the BSE; however, many feedmills produced both ruminant and non-ruminant types of feed using the same production lines. This led to cross-contamination between the feed types and continued the spread of BSE through ruminant feed. All animal feed was later subjected to the animal specified bovine offal (SBO) ban. This prohibited the use of SBO (highly infective tissues) in all animal feed. The SBO ban was thought to reduce the risks associated with cross-contamination, but poor compliance with the ban negated its potential benefit.

Technical and Operational Management. All of the factors at this level shown in Figure 3 represent the failure of management to comply with regulations. The most preventable factor was the deliberate sale by feedmills of cattle feed produced before the RFB after the RFB took effect.

Local Government. Local authorities were responsible for enforcing compliance with BSE-related regulations in slaugherhouses, renderers and feedmills. Enforcement was done with a lack of assiduousness for several reasons including: a perception that the regulations were not important, wanting to refrain from placing additional burdens on slaughterhouses, and lack of motivation. Enforcement of the RFB was also hindered because no test existed to detect the presence of ruminant protein in compound feed.

Regulatory Bodies. One of the major factors at this level was the inadequacy of the BSE-related regulations. The inadequacy of the RFB resided in its inability to protect against cross-contamination between ruminant and non-ruminant feed. The inadequacy of the Specified Bovine Offal (SBO) regulations, which made it an offense to include certain potentially highly infective tissues in food products for human (and later animal) consumption, was that it did not include a comprehensive list of tissues that posed significant risk based on an analogy with scrapie – a well-known, and similar type of disease in sheep.

Government. The implementation of the slaughter and compensation policy as a means of removing all clinically affected cattle from the human food chain was delayed by six months because of fear of economic consequences and poor communication between MAFF and the Department of Health (DH). During this six month period BSE-infected cattle continued to enter the human and animal food supply.

At the time of BSE, the Deregulation Initiative was a key objective of the Government. The aim was to lift the burden of state regulation on industry and small businesses. Any proposals for new measures had to be tested against their cost to industry. For new and existing regulations "enforcement was expected to be done with a light touch" (Phillips et al., 2000, Vol.1, p. 30).

Assessing the Seven Predictions

All seven of the predictions made by Rasmussen's risk management framework are supported by the evidence in this case study. The seven predictions and how they are supported are discussed here.

1. *Safety is an emergent property of a complex socio-technical system. It is impacted by the decisions of all the actors.* The AcciMap shown in Figure 3 shows how the involvement of actors at all levels of the system set the stage for the BSE epidemic.

2. *Threats to safety are usually caused by multiple contributing factors, not just a single catastrophic decision or action.* None of the factors in Figure 3 are independently responsible for the BSE epidemic in the UK. Many factors are influenced by at least two other factors. For example, failure of the local authorities to enforce RFB and SBO regulations can be attributed to: the absence of a test for ruminant protein; a lack of communication from MAFF about how the regulations should be enforced and the importance of their enforcement; too few inspectors; and an incomplete understanding of the risks associated with BSE due to the state of knowledge available at the time.

3. *Threats to safety or accidents usually result from a lack of vertical integration across all levels of a complex socio-technical system, not just from deficiencies at any one level alone.* Figure 4 shows some of the mismatches between individuals and organizations across the levels of the socio-technical system responsible for human and animal food production in the UK. These examples of vertical misalignment punctuate how the priorities or objectives of individuals and organizations at different levels of the system can conflict as a result of the specific pressures that each is operating under.

4. *The lack of vertical integration is caused, in part, by a lack of feedback across levels of a complex socio-technical system. Actors at each level cannot see how their decisions interact with those made by actors at other levels, so the threats to safety are far from obvious before an accident.* An example of the lack of feedback across levels of the system can be seen in MAFF's efforts to end the propagation of BSE. These efforts were performed in isolation from the other levels of the system. Determining the success of their efforts was subject to a very long time lag because there were no established feedback mechanisms from the lower levels of the system. It was not until at least an incubation period of time passed (five years) that the inadequacy of, and lack of compliance with their regulatory efforts was realized.

5. *Work practices in a complex socio-technical system are not static. They will migrate over time under the influence of a cost gradient driven by financial pressures in an aggressive competitive environment and under the influence of an effort gradient driven by the psychological pressure to follow the path of least resistance.* Both economic and efficiency pressures influenced the decisions and actions of actors in the food production system. An example of financial pressure is MAFF's decision to develop a test to detect the presence of ruminant protein 'in house' rather than outsourcing its development. Developing it 'in house' meant that MAFF could retain intellectual property and potentially benefit financially from its wide use. Development was expected to take 12-18 months, but in actuality took more than five years. Outsourcing its development, while being more costly and without potential for future financial gain, was estimated to take only three to four months. The consequences of not having a test for the presence of ruminant protein in compound feed have been discussed earlier.

   Efficiency pressures had the largest impact on Meat Inspectors. Staffing levels were such that Meat Inspectors had little time for enforcement of regulations. Inspectors who tried to achieve 100% compliance with spinal cord removal were under tremendous pressure. "The speed of operations, and the speed of the slaughter itself put pressure on inspectors without the ability to do the task properly" (Phillips et al., 2000, Vol. 6, pp. 317-318).

6. *The migration of work practices can occur at multiple levels of a complex socio-technical system, not just one level alone.* The migration of work practices occurred at three levels – Regulatory Bodies, Local Government, and Technical and Operational Management level. Migration at the Regulatory Bodies and Local Government levels was discussed in prediction 5. At the Technical and Operational Management level financial pressures contributed to the poor compliance with the (initially voluntary) animal SBO ban. The temptation for slaughterhouses to pass off SBO as non-SBO material was considerable because slaughterhouses had to pay for the removal of SBO and were only being paid by the renderers for non-SBO material; the difference in income being £200/tonne. Renderers were also tempted not to look too closely at the material because, should they have to treat it as SBO, they would have to pay the disposal cost. Disposal of SBO ranged from £40-200 a tonne.

7. *Migration of work practices causes the system's defenses to degrade and erode gradually over time, not all at once. Accidents are released by a combination of this systematically-induced migration in work practices and a triggering event, not by an unusual action or an entirely new, one-time threat to safety.* Some of the forces that set the stage for the BSE epidemic had been actively shaping the system long before the arrival of BSE. There was a history of poor general hygiene standards in licensed slaughterhouses as a result of sloppy work practices and poor enforcement with respect to the movement of unfit offal. Flouting the regulations had not resulted in adverse outcomes in the past, and the new regulations were not presented as an important measure for protecting human health.

DISCUSSION

The objective of this study was to investigate the ability of Rasmussen's risk management framework to explain how and why accidents occur in the food safety domain through the use of BSE and vCJD in the UK as a case study. This was accomplished by testing whether the BSE and vCJD-related events that occurred in the UK from 1986 to 1996 supported each of the seven predictions of the framework. Indeed, evidence for each of the seven predictions was identified.

There is one contributing factor in the BSE epidemic that the framework did not anticipate, namely MAFF's restraint from taking further precautionary measures even when a cheap, simple, and risk reducing measure was available (Van Zwanenberg & Millstone, 2001). MAFF avoided taking further precautionary measures because they were liable to undermine previous decisions and the government's reassuring message to the public about the safety of beef. This action represents the government's response to public opinion (or the fear of inviting negative public opinion). While public opinion is acknowledged by the framework as an environmental stressor having the potential to influence decisions and actions, the predictions of the framework do not anticipate this unsafe behaviour exhibited by MAFF. If the tendency to avoid taking precautionary measures that may undermine previous decisions is shown to be a frequent contributor in other case studies using this framework, an addition to the framework, perhaps in the form of an additional gradient, may be warranted.

ACKNOWLEDGEMENTS

This research was sponsored by a research grant from the National Sciences and Engineering Research Council of Canada. We would also like to thank Prof. Erik Millstone and Dr. Ron Rogers for their review of the analysis of this research.

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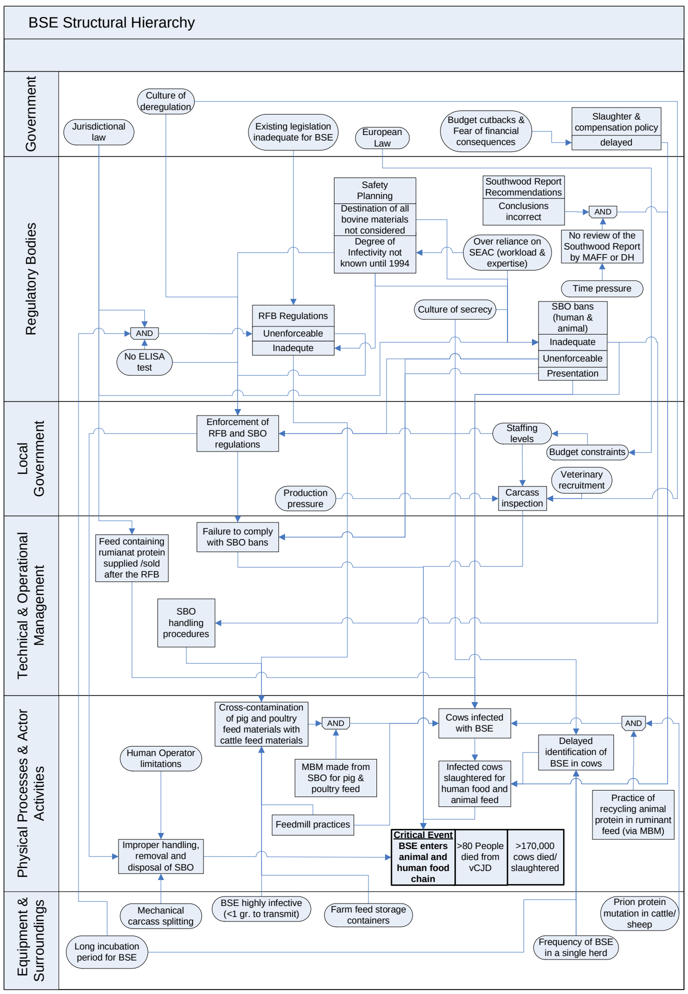

Figure 3: AcciMap of contributing factors

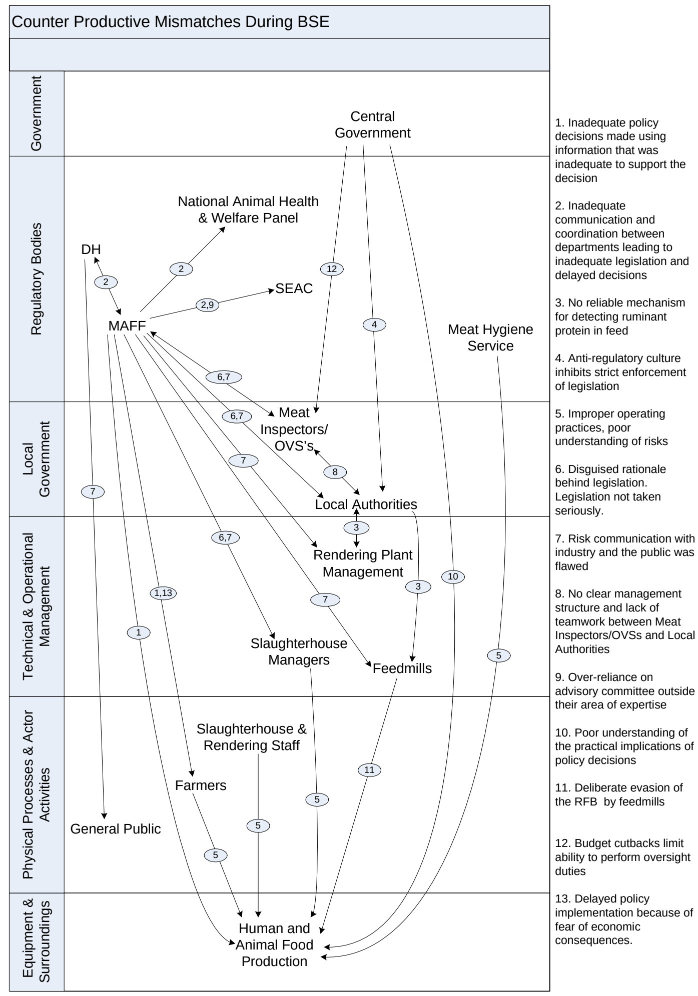

Figure 4: Conflict Map of counter productive mismatches

Legend for Figures 3 and 4

DH = Department of Health
MBM = meat and bone meal (animal protein)
OVS = official veterinary surgeon
RFB = Ruminant Feed Ban
SEAC = Spongiform Encephalopathy Advisory Committee
SBO = Specified Bovine Offal