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# SYSTEMS ANALYSIS FOR INFECTION CONTROL IN ACUTE HOSPITALS

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This paper makes the case for applying a systems perspective to the analysis of hospital-based infection outbreaks. Most of the research that has been conducted on behavioural aspects of infection control has focused on explanations at an individual level of analysis (e.g., interventions to improve hand washing). The infections outbreaks at the Maidstone and Tunbridge Wells NHS Trust are analysed in detail using an established framework for risk management. The paper further outlines the human and organisational issues raised by the analysis and provides a means through which these aspects of infection can be highlighted as part of a future research agenda within systems ergonomics.

## Introduction

Within the last few years the subject of hospital infection control has become the subject of much media attention (e.g., BBC Panorama, 2008). A number of high profile hospital outbreaks within the UK involving bacterium such as *Clostridium difficile* (*C. diff.*) and MRSA (Methicillin-resistant *Staphylococcus aureus*) and the number of mortalities resulting from these outbreaks, has made infection control into a central priority for the UK NHS and other health care systems worldwide (Allegranzi et al., 2007). Much of the debate so far has concentrated on improving hygiene within hospitals (e.g., hand washing), very little research has been conducted on the wider behavioural, social and organisational factors that may also determine infection control outbreaks (Griffiths, Renz and Rafferty, 2008).

The intention of the present study is to consider the potential of adopting a systems ergonomic perspective towards hospital-based infections. More specifically, the paper describes the advantages to be gained from applying existing systems analysis techniques to infection outbreaks and using these to draw out both lessons learnt as well as strategies for improvement. In order to demonstrate the value of such an approach the paper focuses on a specific case study namely, the Maidstone and Tunbridge Wells NHS Trust outbreaks which occurred between 2005-2007 (Healthcare Commission, 2007).

### Systems analysis and systems ergonomics

Hospitals represent a good example of a complex large-scale sociotechnical system involving a large diversity of professions spanning a range of roles and specialisms as well as technologies

that range from the latest eHealth applications (e.g., electronic records) to more established aspects such as physical design components (e.g., wards and buildings). Within systems ergonomics, Rasmussen (1997) has provided a modelling framework for understanding the dynamic interaction between levels within large-scale sociotechnical systems. Vicente and Christoffersen (2006) have used the modelling framework to identify the lessons learnt from the May 2000 outbreak of *E. coli* which occurred in Walkerton, Canada. Their analysis used a graphical representation of the contributing factors that led up to the Walkerton outbreak. These ranged from decisions made at governmental levels (e.g., privatisation initiatives), the action of actors within the system (e.g., failures to take water samples), as well as equipment failures (e.g., shallow water wells). In the next section the main events leading up to the outbreaks at Maidstone and Tunbridge Wells are outlined. These are used to suggest ways in which the outbreak could be analysed in more detail, and modelled using the Rasmussen and Vicente frameworks.

**The *Clostridium difficile* outbreaks in the Maidstone and Tunbridge Wells NHS Trust**

*Background to the outbreaks and timeline*
During the period between April 2004 and September 2006 an estimated 90 people died at the Maidstone and Tunbridge Wells NHS Trust as a result of becoming infected with the *Clostridium difficile* (*C. diff.*) bacteria (Healthcare Commission, 2007, p.5). *C. diff.* is the major cause of serious bacterial infectious diarrhoea acquired in hospitals in the UK and is particularly resistant to drying, chemical disinfectants and alcohol. The main events at the Maidstone and Tunbridge Wells NHS Trust are summarised in table 1.

**Table 1: Summary timeline of infection outbreaks**

| Time Period | Event |
| --- | --- |
| April 2000 | Trust established following merger between two other local NHS Trusts |
| 2001/2-2005 | High turnover of senior managers and period of organizational stability |
| October 2005 - September 2006 | More than 500 patients developed the infection, 60 patients estimated to have died due to *C. difficile* infection. |
| Before 2005 | Trust has a high level of infection with *C. difficile* but no one in the trust or local health authority was aware of this |
| Autumn 2005 | Number of patients infected doubles. Approximately 150 patients affected, a number of whom died as a result of the infection. (first outbreak) |
| April – Sept. 2006 | 258 patients in total affected |
| Beginning 2006 | Number of newly infected patients declines. |
| April 2006 | Trust recognizes it has a major outbreak and reports this to strategic health authority and health protection unit. (second outbreak) |
| April 2007 | Healthcare Commission finds unacceptable examples of the use of contaminated equipment |
| October 2007 | Healthcare Commission Report published. |

*Contributory factors leading up to the outbreaks*

The Healthcare Commission (2007, HC, 2007) report identified a number of factors that contributed to the outbreaks that occurred with the Trust. These can be summarised in terms of five main themes: the role played by external organisations; management of the trust; clinical management on the hospital wards; the role played by the infection control team; and, equipment and hygiene factors.

*The role of external organisations*
Within the report both the setting of government-led targets and financial pressures on NHS Trusts are mentioned as background, contributory factors that had an impact on the day-to-day operation of the Maidstone and Tunbridge Wells Trust. In particular, the report mentions the need for Trust board members and managers to meet targets for the use of beds. Higher bed occupancy meant that there was less time for the cleaning and a higher probability of transmission of infection between patients (HC, 2007, pp.69-70). The need to meet financial targets such as spending on equipment and buildings also placed pressure on the Trust to cut back in areas that impacted upon infection control such as financing for new buildings and isolation areas.

Infection control within the UK NHS is regulated by a number of bodies including the Health Protection Agency (HPA). The remit of the HPA is to provide advice and support to NHS, local authorities and other agencies with regard to public health issues. The creation of the HPA in April 2005 coincided with the first outbreak at the Trust. One part of the HPA, the health protection unit (HPU), was set up in order to support organisations in their management of infections. The report highlights that this caused some confusion within the Trust at the time of the outbreaks, as the expectation was that the HPU could give provide guidance covering the supervision and monitoring of infection control. The HPU did not have close involvement with the Trust and generally worked in a reactive way, responding to concerns as they arose (HC, 2007, p. 8). Similar problems were encountered within the much larger Strategic Health Authority (SHA) who are responsible for implementing government policy and fiscal control within regions of the UK.

*Management of the Trust*
The report describes a catalogue of problems and failures associated with the management of the trust at the time of the outbreaks. In terms of clinical risks and incidents, management strategy in general "had been fragmentary and poorly understood" (HC, 2007, p. 77). The reports from an internal group set up within the Trust in order to analyse complaints, claims and incidents highlight, amongst others, the following issues: the unsatisfactory nature of some "escalation" areas (areas temporarily set up to deal with infected patients); the impact that the accident and emergency (A&E) target had on the quality of care; poor quality handover and transfer to wards from A&E; concerns about staffing levels, and, bank staff managing wards on some shifts.
The style of leadership within the Trust and the overall management culture are criticised in the report. Many staff described the leadership of the chief executive as being "autocratic" or "dictatorial" (HC, 2007 p. 91). The report concluded that the person appointed as director of infection prevention and control had "no real understanding of the role at the outset" (HC, 2007, p. 5). Turnover of managers and directors was also high.

Finally, the trust's management of staffing is criticised heavily within the report in several places. The number of nurses working on wards had fallen since the period 2002/03. and at the same time the number of beds had also reduced. In 2006/07 the number of nurse per bed was

1.52, the same number as in 2003/04 (HC, 2007, p. 82). Trust managers had not carried out a comprehensive review of staffing levels or a determination of minimum staffing levels.

*Clinical management on the hospital wards*

A review of the case notes of 50 patients who had died having had *C. diff.* found that in 80% of the cases, at least one element of the clinical management, or monitoring of *C. diff* at ward level was unsatisfactory (HC, 2007, p. 4). A number of elements were mentioned, including: infrequent reviews of patients by doctors; lack of systematic monitoring as to whether or not a patient was recovering from *C. diff.*; and, failure to change antibiotic treatment when a patient failed to respond to the initial treatment (HC, 2007, p. 4). Delays in starting treatment occurred on the wards, mostly because there was a delay in sending samples for analysis (HC, 1007, p. 33). There was also little evidence that once *C. diff.* had been diagnosed, that patients were monitored for severe signs of the infection (HC, 2007, p. 34). In other cases, it was clear that diagnoses were either not considered or had been missed. In 34% of the cases reviewed, medical records did not indicate that a regular review of *C. diff* had taken place (HC, 2007, p. 38). The management of fluids and nutrition on the wards was also inconsistent. In 36% of the cases there was evidence of poor fluid management and in 34% nutritional needs had not been assessed or managed (HC, 2007, p. 38).

*The infection control team*

The role played by the infection control team within the trust was a complex one and one made difficult by problems relating to accountability, the amount of resources available to them and their ability to function as a team. The arrangements for accountability were not clear (HC, 2007, p. 54) and it was not clear who was responsible for the team. Infection control nurses were accountable to the director of nursing, however, the pathology manager held the budget for these nurses, but did not consider that he had any management responsibly for infection control. Not until September 2006 did the trust take steps to clarify the management of the team (HC, 2007, p. 51).

*Equipment and hygiene*

Hygiene practices within the trust and the state of hospital buildings contributed a great deal to the outbreaks. Wards, bathrooms and commodes were not clean and patients had in some cases to share equipment (e.g., Zimmer frames) which were not cleaned before use (HC, 2007, p. 4). The infection control team were keen to isolate patients once they had been identified as *C. diff.* cases, however the scarcity of side rooms made this difficult. As a result many patients before and after the outbreaks were kept on open wards. The design of buildings and their age meant that many wards did not have sufficient space for storage or the provision of hand basins in utility rooms. The buildings in the trust were generally old or in a poor state of repair and when they were first opened di not have adequate cleaning and laundry services (HC, 2007, p. 6).

**Analysing the outbreaks: A systems perspective**

The outbreaks which occurred within the Maidstone and Tunbridge Wells Trust represent the combined impact of a complex set of factors extending over several years. In common with most examples of accidents, disasters or large-scale adverse events, the outbreaks are best interpreted as arising through the combination of a number of interrelated systemic factors and influences (Turner, 1978; Reason, 1995). Figure 1 attempts to use some of the elements of Rasmussen's (1997) risk management framework in order to further analyse the outbreaks. In order to illustrate the framework as it applies to the outbreaks, a small sample of the contributory factors are used to link together some of the system components. In the following
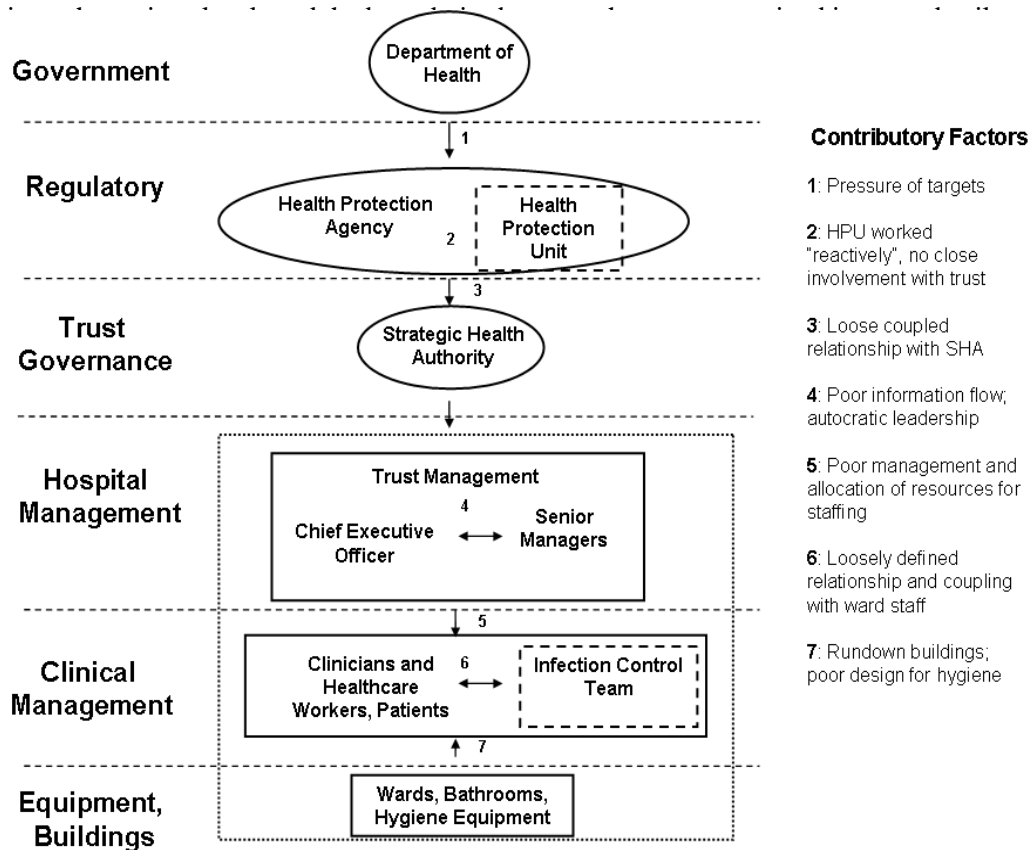
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**Figure 1: Mapping of infection outbreak influencing factors with system levels and boundaries**

*Government, regulatory bodies and trust governance*

At the very highest level of the system it is difficult to isolate the role played by government-set targets as a contributory factor leading to the outbreaks. Targets placed many individuals, particularly those at trust board and management levels under a great deal of pressure. This pressure in itself may have led them to make poor decisions, and in some cases to prioritise bed occupancy rates at the expense of the risk of an infection outbreak. Previous research on the influence that targets have on management decision-making in health care tends to be equivocal. Bean and Hood (2006) for example, show that the impact of satisfying a specific target (e.g., hospital waiting times) has not been analysed in terms of how this influences other related services (e.g., quality of care). Others have suggested that health care targets represent: "tin openers rather than dials … they do not give answers but prompt further investigation and inquiry, and by themselves provide an incomplete and inaccurate answer" (Carter, Klein and Day, 1995). Within the trust it is likely that targets exerted considerable pressure on the system as a whole and this pressure filtered down various levels of the system. It is possible that the drive to comply with these targets increased the likelihood of an adverse event or set of events taking place at some stage within the trust.

Poor communication, confusion of responsibilities and accountabilities between and within the various regulatory bodies delayed the time in which they could react to the outbreaks. A separate report by the Healthcare Commission (2008) examined the underlying causes of serious failures in NHS health care providers and identified large-scale organisational processes such as mergers and poor change management procedures as common factors. Within the wider literature on disasters (e.g., Perrow, 1999) the nature of organisational linkages and structures are also widely acknowledged to be significant explanatory factors.

*Hospital management*
Within the hospital the actions of senior managers were identified as significantly contributing to the failure to prevent and deal with the outbreaks. The link between management, human resource management (HRM) practices and work performance outcomes has been investigated in detail in the last few years. Wood and Wall (2002) for example, reviewed the evidence that suggests there is a link between high-involvement HRM practices and employee productivity. High involvement HRM practices typically include empowering employees to make their own decisions and the presence of self-managed teams. The review showed that there these types of practices in organisations do tend to increase levels of employee productivity. Similar effects have been shown between HRM practices and measurements of safety outcomes (e.g., number of adverse events). In general, there is strong evidence to suggest that aspects of management behaviour partially shape and determine the culture of safety within organisations (e.g., Zohar, 2000). Within health care specifically, West et al. (2002) carried out a large-scale survey of the relationship between HRM practices and general in-hospital mortality. The survey showed some aspect of high involvement HRM were associated with lower mortality rates after adjustment for patient and hospital characteristics.

Aside from the way in which senior managers behaved at the trust, the questions still remains as to why they ignored, or at least failed to realise the seriousness of the outbreaks and their consequences. Many of the managers interviewed in the original Healthcare Commission report reported that they were aware of how serious the situation had become within the trust, but were powerless to do anything about it. One possible explanation is what Vaughan (1996) in her study of the Challenger shuttle disaster termed the "normalization of deviance", namely that managers over time began to accept and take for granted the level of infection risk within the Trust. Only after the level of risk built up to a point where it could not be controlled, did they begin to realise the gravity of the situation.

*Clinical management and equipment and buildings*
Understaffing and general lack of resources together played a part in the outbreaks. Staffing ratios and levels of staff morale almost certainly contributed to the problem of containing the spread of infection on the wards. In general, the research literature provides some evidence that lower levels of staffing increase the likelihood of infections occurring. Hugonnet et al. (2004) (cited in Griffiths et al., 2008) examined the numbers of nursing staff and staff downsizing relative to infection levels. The researchers found an inverse relationship between staff downsizing and the rate of hospital-based infection. Curiously, little research has been conducted on the impact of job satisfaction/morale on hospital infection levels, however, work in other domains (e.g., manufacturing and service industries) suggests that lower levels of satisfaction are clearly linked to lower levels of job performance (e.g., Parker, 2007).

It might be conjectured that the behaviour of clinicians and other health care professionals within the trust shares similarities with those of senior managers and trust board managers.

Many individuals at ward level were aware of the levels of poor hygiene and inadequate patient monitoring practices, but saw no way to improve the situation. Weick and Sutcliffe (2003) analysed data from the Bristol Royal Infirmary Report (2001) and concluded that hospital staff became locked into particular lines of action or behaviour where they "search for confirmation that they are doing what they should be doing" (p. 73). These so-called "cultures of entrapment" inhibit an organisation's ability to break out of patterns of behaviour that over time can lead to adverse outcomes. In the case of the trust they may provide some means with which to explain shared boundary spanning behaviours between levels within the hospital subsystem (figure 1).

**Ways forward and conclusions**

The analysis presented in the paper has shown that there are advantages in analysing hospital-based infection outbreaks from a system's perspective. Many of the issues that have been discussed have not been researched within the patient safety literature in much depth, particularly organisational phenomena (Waterson, 2008). It is still the case that most research within the area of infection control has concentrated on individual levels of analysis (e.g., behavioural interventions in the form of hand washing campaigns). The paper has only touched upon some of the behavioural issues involved with a system as complex as hospital-based healthcare. Future research should examine causal links between system levels in a more systematic manner and address the issue of influences at the meso-level of analysis, that is linkages and relationships between individual (macro-) and organisational (macro-) system levels (Karsh and Brown, in press). Further empirical studies which focus on behavioural aspects of infection control which go beyond individual levels of analysis are needed. In addition, there appears some scope for modelling the relationships between system components and comparing these models against hospital-based data (e.g., Brailsford and Schmidt, 2003).

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