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Decision support or support for situated choice: lessons for system design from effective manual systems

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Abstract

In a number of organisational settings where work is highly skilled but substantially routine, certain entrenched manual systems have resisted digitisation. These systems include card-based systems in emergency despatch, the paper flight progress strips system used in air traffic control, the Kanban system and whiteboard systems used in hospital wards. Research to understand or replace these systems has frequently regarded them as decision support systems (DSS). We report here a detailed case study of a manual whiteboard-based bed allocation system in the ICU of a large general hospital, which shows that the support it provides for users' action choices cannot be validly conceived as decision support. This system and other effective manual systems may be better understood as a 'situated choice support system' (SCSS). Whereas DSS provide actors with a model of the action environment in order to support reasoning about the consequences of alternative actions, SCSS provide actors with structured work environments that reduce possible actions and cue-providing information resources to support a reactive choice between these limited alternatives. The findings warn of the danger of uncritically applying the DSS design paradigm to supporting action choice in skilled routine work, and provide an alternative design theory, which can potentially inform new ICT-based designs.

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Introduction

In a number of organisational settings where work is highly skilled but substantially routine and time-constrained, certain entrenched artefact-based manual systems have resisted digitisation. These systems, which we term here effective manual systems (EMS), include card-based systems in emergency despatch (Wong & Blandford, 2004, p. 293), the paper-based flight progress strips system still widely used in air traffic control (Koskela, 2007), the Kanban (card) system used in automotive assembly plants (Rabanni *et al.*, 2009) and whiteboard-based allocation systems in hospital wards (Wears *et al.*, 2006), to name just a few. Even in cases where these systems have been partially computerised, the greater effectiveness of some aspects of the previous manual systems is frequently acknowledged (Mackay *et al.*, 1998; Fitzgerald & Russo, 2005, p. 1; Mackay, 2007). Evidently, these systems provide a kind of support that is appropriate to the activity undertaken in these work situations.

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Researchers who have sought to understand these systems or to design ICT-based replacements for them have frequently regarded them as decision support systems (DSS) (Kaempf *et al.*, 1996; Wong, 2000; England, 2001). These systems clearly provide support for the process of selecting actions among alternatives such as which ambulance to dispatch, which materials to replenish, what airspace to allocate and so forth. Less clear is that the process of action selection supported can be adequately characterised as 'decision making'. What we normally mean by this term is making a reasoned choice among alternatives to 'evaluat(e), which of various actions would yield the most positive consequences' (Loewenstein & Lerner, 2003, p. 619).

It does not follow, however, that because an action choice is made in the course of work that a decision is necessarily involved. March (1994, p. 2) distinguishes two possible 'logics' of action choice; the 'logic of consequences' and the 'logic of appropriateness'. The former is what we normally associate with making a decision. The latter refers to the way skilled actors familiar with situations occurring in their work environment can apprehend the appropriate action response to a given situation without recourse to explicit reasoning about the consequences of their actions. A similar distinction between decisions and situated action choices is found in cognitive science (Hutchins, 1995a; Hendriks-Jansen, 1996; Clancey, 1997). In psychology (Bargh & Ferguson, 2000, p. 931), these alternatives are called controlled and automatic behaviour, and recent research in experimental neuroscience (Lieberman, 2007b) demonstrates that distinct brain systems are involved in these two modes, making it clear that they are not simply degrees of a common phenomenon. Furthermore, the literature on routine action in general (Becker, 2004; Pentland & Feldman, 2008), as well as studies of specific manual systems listed above (Mackay, 1999; Wong, 2000; Wears *et al.*, 2006), give preliminary support for the interpretation that in the routine work activities where these manual systems are most effective action selection is made in this mode of 'situated choice'. Thus, the notion that these manual systems are DSS to be replaced by computer-based DSS may not be valid.

The aim of this paper is to challenge the notion that all systems that support choices by humans in the course of work should be conceived of as DSS. First, we review literature on existing EMS, the nature of human choice and routine work activity to determine the nature and characteristics of the kind of human actions choices that occur during routine work. Second, we present a detailed case study of a manual whiteboard-based hospital bed allocation system in an intensive care unit (ICU). Using a grounded theory approach, we determine the ways in which the system consisting of the whiteboard, markings and tokens used on the whiteboard and the structuring of the ward environment in which the whiteboard is embedded assist the skilled routine work of the caregivers on the ward. We find that the conditions that the ICU ward system creates are precisely those that according to our literature analysis would logically support the situated, reactive type of action choice that is known to be characteristic of routine work. We then make a tentative generalisation, based on commonalities among the whole class of EMS, that two fundamental principles underpin the effectiveness of all these manual work support systems.

These principles constitute an alternate design theory for systems supporting action choice in routine work, which we call situated choice support systems (SCSS), in contrast to DSS. Although this design theory has been induced from extant examples of EMS, there is no reason why this theory could not also be applied to systems employing digital computing devices. It is not within the scope of this paper to present precise guideline for designing digital SCSS. However, we do contrast the broad principles of this novel design theory with the approach taken by DSS in the hope that this exposition might influence future software designers.

The paper contributes to information science by pointing out the implications of different theories of the nature of human action choice for the kind of systems that would effectively support action selection. It points to a class of manual systems that have resisted replacement by systems designed using the decision support paradigm and may be better conceived of as a separate class of SCSS. The work has potential importance for practice as well since attempts to computerise EMS have often attempted to overcome their scale limitations or to improve the ease with which they interface with computerised management and planning systems. Given the situated nature of routine activity, mobile and ubiquitous technologies (Waller & Johnston, 2009) may have a role in future enhancements. However, if these new technologies are deployed under an erroneous understanding of the problem at hand costly failures may result.

Effective manual systems and the nature of action choice in routine work

Effective manual systems

There are many artefact-based EMS described in the literature such as the Kanban-based stock control system used in manufacturing (Grief, 1989; Schmidt & Simone, 1996; Zhang *et al.*, 2005; Rabanni *et al.*, 2009), the paper-based manual flight progress strip system used in air traffic control (ATC) (Mackay *et al.*, 1998; Benhacene *et al.*, 2007; Koskela, 2007; Mackay, 2007; Belobaba *et al.*, 2009), card-based systems used in emergency ambulance control (Wong, 2000; Wong & Blandford, 2004) and whiteboard-based scheduling systems used in hospitals (Xiao *et al.*, 2001; Wears *et al.*, 2006). This section establishes the common and essential characteristics of this class of system beginning with two that have been widely adopted: Kanban and the flight progress strip system.

The Kanban system is a card-based materials replenishments system used in the automotive assembly industry worldwide (Rabanni *et al.*, 2009). A 'kanban' is a card on which minimal information is printed about a part to be replenished, typically the product ID, the supplier and the work station where the part is used (Figure 1a). Each kanban card is associated with a fixed number (usually a container) of parts. When a container is used by production, the kanban card so freed is posted on a 'kanban-board' (Figure 1b) visible to those responsible for replenishing parts. These free kanban cards are taken to the supplier work station and authorise parts production in the quantity associated with the free kanbans. The replenishment parts and their associated kanban cards are delivered to production and the process repeats. Kanbans on the kanban board thus serve as a visual cue that triggers a parts replenishment routine. However, it has long been recognised (Womack, Jones & Roos, 1990) that a Kanban system cannot operate effectively unless embedded in a highly structured work environment consisting of among other things, smoothed assembly schedules, small-lot production, minimal parts inventories held near the assembly work station and work area layouts which make both the parts and kanban-board directly visible for replenishment. Such a structured environment is essential to the operation of the Kanban system and can even be considered an extension of the system (Sugimori *et al.*, 1977).

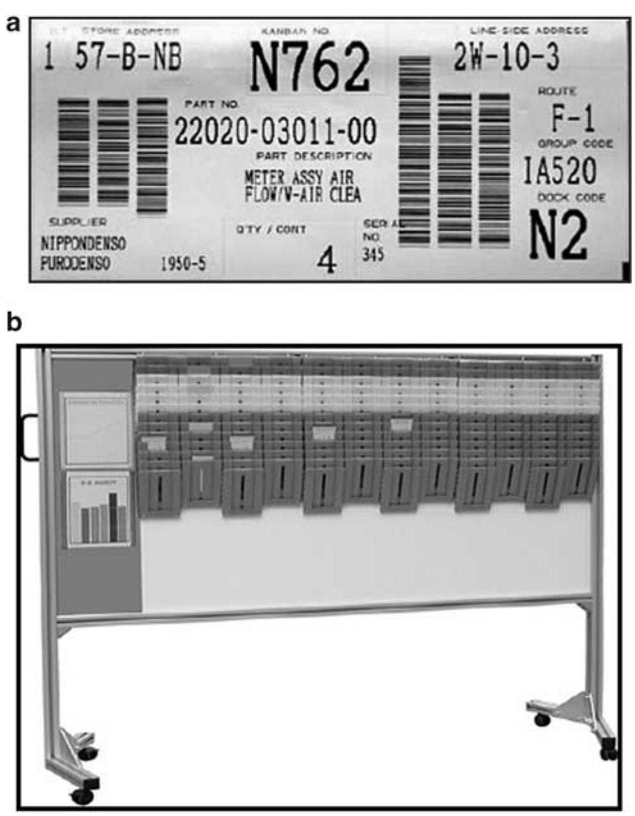

Figure 1 (a) Typical Kanban Card. www.resourcesystemsconsulting.com. (b) Kanban Board. www.leanproducts.eu/eng/kanban_lav_kanban.php.

Kanban operation can be compared to the operation of the manual flight progress strips systems used in air traffic control (ATC) such as at at Orly, Roissy and Athis-Mons terminals in Paris (Benhacene *et al.*, 2005, 2007; Mackay, 2007), in Bordeaux, in France (Conversy *et al.*, 2010) and in many US, Canadian and Australian airports (Koskela, 2007; Belobaba *et al.*, 2009; U.S. Department of Transportation, 2010). In this system, computer generated paper flight strips (Figure 2a) contain some basic printed flight data (airline, flight number, aircraft type) and areas on which to record basic flight progress information by hand – such as changes in altitude, routing and speed – as the flight plan evolves. Flight strips are attached to uniform plastic battens and are arranged in patterns on a purpose designed controller area (Fields *et al.*, 1998; Conversy *et al.*, 2010). Use of the manual flight landing system commences with a controller removing a paper flight strip from the printer and attaching it to a batten. The flight strips are arranged on a work area in front of the controller (see Figure 2b). As flights progress, the controller examines the printed information on the strip and annotates the strip, for example, underlining the approved flight level communicated to the pilot and indicating ascent or descent with an upward or downward arrow. Using this information, the controller rapidly rearranges the strips on the work area in front of him/her to indicate the order in which flights will be landed.

Controllers group the flight strips by the names of beacons along the route to produce a 'schematic model of the airspace' (Fields *et al.*, 1998, p. 3) and in order to avoid a conflict (Conversy *et al.*, 2010). This 'shared artefact' (Fields *et al.*, 1998, p. 3) can be seen by a number of controllers who deftly refer back and forth to the flight strips under their's and their neighbours control, as new strips are added and removed from the flight strip holder in order of flight position.

The system operates in an environment that is structured to assist action. The placement of the strips on the work area provides the controllers with information regarding sequencing of flight landings additional to the written markings on the strips. Strips are removed from the group, or slid left or right, to indicate conflict or to 'set reminders' (Mackay, 1999) so that controllers can return to a particular flight control activity when required. Strips are reordered, grouped, moved into columns and rearranged on the controller's work area to denote different traffic conditions. A controller can see at a glance, for example, that a work area space is full and a sector busy, and can also see and monitor the work areas of adjacent controllers without interrupting them. Controllers work side-by-side during the handover to

Figure 2 (a) Paper Flight Strips. discmd.com/atom/atom_functions/flight_strip_printing.htm. (b) Flight Strips in the Work Area. Essendon Airport, Victoria, Australia.

another sector to ensure that a flight cannot get lost. They use the physical environment to 'push information at each other, or pull information in' (Mackay *et al.*, 1998, p. 3), which they can use in directing flights to land. Controllers can handle the physical strips and simultaneously interact closely with their fellow controllers 'but (the system) breaks down completely for controllers at a distance' (Mackay *et al.*, 1998, p. 3) when the cues and constraints in the immediate environment are removed. Again, an appropriately structured environment is essential to the operation of the manual system.

The nature and operation of the Kanban and flight progress strip systems share common features. First, information support is provided in these systems by physical artefacts, the kanbans and flight strips. The use of physical artefacts is a characteristic of other manual systems also such as paper cards for ambulance despatch (Wong & Blandford, 2004) and whiteboards with physical markers for hospital ward systems (Wears *et al.*, 2006). Second, these systems rely on visual triggers and structures in the environment in which the systems are embedded for cues about possible courses of action (Grief, 1989; Schmidt & Simone, 1996; Zhang *et al.*, 2005; Wears *et al.*, 2006; Mackay, 2007) and to limit the number of action options. For example, in the same way the effectiveness of the Kanban system is dependent on the physical layout of the production environment, the effectiveness of the paper flight strip system also depends crucially on the workplace layout. The arrangement of the physical environment in these systems functions as an extension of the system by providing necessary constraints and enablers of action.

Thus, these systems and the others previously listed, have a common nature despite the work contexts being superficially different:

1. The systems use physical artefacts such as paper air traffic control strips, kanbans, ambulance allocation cards or hospital whiteboards. These physical artefacts function as informational resources whose informativeness exceeds that of any conventional information (such as written notations) which they bare.
2. The operation of these systems depends on rules for the placement of these artefacts in relation to each other and features of the work environment, which must be learned by the users.
3. The support for action choice provided by the systems depends in essential ways on a structured physical environment to the extent that the structured environment should be viewed as an extension of the system.

The above qualities will constitute our definition of the class of systems which we refer to as 'EMS'.

Attempts to computerise EMS

Many of these systems are still used as freestanding manual systems, as described in the previous section (Koskela, 2007; Haghirian, 2009; Rother, 2010) often used alongside related computer systems, for instance, computerised radar systems, flight planning systems, radio and telephony in the case of flight strips. However, there have also been attempts to computerise or partially computerise many of these systems. It is important to the examination of how these EMS work to understand the forms of computerisation adopted, the role physical parts of these systems play in these computerised versions and whether these adoptions successfully support routine work. As in the previous section, we will mainly illustrate these issues using Kanban and flight progress strips, given the significant literature available on these examples.

Two main approaches to computerising EMS are found in the literature. In the first approach, the manual artefacts of the EMS are interfaced with surrounding computerised systems so that data can be acquired from the movements of the manual artefacts or so that aspects of the manual system can be manipulated by the computerised system. In the second approach, the artefacts of the EMS are replaced with digitised representations as part of a fully computerised system.

To illustrate the passive version of the interfacing approach, kanbans are now frequently enhanced with auto-ID technologies, either barcodes or RFID (Drickhamer, 2005). Tracking kanbans using auto-ID allows data to be acquired by computerised accounting and planning systems. These systems may be part of ERP systems (Wan *et al.*, 2009) which commonly provide modules for receiving data about manual kanbans (these modules should not, however, be viewed as computerised Kanban systems). Using these technologies, kanbans can be electro-mechanically sorted into ‘pidgeon holes’ that are the equivalent of the kanban board (Rabanni *et al.*, 2009; Ramkhamhaeng *et al.*, 2009) and data can be sent electronically to supplier’s computer systems for planning purposes, or to eliminate the transfer of physical kanbans, while still maintaining the traditional manual system on the factory floor (Drickhamer, 2005; IndustryWeek, 2005). Alternatively, a digital image of the Kanban can be sent and reprinted at the supplier site.

In ATC, attempts to interface paper flight strips to computerised tracking systems retain the strips but add additional ways for inputting data into the system such as using barcodes to acquire information from the strips for computerised systems. Inputting with touch-sensitive screens and projecting flight strip information with a video projector have also been explored (Mackay *et al.*, 1998; Mackay, 2007) to find ways to cope with ‘mounting levels of traffic’(Mackay *et al.*, 1998, p. 1) already evident and problematic over a decade ago.

To illustrate the more active type of interfacing, the use of Auto ID technologies for the electro-mechanical sorting of kanbans allows the number of kanbans in circulation to be manipulated by an interfacing computerised planning system, which can add or remove kanbans from circulation during sorting. These ‘intelligent’ Kanban systems do not change the fundamental physical card-based nature of the Kanban system (Zhang *et al.*, 2008) but use RFID and software agents to dynamically change the operating characteristics of the manual system to adapt to changes in product demand, which is difficult to achieve in the standalone manual version. Similarly, in the ATC case, an AMAN (arrival management) system (Benhacene *et al.*, 2007; Belobaba *et al.*, 2009) can calculate an acceptable aircraft sequence in a given order and spacing as the aircraft approach the sector. Once in the sector, flights strips can be created by the AMAN and there is a changeover to the use of the manual strips systems.

The second more extreme case of computerising EMS involves adoptions, or proposed adoptions, where the physical artefacts have been replaced by digitised representation within a fully computerised system. Examples are attempts to digitise the paper flight strips such as Vigiestrips and Vertidigi (Benhacene, 2002; Benhacene *et al.*, 2005, 2007). In these systems representations of paper strips are arranged on a computer screen and can be manipulated by touch and ‘shifted in a way similar to what controllers do with actual paper strips’ (Benhacene, 2002, p. 4). Some electronic representations of Kanban have been proposed commercially (Real-Time-Kanban, 2010), but we do not know of any implementations or any research documenting successful long-term adoption. Reprinting of a digital representation of a kanban after transmission over long distance has been proposed (Ramkhamhaeng *et al.*, 2009), although this only captures one element of the manual system.

Resistance of EMS to computerisation

The somewhat limited extent to which some of these types of computerisation have been accepted underlines the persistence of the manual systems and the keenness of users to retain what is currently effective. For example, in many enterprises where manual Kanban systems have been effective management has been loath to replace such systems completely and have retained many of the manual aspects (Haghirian, 2009). The greatest level of adoption has occurred where essential parts of manual systems are retained and are interfaced with computerised systems. Those attempts that preserve or improve the support provided by the manual systems for routine activity are the ones that have been successful.

In the ATC arena, Digistrips and Vertidigi have been found to be difficult to interpret (Benhacene *et al.*, 2007) and have not been fully embraced. Research suggest that average times to input data with Vertidigi are higher than with the paper strips and the number of clearances achieved is lower (Benhacene *et al.*, 2005). Similarly, controllers were unenthusiastic about augmenting paper strips in ways that introduced software displays or interaction techniques that required multiple steps and added complexity (Mackay *et al.*, 1998, p. 7). Thus far, adoption of all of these computerised flight-strip projects has been slow (Merlin *et al.*, 2009).

What all these digital projects underscore is the documented benefits of the paper strips: being able to manipulate and place the strips, user appropriation of the flight through ownership of the strip, the reminders that come from handling and writing on the strips and the ability for strip use to be adapted to individual working conditions and practices (Mackay, 1999; Koskela, 2007). One project, for example, addressed three perceived design problems: how to capture information from the strips using a graphics tablet with pen input and a touch sensitive screen; how to present the information on the paper strips by projecting it on to a screen; and how to track information using a stripboard that detects resistance in the strip holders (Mackay *et al*., 1998). MacKay noted in attempting augmentation of the paper strips that the paper strips play an important communication role 'beyond their information content' (Mackay *et al*., 1998, p. 8) stressing the 'rich interplay' (Mackay *et al*., 1998, p. 7) of the total work environment.

In the kanban case, as noted earlier, successful long term use of fully digital kanban systems have not been reported in the literature. The desirable affordances of the physical kanban (visibility and physical association with the part) are highly valued in manufacturing environments (Grief, 1989; Ramkhamhaeng *et al*., 2009). In addition to Kanban and ATC flight progress strip systems, other manual systems such as manual hospital ward scheduling systems (Wears *et al*., 2006), either standalone or partially interfaced with computerised systems, have been retained for similar reasons of endurance, flexibility and effectiveness in facilitating routine work. While many hospitals now use electronic whiteboard systems such as Orion's Concerto Clinical for patient management, these are promoted as increasing patient privacy, adding audit trials and password controls (Parry & Parry, 2008) rather than for increasing system effectiveness in routine use. Thus, in many hospitals manual systems still persist with researchers claiming that 'large electronic display boards …. will not necessarily replicate the functions that the (manual) whiteboard has grown to accommodate' (Xiao *et al*., 2007, p. 390). Similarly, in ambulance dispatch (Wong & Blandford, 2004) manual systems that support routine processes have survived into the present.

These EMS are clearly still widespread and resistant to replacement, either when used stand-alone or when operating as specific routine-oriented subsystems within larger scale computerisation. Thus, EMS still constitute an important class of work support system used in practice and there is much to be gained from a deeper understanding of how these physical artefact-based systems operate.

How effective manual systems operate

The literature provides a number of explanations for how these manual systems support work in the environments in which they occur. They are said to rely on learning and prior knowledge of actors, cues or triggers which direct actors to particular actions choices, and the properties of the physical artefacts that support action.

Annebicque *et al*. (2008, p. 46) claim that actors use their prior knowledge of the work task to choose appropriate action. 'Knowledge of the solution' and having a 'fairly accurate idea of how they will resolve a conflict' before commencing work tasks (Annebicque *et al*., 2008, p. 46) is claimed to be intrinsic to a 'decision making process' and allows flight controllers to limit solution choices. Because of this prior knowledge, air traffic controllers can deftly manage multiple tools such as a radar view, paper flight strips and a telephone (Koskela, 2007; Annebicque *et al*., 2008).

Users of these systems also apply previously formulated rules to select an action by matching cues to the most appropriate action, then 'evaluating' and modifying the action (Endsley, 1995; Wong, 2000). In manual ambulance allocation, ambulance operators formulate an action response by assessing the situation or environment through recognising critical cues to status changes such as whether or not the ambulance is on the way or has arrived (Wong & Blandford, 2004). These cues, which trigger learnt, rule-like routine responses, are provided by such things as where or how an allocation ticket is placed on an allocator's desk (e.g. forward facing while the vehicle is on the call).

It has been suggested consistently across a number of contexts (ATC systems, ambulance control systems and whiteboard based hospital systems) that manual artefacts are flexible and shareable in supporting collective decision making (Hughes *et al*., 1992; Schmidt & Simone, 1996; Wong, 2000). This is particularly true of paper artefacts that simultaneously facilitate the sharing of information and the organising of the related work (Sellen & Harper, 2001; Gladwell, 2002; Petterson *et al*., 2002). The artefacts provide visual triggers (Grief, 1989; Gaver, 1991; Hutchins, 1995a; Mackay *et al*., 1998; Bonvik, 1999) and *aide memoire* (Mackay *et al*., 1998) and provide situation awareness (Hutchins, 1995a; Wong & Blandford, 2004). They work because they are integrated with procedures that are known and understood by users (Schmidt & Simone, 1996).

Despite these varied observations about support provided by the systems, a striking common theme is evident in these discussions; they all explicitly or implicitly assume that the choices made using the systems can be explained as 'decision making'. This previous research focuses on evaluating the decision-making approaches taken by users of these systems and on decision support provided by artefacts (Hughes *et al*., 1992; Schmidt & Simone, 1996; Wong & Blandford, 2004). The systems are frequently referred to in the literature as decision making supports and the work carried out with them as decision-making work (Bodker & Christiansen, 2002) using cognitive processes in which actions are thought through using mental models (Cohen *et al*., 2006). The assumption appears to exist that the existence of a choice between actions must be evidence of a decision. None of these authors specifically explains why they are using decision-based approaches; they just assume that the routine activity that occurs in these systems involves decision making. Referring back to our earlier definition of decision making as 'evaluat(ing) which of various actions would yield the most positive consequences' (Loewenstein & Lerner, 2003, p. 619) we see that many of the actual descriptions above of use of manual systems do not fit the definition of decision making. For example, Wong and his co-authors describe actors reacting to environmental cues and Annebicque describes actions that involve learnt and practiced responses even though these authors call these types of actions decision making. Actors using these systems seem to be making choices, yet neither of these descriptions fits well with the idea that in making these choices actors are *evaluating consequences*. Rather they are described as responding reactively, which appears to be at odds with the evaluative emphasis in the definition.

Thus, while the literature contains quite detailed descriptions of the activities performed within these systems, the common assumption of the literature (particularly the DSS literature) that choices involved in routine work must be decisions may not provide a satisfactory explanation for how these systems work. Consequently, how these systems support the particular characteristics of routine work is still unclear.

The nature of choice: are all action choices decisions?

It is a common belief that all action choices involve decisions. However, a diverse literature which spans all the levels on which human behaviour is studied scientifically, from group behaviour down to physiological brain function, recognises that people can behave in choice situations in two different ways. The first is what we would recognise as decision making according to the definition given above. The second involves reactive choice that does not involve decision making.

In the context of management theory, March proposes an actor may approach an action choice in two ways, either using a 'logic of consequences' or using a 'logic of appropriateness' (March & Olsen, 1989; March, 1994, p. 2). Using a logic of consequences, choices are made by evaluating alternatives based on the preferred future consequences of each alternative. Using a logic of appropriateness, actors respond to situations, familiar rules and knowledge of work roles and identities pre-established in organisations. Appropriateness involves 'learning to act in a particular way …. linked to … an understanding of the social and physical environment' (March, 1994, p. 62).

Studies of organisational behaviour suggest an alternative but similar dichotomy that contrasts 'more mindful' and 'less mindful' activity. In more mindful processes, authors claim there is more thoughtful and self-focussed 'attention' directed to the activity (Costello, 1996) and 'effortful accomplishment' (Pentland & Rueter, 1994, p. 488). Some activity can, however, involve little mental processing (Levinthal & Rerup, 2006, p. 505) and in this sense is less mindful. When actors choose from competing practical repertoires of habitual activity, activity can be less mindful in the sense that actors use 'relatively modest … deliberative calculation' (Levinthal & Rerup, 2006, p. 505). During less mindful activity actors 'do not draw on substantial cognitive resources from the realm of consciousness' (Becker, 2004, p. 648) but rather 'choose from an existing repertoire of established routines' (Levinthal & Rerup, 2006) thus limiting activity choice and reducing the need to direct attention to evaluating choice options.

Within cognitive science, a distinction is often made between 'planning' and 'situated action' (Suchman, 1987). Early research in artificial intelligence (Newell & Simon, 1972) and robotics (Raphael, 1976) viewed the brain as essentially a computer that manipulates mental symbols representing things in the world. Thus, cognition is symbol processing and action is the execution of plans created by reasoning about symbolically represented future states. In the past few decades, however, this view has been challenged by an alternative account often referred to as situated action (Suchman, 1987). On this view, agents can act with apparent purpose by selecting actions in reaction to situations they encounter without the need to represent these situations symbolically and consequently without the possibility to select actions by symbolic reasoning. Studies of software agents (Agre, 1997) and real robots (Brooks, 1991) based on this situated action selection principle provide a precise 'proof of principle' that reactive situated action is a viable mechanism for routine kinds of human action which do not involve explicit reasoning about consequences (Agre, 1997), especially in appropriately structured environments (Agre & Horswill, 1997).

Within behavioural psychology, the dual process theory draws a related distinction between 'controlled' and 'automatic' behaviour, where controlled processes require symbolic reasoning and conscious attention (Bargh & Ferguson, 2000), and automatic processes do not require conscious processing or high levels of awareness. Automatic processing is regarded as 'sub-symbolic' and involves pattern matching to the directly perceived environment or situation (Chaiken & Trope, 1999). Other authors in psychology also suggest that automatic processing leads to more rapid action in contrast to the controlled approach where evaluation, effort and attention are required and take up time. It is accepted in the psychology literature that the conscious reasoning that occurs in controlled processing can in fact get in the way of rapid action and that using cues in the environment for rapid action can produce a quicker response. When performing automatic activities, such as driving a car, actions occur within a fraction of a second after the presentation of relevant environmental stimuli and more quickly than it would take for an 'individual to hav(e) the intention to evaluate or the awareness that he is doing so' (Bargh & Ferguson, 2000, p. 931).

Researchers in neurophysiology have recently used functional magnetic resonance imaging (FMRI) to find the underlying mechanism for these psychological behaviour descriptions in brain functions (Lieberman *et al.*, 2002). It is notable that work of this kind has already been seen as having the potential to inform IS research (Dimoka *et al.*, 2007). Authors in neurophysiology associate the brain processes underlying controlled and automatic behaviours with distinct neurological systems, a 'reflexive' system (or X-system) and a 'reflective' system (or C-system), which are activated in distinct non-overlapping regions of the brain. The X-system is activated under conditions that promote efficient and speedy responses and is more primitive, whereas the reflective system (or C-system) 'is a symbolic processing system that produces reflective awareness' (Lieberman *et al.*, 2002, p. 13). While the X-system is impulsive, the C-system processes information 'serially', or one at a time, which 'limits its speed and the number of problems that can be handled simultaneously' (Lieberman, 2007a, p. 297). The X-system is thus associated with increased speed (Lieberman *et al.*, 2002) caused by parallel operation of X-system processes and reactive activity such as 'fight or flight' responses that evolved from fear conditioning (Lieberman, 2007b, p. 293) rather than a considered evaluation of options.

Thus, two distinct modes of action are recognised in this wide range of disciplines. While each discipline labels the behaviours with different names, the essential characteristics of each pair of behaviours are similar. The first category is behaviour based on the logic of consequences, mindful behaviour, controlled behaviour and reflective behaviour. These all involve using symbolic reasoning and thoughtful and effortful consideration of a plan of activity to evaluate alternative courses of behaviour before acting. This description of behaviour fits well with accepted definitions of decision making. The second is behaviour that is rapid, habitual, efficient and based on the logic of appropriateness, less mindful behaviour, automatic behaviour, reflexive behaviour and situated action. All entail reacting to situations or environmental cues rather than evaluating consequences. Thus, it is evident that there is a clearly supported alternative form of behaviour that would seem to be appropriate in some work environments where activities need to be performed quickly and efficiently and where aspects of the environmental structure make it possible to limit the range of activity choices and reduce the need to weigh up alternatives. This behaviour can give rise to the type of action choices that do not accord with pre-established characteristics of decision making.

The nature of routine activity

The evidence presented so far suggests that EMS are most successful in environments where actors learn to perform the same repertoire of work tasks repeatedly and in a routine manner, and that EMS support these types of routine tasks. In this section, we present the literature on routine work to see what conclusions we can reach about what kind of action choice predominates in this kind of work.

The literature about how routine work is performed is largely divided into two camps, the first of which considers that routine activity is carried out without devoting significant attention or effort (Ashforth & Fried, 1988; Cohen, 1991; Becker, 2004) and the second considers routine action mindful and requiring cognitive input (Costello, 1996; Betsch *et al.*, 2002).

The first approach emphasises the automaticity of a routinised action (Ashforth & Fried, 1988) in response to environmental triggers or cues (March & Olsen, 1989; Gersick & Hackman, 1990), tacit rules (March, 1994), or organisational structure (Becker, 2004, p. 648). When there is a strong association between a situation and an action option through frequent occurrence and an established pattern of behaviour (Koestler, 1967; Winter, 1985), actors are more likely to invoke a routine (Betsch *et al.*, 1998) 'without devoting attention … or draw(ing) on substantial cognitive resources' (Becker, 2004, p. 248). These authors emphasise the mindless quality of routine activity (Ashforth & Fried, 1988) suggesting that frequency of recurrence (Cohen, 1991), habit and learnt local knowledge (Weiss & Ilgen, 1985; Ashforth & Fried, 1988; Gersick & Hackman, 1990) provide an opportunity for routine behaviour that does not require conscious effort. This position is supported within cognitive science (Agre & Chapman, 1987; Agre, 1997) studies of work (Suchman, 1987) and anthropology of work (Lave & Wenger, 1991; Hutchins, 1995a, b).

Authors in the second camp claim that routine activities may still involve decision making (Betsch *et al.*, 2002) and 'effortful accomplishments' (Pentland & Rueter, 1994). However, Becker (2004), reviewing the studies that fall into the second camp, claims that they tend to involve changeable or variable organisational processes. In these situations, there will sometimes be call for effortful consideration even when many of the episodes in an extended activity can largely ensue automatically. Winter refers to these situations as involving a combination of 'mechanistic decision making' and 'genuine, deliberate choice' (Winter, 1985, p. 109).

In evaluating these opposing positions, we should not lose sight of the richness of work in the environments we are considering. This work may involve a number of interleaved action sequences, where some are mentally effortful and others are not. For example, in a work environment using the Kanban system, a kanban may go missing and a novel response thought out or there may be reasons to decide not to replenish an item despite a kanban indicating replenishment. Similarly, in the ATC environment '… control is mostly routine: controllers engage in a constantly repeated cycle of systematically looking at each plane on the radar and the corresponding paper flight strip …… During emergencies, this routine enables controllers to handle all the simultaneous jobs that do not go away' (Mackay *et al.*, 1998, p. 4). Thus, while emergencies and irregular situations may call for some greater cognitive input and evaluation of alternative courses of action, these episodes of controlled or planned behaviour interleave with the more usual reactive behaviours.

In each of the literatures cited in the previous section, it is recognised that humans switch between the two modes of behaviour according to demands. For instance, Lieberman (Lieberman *et al.*, 2002, p. 293) states that the C and X systems are not fully independent and discrete and the two systems can be used alternatively. For routine activity the X system is used and in novel or exceptional situations that require evaluation the C system is used, although these uses may span one multi-part activity. Thus, we recognise that interspersed in routine activity there may be non-routine episodes that could be described as decisions and for which DSS could be appropriate. However, our claim is that EMS support the routine sequences of action that characterise what we would normally term 'routine work' in these environments. Thus, while in the work environments we are studying work may include some episodes that require decision making or mental effort, the literature on the nature of routine work indicates that humans acting routinely make action choices that are automatic, reactive and less mindful.

Summary

This review of the literature has identified a class of EMS that have resisted digital replacement. Their common operating characteristic is that they employ physical artefacts as information resources embedded in structured physical environments that provide complementary support. Not simply a legacy of a bygone pre-computer age, many of these systems are still used and promoted today and even where they have been computerised the physical parts of these systems are often retained because of their recognised efficacy in repetitive, skilled routine work environments.

Most research studying their operation has viewed them as DSS, reflecting a widely held belief that any choice between action alternatives necessarily involves a decision. However, a wide literature reviewed establishes that in addition to choosing by explicitly deciding between future consequences of action, humans can also make effective action choices as a direct reaction to situations without symbolically representing or reasoning about the options. Furthermore, recent research in experimental neuroscience demonstrates that distinct brain systems are involved in these two modes of action choice making it clear that they are not simply degrees of a common phenomenon.

The literature provides evidence that this second situated reactive kind of choice is a common feature of the routine human activity that is supported by EMS. That is, these systems and this type of action choice commonly co-occur. Together with the observation that EMS have evolved and persisted in just those work environments where much of the work is routine, we conclude that the characteristics of the EMS artefacts and environment of the EMS are particularly appropriate to support this kind of action choice. Consequently, analysing these systems using decision theoretical models or attempting to replace them with fully digitised systems designed to support decision making is likely to be unsuccessful because such approaches ignore the different nature of situated reactive action choice. Instead, we need to enquire more deeply into just how these EMS support the kind of situated choices that characterise routine work activity. We do this next by describing our grounded empirical study of the workings of one such system.

Methodology

This section describes the empirical case study of one EMS, a whiteboard-based bed allocation system used to support routine work in the intensive care unit (ICU) of a large public hospital in Melbourne, Australia. The system monitors the movement of ICU patients and supports ancillary activities such as visits to discharging patients from physiotherapists, chaplains and private visitors.

Case selection and data collection

A number of other case study sites were examined but only one is discussed in this paper. The site was sourced through word of mouth and selected based on the common characteristics of EMS derived from the literature review. Within the case study site, routine activities were selected based on the characteristics of routines discussed earlier, that is, activities that were learnt and performed repeatedly and executed rapidly and reactively without apparent analysis or evaluation of the consequences of action.

The case study was conducted over 3 months with approximately 100 h spent in the nurses' station of the ICU ward at different times of the day and week observing staff using the whiteboard, handling, managing and rearranging the artefacts on the board, conducting conferences around the board and moving between the nurses' station and the beds. Observations were carried out in a non-obtrusive way by sitting near the whiteboard and 'eavesdropping'.

Data was collected by sketching the whiteboard, memoing, notetaking and interviews. Sketching was used to record snapshots as the arrangement of the board changed over time. Only one photograph (Figure 3) was permitted. Theoretical memoing (Glaser, 1978, pp. 83–4) and operational memos or notes were compiled to revise previously collected data and to provide a reminder and focus as the work progressed. Interviews provided the bulk of the data. Interviews continued until theoretical saturation occurred (Strauss & Corbin, 1998) with 53 face-to-face interviews with system participants of 10–15 min duration conducted by the whiteboard. All participation was voluntary and interviewees were selected with a representative proportion from all job categories of whiteboard users: nurses, medical registrars, surgeons, chaplains, physiotherapists and ward clerks, with nurses making up the bulk of staff in the ward (see Table 1). At least one staff member in each job category was re-interviewed after the first two coding cycles to verify findings.

E-mails from the head nurse and department head were sent to all potential interviewees and a letter detailing

Figure 3 Whiteboard in the ICU ward. (Patient names have been changed for anonymity).

Table 1 Distribution of interviewees in each job category

Job category	*Interviewees*	*Interviewed once*	*Interviewed twice*	*Interviewed > twice*
Head of ICU	1		1	
Chief nurse manager	1			1
Nurse managers	5	3	2	
Registered nurses	20	19	1	
Registrars	8	7	1	
Surgeons	6	6		
Physiotherapists	5	4	1	
Ward clerks	4	3	1	
Chaplains	3	2	1	

head of department support was displayed next to the whiteboard during the project. The researcher requested interviews face-to-face at the board for times arranged during the work day. Interview questions were not fixed but all staff members were asked to consider how they used the board to assist them in their activities in a general way and in reference to specific examples, such as selecting a patient to treat or to discharge, depending on their role.

Data analysis

The objective of the data analysis was to determine how support for routine action is provided by EMS. Analysis was guided by accepted theory building methods for discovering emergent themes (Glaser & Strauss, 1967; Neuman, 1997; Strauss & Corbin, 1998) and was a variant of grounded theory method and Eisenhardt's roadmap for generating theory from case studies (Eisenhardt, 1989).

Open, axial and selective coding were undertaken as suggested in all coding approaches (Glaser & Strauss, 1967; Neuman, 1997; Strauss & Corbin, 1998) and the data was marked up with Nvivo. The ultimate goal was to refine the coding down to a small number of propositions about how routine action is supported.

Because a large number of interviews were conducted, the research also used vignettes (Miles & Huberman, 1994) as a supplementary analysis tool. These were verified by the nurse manager in the ICU as a realistic representation of typical activity performances and were valuable in giving a broader view of the data.

Validity and reliability

Internal validity was achieved by following the three stages of coding detailed above and further triangulating the data analysis with operational notes, memos and vignettes. Case study selection criteria were defined drawing on the literature review above. Miles and Huberman's tests for reliability were used so that the case study setting was adequately described using 'thick' descriptions that could be replicated (Miles & Huberman, 1994, p. 279) to permit possible comparisons. Clear definitions of the main constructs are given in the paper allowing others to replicate the study.

This research aims for analytical generalisability (Yin, 2003) not statistical generalisability. In addition, theoretical conclusions were induced from the data that do not depend heavily on the system or setting particulars. Consequently, the research has some analytical generalisability to other settings (Seddon & Scheppers, 2006) where EMS similarly rely on physical artefacts in structured environments as information resources.

Case description: the ICU bed management system

The ICU under examination has 24 beds: 20 intensive care beds and four high dependency beds. The goal of the ICU system is to manage the status of bed usage and in and out movement of beds in the short term. The following describes the organisational components including people and physical artefacts in the system, and the procedures used to manage patient beds.

Organisational components

Staff: the staff includes a head nurse, other ICU nurses, medical resident doctors, medical specialists, physiotherapists, chaplains, ward clerks, cleaning staff and technical staff who set up beds and equipment.

Work Area: the work area is about 400 square metres edged by 24 intensive care beds. In the centre is a nurses' station that has two ward clerks sitting at one end closest to the door of the ward so they can see patients and visitors coming in and out and a whiteboard running along the left hand side of the station whence it is possible to stand and view the ward (Figure 4).

Bed Cubicles: the 24 bed cubicles are arranged around the outer perimeter of the ward. Each cubicle contains a bed and a surround of about 6 square metres for medical equipment, a sink and a visitor's chair. All cubicles can be viewed, by facing or turning around, from a standing position next to the whiteboard in the nurses' station (Figure 4).

Whiteboard: the board is located in a central position in the nurses' station in full view of the beds that it depicts. It has a large rectangle in the middle representing the nurses' station with 24 blank rectangles drawn around it corresponding to the actual physical position of each bed relative to the nurses' station, space in the centre of the board for additional nursing information, and space around the sides for additional patient information.

There are a number of items on the board: writing produced by erasable and non-erasable coloured board markers, magnetised name labels and coloured magnets. Aside from the information on the magnetised name labels (described below), there is some written information placed around the labels by staff over the course of the day describing relevant situations such as surgery taking place at a particular time or the possibility of a bed being available in another ward for a patient to be discharged into.

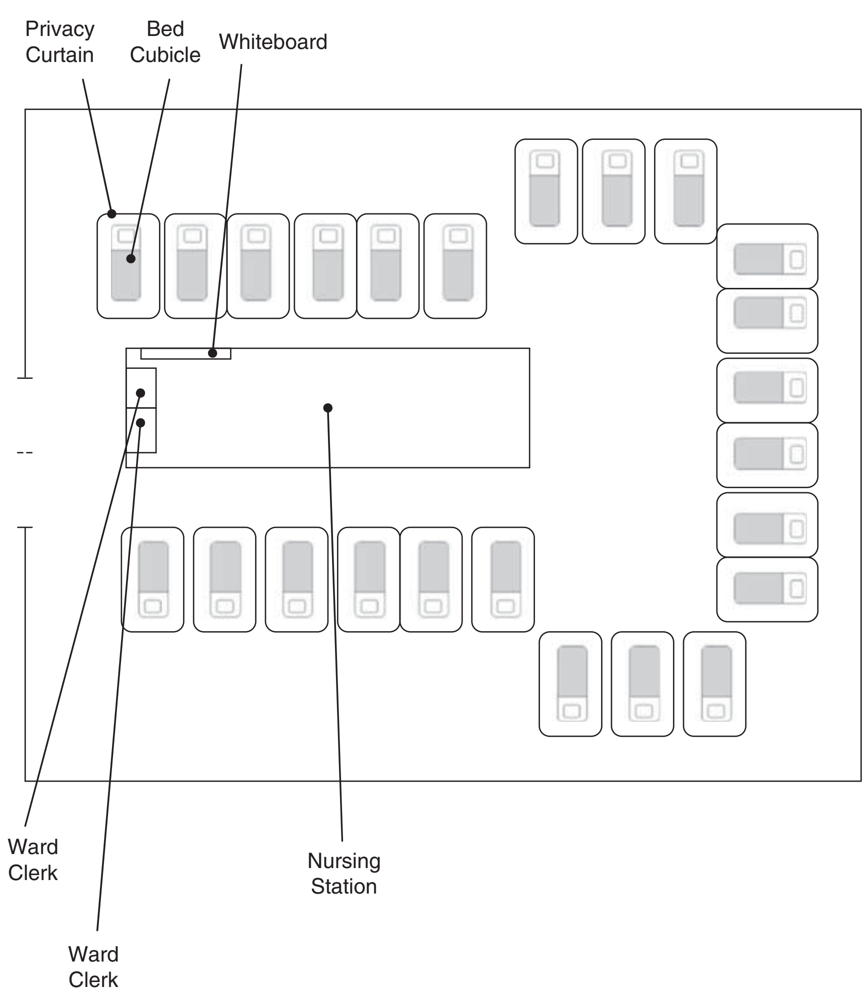

Figure 4 Plan view of the work area in the ward.

Name Labels: adhesive magnetic name labels have patient names written on them using coloured markers. A name written in blue marker indicates a cardiac patient, one in black marker can be any other non-cardiac patient.

Coloured magnets: coloured magnets can be placed on particular bed positions on the whiteboard on top of or next to the name labels. An orange magnet means possible discharge, a green magnet means definite discharge, a red magnet means incoming patient, a blue means that the patient requires isolation and yellow means the patient is palliating. Patients with red magnets may not have yet been allocated a bed but may be placed as 'pending' set to the left side of the board.

Procedures

At the start of her 7.30am shift, the head nurse stands in front of the board and reviews any overnight movement. There is a chronic bed shortage and a patient can only be moved out of ICU if a bed is available in another ward. Consequently, the daily procedure for the managing nurse involves constantly fielding questions about bed availability that need to be dealt with quickly over the telephone through just a glance at the board.

The medical staff and ward clerks interact with each other around the board continually exchanging valuable patient information throughout the day. This information can be actively elicited, just overheard and absorbed as a result of physical proximity, or gauged directly from the board. The work practices and specific tacit rules of the workplace trigger certain routine responses in staff that have learnt these rules, many of which have evolved gradually through input from previous and current staff. For example, a cardiac surgeon knows that patients with names on the board written in blue are cardiac patients. Thus, when s/he views the board s/he need pay no attention to half of it. Similarly, chaplains are keen to tend to palliating patients and might only look for yellow magnets. These physical features allow the selection of patients to be routinised once the significance of particular colours, for example, is learnt by the staff member. Other 'local' knowledge is also important to bed management. For example, staff have learnt that a '2pm heart' patient listed on the right of the board for possible admission will not arrive before 5pm.

When discussing placement choices, the staff are often seen picking up and putting down the name labels that can be transferred from one position on the board and fitted easily into another position. The tangible quality of physical labels, as well as actually handling them, seems to be important in assessing patient movements.

Referring to Figure 3, there are many things that staff can observe at a glance. For example, nurse 'Kirst' (allocated beds 1–7) needs only to attend to the first seven beds on the right (her patient list) when she comes up to look at the board; an AM heart patient listed on the right (Johnston) has now been crossed off so no longer needs to be considered for admission; three anticipated patients on the left are not yet in beds (one of these is put askew – not firmed up) and while there is some uncertainty as a result of the number of orange stickers there are also two empty beds so the situation is not as difficult to manage as on some other days. A doctor standing in front of the board can perceive all this while also observing the busyness of the ward itself, listening to the ward clerks converse on the phone to operating theatres about expected admissions and viewing the ward entrance where patients are being wheeled in. Thus, a full body of information relating to admission and discharge is immediately available from a combination of the board and its setting and can be acted on rapidly without reading or recourse to patient records.

Case analysis

Our analysis followed three steps:

1. Initially, we read and reread the interview transcripts and observation notes and, through open coding, produced a list of recurring themes. Through this initial coding we identified a number of routine activities (selecting a patient to admit to a bed, selecting a patient for discharge and selecting a patient to attend) before we coded the data to identify how the EMS provided support for these activities.
2. Second, we clustered our codes into related groups to produce a condensed code list of types of support that the EMS provides (see column 1, Appendix 1) for these routine activities.
3. Finally, we condensed and pruned the themes to selectively code the list into four main categories of support (column 3, Appendix 1). The first category was support that came from the system design. Many of the examples of this included artefactual design features such the colour or placement of an object. The second category is support provided by a tacit or learnt response that, for example, enables an actor to act quickly in responding to a physical cue. The third is support provided by a structured environment, such as the placement of the nurses' station in view of the beds, which may either enable or constrain a particular course of action. The fourth category is a sub-set of the third; support provided by the physical proximity of system components such as the position of the whiteboard in relation to the beds.

The coding lists were checked through the three coding cycles by two researchers and a third independent reader.

These initial results were then compared to theoretical concepts in the literature (Glaser, 1978) to produce an integrated theoretical position that we encapsulated into three propositions, and the evidence for them, described in the subsections that follow below. These three induced propositions about how the ICU system supports routine work in the ICU are thus generalisations, derived through the coding process, about how the system supports the users in making routine action choices.

Proposition one: a structured environment reduces action choices

The work area in the ICU is structured in ways that make the possible courses of action obvious to staff. In fact, a specifically structured environment is so essential to the functioning of this class of system it can even be thought of as part of the system. For example, in the ICU ward cardiac patients are on the left hand side of the ward and trauma patients on the right. Infectious patients are generally placed in beds 16, 17 and 18. On discharge, cardiac patients need to be seen by a cardio-thoracic physiotherapist. Because of the way the ward is structured, action choices relating to these patients are reduced to beds 19–24. One physiotherapist commented 'I never look at my list. I just head over to the far left'.

Positioning the nurses' station in the centre of the ward makes it possible for staff to instantly evaluate the fullness of the ward. The ability to scan the ward from a central position reduces many of the choices required. For example, if the ward seems full then a nurse manager would start trying to find empty beds immediately; if it seemed less full this task could be delayed. This was evidenced every morning at 9am when the nurse manager would call the operating theatres about the likely demand on ICU beds should particular surgeries proceed. Despite having a desk elsewhere, the nurse manager always made this call from the telephone next to the ward clerks where she could survey the ward while discussing possible bed options with operating theatre staff. One managing nurse reported that 'even though (I) have it all on paper, I just like to look at the beds while I talk. The way the ward was organised made it possible for her to do this. The ward clerks' work is also made simpler by the way their desks are positioned next to the board in the nurses' station. One ward clerk standing at her desk and looking at the ward commented: 'Going to be a bit of juggling going on today, I'd better get some discharge cards ready'.

Clerks prepare beds for admission and discharge. Because of the location of the clerk's desks, they can see and hear doctors and nurses gathered around the board collectively discussing patient movements. They know whether or not beds are likely to be free without needing to actually absorb the substance of those conversations. A desk clerk commented: 'From where I sit I can see what's going on. There are lots of people moving around today. I'd better keep an ear open when the nurses do the changeover'. A large gathering of staff busily rearranging the board makes it clear to the clerk that the bed management situation is difficult and that admission and discharge activity will ensue. Without having to be instructed or even having to look at the board the clerk knows immediately that her next activity will be to prepare for this.

Visitors are severely restricted in ICU: ward clerks control the only entry door to the ward. Because they can view all the beds from where they are sitting and can see the levels of activity around a particular bed, they can choose whether or not to admit visitors simply by looking at the relevant patient bed. They do not necessarily have to refer to written information relevant to a particular patient's condition or visitor allowance. One ward clerk commented 'if there is a lot of staff around the bed I don't let visitors in. I can see that straight away from where I'm sitting'. Thus, the visibility of the ward creates an environment where the clerk does not have to choose between possible courses of actions.

Proposition two: the manual system design makes remaining action choices obvious

In many situations interacting with the actual ward provides sufficient cues to resolve action choices as illustrated in the previous section. However, when this is not the case the manual whiteboard system, including the structured environment in which the whiteboard is placed, makes the remaining choices obvious, providing the additional information required for swift action.

Sometimes it is obvious by just looking out at the ward that a number of beds are free to receive new patients. However, if beds are obscured or all the beds appear to be full reference to the whiteboard can make action choices simple. A nurse glancing at the whiteboard can see easily if there are a number of green magnets and know instantly that discharges are imminent. Similarly, no magnets or just a few orange ones make it possible for the nurse manager to reject an admission request without further consideration.

The design of the ward and the way cardiac patients are placed in the ward (on the left side) usually but not always limits the beds where these patients will be placed. The associated patient name labels are all written in blue on the board and are also generally placed on the left hand side of the board. If a cardio-thoracic physiotherapist is unsure whether or not to visit a particular patient just from indicators in the ward, these colourings on the board make it simple to resolve this choice.

When the cardio-thoracic physiotherapist goes to the ward s/he needs to see patients who are being discharged. Her choice of corresponding patients on the board is limited to patients written in blue with green labels. Thus, in Figure 2, beds 20 and 23 are readily selected as the patients to be seen (blue writing, green label, on left side of board) and the patients easily located by staff using a combination of their knowledge of the whiteboard system and the ward.

In other work in the ward, such as that conducted by the ward clerks, the whiteboard design also makes action choices obvious. Ward clerks are in-charge of visitor admissions and need to make rapid, on-the-spot choices to admit or refuse visitors. This is not always simple as, for example, sometimes patients who have been injured at a crime scene may have a police escort and non-standard visiting rights. While a flurry of doctors around a bed is an obvious indicator that visitors may not be allowed, the absence of doctors is not a clear indicator that visitors are permitted. Consequently, a pink sticker alert is placed on the board for these patients with restricted visitor access. If the ward clerk needs to make an instant choice about how to respond to a visitor at the door and it is not clear from looking at the bed how to respond, they can glance at the board to have their action choice resolved.

The use of the whiteboard to resolve action choices depends also on a number of shared conventions that staff members have learnt. These include placing a patient label askew on the side of the board if their admission status is unclear and writing a trauma patient's name in black or placing the trauma patient label on the right of the board. These shared conventions constrain representational possibilities on the board, although they do not physically prevent an activity in the way that a physical structures such as a full beds do. If staff see that a patient label is written in blue they know it is a cardiac patient even if that is not clear from the position where the patient has been placed in the ward. For example, a cardio-thoracic physiotherapist was looking for cardiac surgery patients to visit. By looking at the ward she saw there was a trauma patient in a cardiac bed on the left hand side of the ward. To double check if she should avoid this patient she looked to the board and saw that the patient label was written in black. Her knowledge of this convention was used to supplement the information she gleaned from the environment.

The structured layout of the board also imposes constraints that are not already imposed by the layout of the ward, thus further reducing choice. For example, physical artefacts such as name labels fit clearly into single bed slots drawn on the board. While it is possible in theory to place two labels on the same slot, it would not really be possible to do so in an unambiguous way and see both labels, in the same way as it would be difficult to put two patients in the same bed in the ward.

Proposition three: the system reduces the need to evaluate consequences of choice

The features of the system discussed above reduce the need to evaluate which action to choose. Except for some rare occasions when routine activity was interrupted (e.g. when a staff member accidently walked off with a name label and records had to be checked with the desk clerk) staff were never observed standing for any extended time reading the board or looking at records before commencing tasks. They simply looked over at the ward and sometimes scanned the board as well before moving to the beds to commence some patient related activity. Staff commented that they only had to 'see the blue writing' or 'look at the ward' or 'hear the commotion' to know what to do next.

Staff do not refer to computers or reference written records; they simply respond to the environment that is presented and act. Staff members claim that having an unrestricted view of either an empty bed, a visitor at the door or a group of doctors gathered around a bed provides them with the ability to act automatically in carrying out their work tasks. They do not have to process action choices cognitively, because they can directly perceive the opportunities for action indicated by the whiteboard. In the words of one nurse, 'I just stand here and I know exactly what to do'.

Users of the system make choices rapidly and this can be taken as evidence, as borne out in the previously cited literature (Bargh & Ferguson, 2000), that they are not reasoning about the consequence of choices. This observation indicates that automatic processes are being used (Chaiken & Trope, 1999) utilising the X-system (Lieberman, 2007b) which, as detailed earlier, is associated with speedier responses and less reflective behaviour. Staff were observed to act rapidly after detecting a situation that required action. Staff constantly arrived at the nurses' station had a brief glance at the ward or board, or both, and then went straight to the appropriate patient bedside. While a physiotherapist, for example, could easily refer to patient records to find out who was ready for discharge, not a single one was observed doing this. They all simply detected the green magnets next to the patients on the right of the board and moved off immediately into the ward. One commented, 'I just look for the green magnets and head straight for those beds'.

Findings

Our grounded analysis of the ICU bed allocation system yielded three generalisations about how this system supports routine work in the ICU environment:

1. a structured environment reduces action choices;
2. the manual system design makes remaining action choices obvious;
3. the system reduces the need to evaluate consequences of choice.

In this section, we use these observations about the characteristics of this manual system, together with our understanding of the nature of action choice in routine work environments from the literature cited earlier, to uncover the principles by which this system, and by extension others like it, provide support for routine work.

Our earlier discussion of the literature established that in routine activity action choices employ a logic of appropriateness rather than a logic of consequences. This means that they are reactive responses to situations based on direct appreciation of patterns in the environment and informed by tacit knowledge of appropriate response. This implies the following requirements for effective action choice in routine work:

1. The situated action choices in routine work do not involve reasoning about the consequences of possible actions. Thus, they do not depend on the availability of a mental model of the possible choices.

2. Rather, situated action choices in routine work depend on the availability of distinguishing features of particular situations which can be directly perceived to prompt appropriate reactions.
3. Situated choices are only reliable when the possible situations encountered in the work environment are those for which the actor has practiced responses. This means in practice that the action possibilities from which to choose must be limited.

If we compare these requirements for situated action choice in routine work with the key features of the ICU manual system induced from the case study, we see that the conditions that the system provides are exactly those that an actor engaged in a situated choice would find supportive. These can be expressed as two principles of operation of the system:

Principle 1 *The environment of work is structured in such a way that action choices are limited to a small number or even one.*

Principle 2 *Cue-providing information artefacts are combined with this structured environment so that residual choices can be resolved to a single appropriate action without recourse to explicit reasoning about future action outcomes.*

In addition, the detailed examination of how the ICU system functions makes it clear that this system cannot easily be conceived of as a decision support system. Although the white board is in a sense a model or map of the bed layout in the ward, it appears that this model-like aspect of the whiteboard is not used by the ward staff as a means for reasoning about action choices as suggested by a logic of consequences, at least not in the normal performance of routine activities. Rather, the configurations of the artefacts in relation to markings on the whiteboard suggest certain possible action choices in the actual work environment because of learned associations between the two which are appreciated in a holistic manner without significant delay and thus without resort to reasoning about the relative merits of the choices. Thus, in the normal course of routine activity, the significance of the model-like organisation of the whiteboard is that it allows its users to grasp situations in the ward in an immediate pictorial way rather than as a basis for reasoning about them.

We can now make a cautious analytical generalisation from our case findings and claim that these two principles above explain how all EMS support routine work in the environments in which they are embedded. First, we demonstrated that all EMS share a set of characteristic features with our case study system. These include the dependence of these systems upon a highly structured work environment for their functioning, the use of physical informational tokens whose informativeness exceeds that of any conventional information which they bare, and a set of learned rules for their placement in relation to each other and features of the work environment. These common features of the class are closely related to the features of the ICU system which we induced by the grounded data analysis. Second, as established in our literature review, all these systems seem to be most effective and entrenched in work environments where skilled but routine work occurs under time constraints and the systems specifically support the routine work episodes in these environments. Third, research evidence from a range of behavioural science disciplines supports the conclusion that action choices in such routine episodes of work are made as situated choices rather than decisions. Thus, there is a similar correspondence between the characteristic features of these systems with the characteristic requirements of situated choice as we have outlined for the specific ICU case. It is likely, therefore, that the explanation for the functioning of all these EMS is the one that we have derived above from a detailed analysis of our specific case example. Like any analytical generalisation from a small case base, it is tentative and requires independent confirmation.

Discussion and implications

The two principles derived in the previous section represent a theory about how the situated choices that occur in routine activity can be supported effectively by an information system. The theory was derived from extant examples of EMS but there is no reason why this theory could not be applied to systems of any nature including those employing digital computing devices. Work support systems that are designed according to this theory could be termed as SCSS in contrast to DSS. All the EMS described in this paper would be examples of SCSS but it should also be possible to design new SCSS based on these principles of operation that make use of digital devices and provide digital data to more conventionally designed digital transaction processing systems such as ERP systems. We emphasise that the term SCSS is not meant to refer merely to computerised replacements for EMS; rather, it refers to the underlying *design principle* of EMS which may be possible to instantiate in new and effective ways using digital technologies in similar environments where support of situated choice is an issue.

Precise guideline for designing digital SCSS are beyond the scope of this paper. Our main aim in this paper is to challenge the notion that all systems that support choices by humans in the course of work should be conceived of as DSS. This challenge is based first on our argument, contrary to common belief, that not all choices that humans make between alternative actions involve decisions, and second, that there is an extant class of systems that effectively support situated choices that do not employ the logic or cognitive functions of decision making. We advise against the uncritical use of a certain orientation to the design of computer support systems in an important application domain, namely support of skilled routine operations, rather than providing an alternative design methodology. Despite this, we can offer some broad deductions about how SCSS would compare in principle and performance with DSS.

First, whereas DSS provide to users a *model* of the work environment through which to evaluate the consequences of action choices, SCSS function in part by engineering the *actual* work environment to simplify choice. Thus, SCSS and DSS bring work environments to users in distinctly different ways. Second, in DSS action choice is made by reasoning about the relative merits of future outcomes with DSS often providing computational software to support this reasoning process. By contrast, SCSS would assist the user in making a choice based on routinised, reactive responses to cues provided by the system that merely make the (limited) options more obvious. SCSS would in effect 'mark-up' the environment to make situations more obvious to human actors rather than enhancing the actors metal modelling or reasoning capabilities. Thus, SCSS and DSS orient users' actions to environments in distinctly different ways. Third, while SCSS would de-emphasise reasoning and modelling in the action choice process, the creation of environments that are suitably structured to allow effective reactive choice may require significant rational thought, possibly assisted by computational process modelling. Consequently, in such systems reasoning is 'compiled into' the environment and the practiced routines at design-time, rather than being the principle of action choice at run-time. Thus, SCSS and DSS deploy human and machine-based reasoning in distinctly different ways. Fourth, where DSS hold out the prospect of flexible, near-optimal action responses to novel work situations through digitally assisted problem solving, SCSS harness the speed and automaticity of human neural systems involved in situated choice to provide reliable and rapid real-time choice. Thus, DSS optimise flexible response whereas SCSS optimise efficiency of human (cognitive) effort. SCSS and DSS consequently occupy different points on the efficiency-flexibility trade-off in operations. In relation to this last point, it is noteworthy that EMS are found in ATC and health care where reliability and safety are arguably more important global measures of system performance than optimality.

As we have noted in our discussion of Kanban and flight progress strips the issues of scaling up these manual systems and interfacing them with planning and auditing systems have driven attempts to automate them with ICT-based technologies. While these embryonic attempts have not been fully effective they have been widespread and it will be worthwhile following these attempts at computerisation to see how they develop. Given the situated nature of routine activity, mobile and ubiquitous technologies may have a role in future enhancements. However, if these new technologies are deployed under an erroneous understanding of the problem at hand, costly failures may result. In future work the two principles of operation of SCSS we have articulated in this paper may lead to designs of new ICT-enabled solutions that authentically leverage the known effectiveness of the manual approaches, but without their limitations, and provide a much needed theoretical underpinning for deployment of these new technologies.

In this paper, we have only taken the analysis of the operation of EMS to the point of deriving a set of general principles for the design of effective SCSS more generally. Because the derivation is based on widely observed characteristics of EMS and firmly established knowledge about the requirements of action choice in routine work, we have reason to believe that it will be useful as a high-level 'design theory' that can be used to design novel SCSS *ab initio* using information technologies rather than manual artefacts. However, the project has not produced detailed design prescriptions, and has not yet empirically tested the efficacy of the design theory. These are valuable directions for future design science work that could further test the line of argument given here.

Conclusion

By analysing literature, it was shown that there is a class of manual systems that seem to be well suited to supporting skilled work that is largely routine and, given what is known about the nature of routines, that treating these systems as DSS may not be appropriate or productive. By analysing extensive empirical observations of one such system three general propositions were induced about how that particular system supported skilled routine activity in multiple activities within that work domain. Combining these two lines of argument, we discerned the outlines of a new approach to providing support for action selection in skilled routine work environments which we call 'Situated Choice Support Systems'. Whereas DSS support decision making by providing users with a model of the work environment and tools for reasoning with this model about the merits of possible outcomes, SCSS support reactive choice by engineering the work environment to simplify choices combined with tools providing cues that enable actors to resolve the remaining choice.

By pointing to and defining a new class of work-support systems whose effectiveness needs explaining, we show that while these systems support action choices the notion that these choices are decisions in the usual sense is not consistent with the nature of the work they support, and therefore, it is not appropriate to treat them as, or replace them with, DSS. This finding places new limits on the applicability of DSS as a design approach. Finally, we have induced two principles for an alternative approach, which these EMS exemplify, and which is also potentially applicable to ICT-based information system design.

To system design practitioners, we warn of the danger of uncritically applying the DSS design paradigm to supporting action choice in skilled routine work. When applying the DSS paradigm to IS design there is an expectation that users will need to reason about alternatives and thus a tendency to turn routine processes into reasoning tasks, slowing users down and rendering the systems less effective in supporting users. Thus, it is more likely that such designs will be rejected as has been seen in the slow uptake of many of the previous attempts to computerise EMS.

We have documented extensively that these manual systems cannot simply be dismissed as legacies of a pre-digital era; they have not only survived as action support systems in the integrated enterprise systems era, but they have been respected for their efficacy in supporting routine activities in some of the most complex operational environments we know. Where they have been computerised effectively, it is usually by embedding them as manual components within surrounding transaction processing systems, rather than by directly replacing them with digitised substitutes, and even when they are digitised the form and manipulation of their manual components is often preserved in interface metaphors. Consequently, it is of vital importance to understand the principles of their operation in a theoretical form that is transportable to future designs that might use computerised components.

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Appendix

Table A1 Examples of the data coding procedure

Support type code	*Examples from transcripts*	*Support category code*
A physical feature of the system reveals course of action	Chaplain: 'I look for the green magnets because people being moved to other wards need to be followed up' Nurse: 'It's obvious the label fits this way on the board'	System design Tacit/learnt response
Layout makes it possible to 'See at a glance' (possible action)	Desk clerk: 'You need to be able to just look at the bottom line (of the board) and see if there's anyone down that side' Nurse: 'I can see the beds from the board'	Structure of the environment Proximity of system components
Alert for action	Desk Clerk: 'And that there (pointing to a red heart with AM written beside it) in bed 13 is for someone who wants to get their machines set up for the first hearts coming back in the afternoon, they can't do much till they know who it is but they can set up the bed there'	System design Tacit/learnt response
An aspect of the system provides ease of use	Medical consultant: 'It's arranged in a fantastic order, every bed number, it's a diagrammatic representation of the whole unit so I can quickly locate the patient and go have a chat with them'	Structure of the environment System design
Action is facilitated by layout or positioning	Desk Staff: 'We always write the "unconfirmeds" on the right so if someone rings up and says "are you expecting a patient form CAS today" I look up and see there's one possible in CAS or one in theatre and its not confirmed, then I speak to Claire, but at least I can look in the spot and see there's one on the board but its not confirmed. I just look at it , I don't have to read anything'	Structure of the environment System design Tacit/learnt response
System provides a general impression	Medical consultant: 'I just come (to look at the board) before the ward round for a general impression of how things are. I'll come back later for specifics'	Structure of the environment
Physical manipulation: touching or holding (facilitates action)	This code was supported by observation rather than verbal notes.	System design Structure of the environment
edundant/repeated information	Desk clerk: 'The "C_Surg" on the label are the cardiac patients that we also write in blue, and the red heart means it's a heart patient coming in'	System design Promotes selective attention
Ephemeral information	Desk clerk: 'We look at the board, listen to what the doctors and nurses say and just keep it in our heads so we can easily act on it later'	System design Structure of the environment
Colour (triggers action)	Desk clerk: 'One of the cardio-thoracic registers came in last night looking for Mr. George, he actually went out yesterday , then came back in , but whoever put him in wrote him in black, so he's saying "Where's Mr. George? Where's he gone? Where's he gone"? And he didn't pick him up because he wasn't in blue'	System design Promotes selective attention
Trust in the information generated (triggers action)	Example: Desk clerk: 'We never trust the computer. The information's always old but the board gets updated all the time'	System design
Information specific to some people	Example: physio: 'I've never noticed the cardiac patients were blue, actually, because I just look at the green magnets for who's leaving'	System design Promotes selective attention Tacit/learnt response
Information specific to individual work practices	Example: desk clerk: 'So generally, all the beds I am managing are on the right, and all of Christine's are on the left'	System design Promotes selective attention Tacit/learnt response
Multi-layered information	Example: desk clerk: 'First we put them up on the left, then when we think they are really coming we make a label with their name and leave it on the side, then we put them on the main part of the board when they actually get here'	System design Structure of the Environment
An aspect of the system provides fuzzy information	Example : nurse 'We preliminarily know about these (points at list on left side) but they firm up in stages during the morning'	System design Tacit/learnt response