



Naturalistic Decision Making in Emergency Ambulance Command and Control

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Introduction

This paper reports on a field study into the nature of decision making in the command and control of emergency ambulances at the London Ambulance Service (LAS). This paper will describe how real-time decisions are made by emergency medical dispatchers and the decision strategies they invoke as they assess the situation, plan and co-ordinate the dispatch of emergency ambulances.

A cognitive task analysis approach known as the Critical Decision Method (Hoffman et al., 1998; Klein et al., 1989) was used in the study. The study showed that decision making in emergency ambulance command and control involves four major processes – assessment of the situation, assessment of resources, planning, and co-ordinating and control. These four processes function within an awareness of goings-on in and around the sectors that the dispatchers operate in. This awareness is referred to as situation awareness and is being reported elsewhere (Wong & Blandford, submitted). The decision making process resembles the decision making described by naturalistic decision making models (see (Zsombok & Klein, 1997) for an extensive discussion on the topic) and is an extension of the Integrated Decision Model (Wong, 1999). The study also suggested that a lot of effort was directed at understanding and assessing the situation and in maintaining a constant awareness of the situation. These observations have significant implications for the design of information systems for command and control purposes. These implications will be discussed separately in another paper.

The paper will first introduce the domain of EMD at the LAS, then explain how the Critical Decision Method was used in the data collection and in the data analysis. It will then describe how decisions are made, particularly during major incidents, and then discuss the implications of those findings for the design of command and control systems.

EMD at the London Ambulance Service

The London Ambulance Service is among the largest ambulance services in the world. The Service responds to between 3200 and 3800 emergency calls per day in an area of about 1500 square kilometers, generally bounded by the M25 highway circling the city. The Service has a fleet of over 400 emergency ambulances to serve a population of about eight million people.

The process of receiving calls and dispatching ambulances to these calls is known as Emergency Medical Dispatch, or EMD (Clawson & Dernocoeur, 1998). There are two broad aspects to this process. The first deals with the receipt of emergency calls. Calls are prioritised according to the extent that the injury is life-threatening. A set of systematic diagnostic questions known as the Advanced Medical Priority Dispatch System is used for this. The second aspect deals with the command and control of emergency ambulances. Once the nature and location of the incident is determined, ambulances are assigned based on availability and nearness to the incident. This research

focused on the planning and decision making associated with the command and control of emergency ambulances.

Emergency ambulance operations are controlled by a central unit called Central Ambulance Control. The control centre is physically divided into two areas. In one half, there are more than 20 workstations which are staffed by call-takers who receive the emergency calls. The other half of the centre is organised into seven sector desks. Each desk is staffed by a sector controller, a radio operator and one or two telephone dispatchers. Each sector desk controls emergency ambulance operations in one of the seven sectors that the city is divided into.

Call-takers receive emergency calls and key necessary details into the computer system. Based on the address of the incident, each call is channelled to the appropriate sector desk. The computer system notifies the sector controller of the call who then prints the details onto a paper ticket. The controller allocates ambulances to the call, and instructs the telephone dispatcher or the radio operator to contact the ambulance. This depends on whether the ambulance is at the station or on the road. The tickets are then placed into a slotted metal box. Each slot represents an ambulance that the sector controls. How the tickets are placed in the box represent status information of the job, e.g. if the back of the ticket faces the controller it means that the ambulance assigned to the job has completed the job and is returning to its station. Updates such as the time an ambulance arrived at an incident location are recorded by hand on the paper ticket.

Naturalistic Decision Making and EMD

The decision process described in this study exhibited features that have been collectively referred to as naturalistic decision making, or NDM (Zsombok & Klein, 1997). It has been explained as "... the way people use their experience to make decisions in field settings." (Zsombok, 1997) p4. Field settings refer to real-time situations that are dynamic, time constrained, uncertain, and where the consequences of wrong decisions are significant to both the individual and the organisation (Klein, 1999). The study of NDM involves probing experienced people working in these natural settings about how they assess the situations they face, determine the problems they need to address, then plan, make choices, and to take actions.

Such studies have improved our understanding of how decisions are made in these complex, dynamic and real-time environments. A number of descriptive studies have been reported in the following domains: emergency decision making in oil production (Flin et al., 1996), military command and control (Drillings & Serfaty, 1997; Kaempff et al., 1996; Kaempff et al., 1993; Pascual & Henderson, 1997), neo-natal intensive care (Crandall & Getchell-Reiter, 1993), and in aviation (Orasanu & Fischer, 1997; Stokes et al., 1997).

Although there are a number of studies in the domain of emergency ambulance control covering issues in workload modeling (Henderson & Mason, 1999; Zhu et al., 1992), software design and reliability of real-time, life-critical systems (Finkelstein & Dowell,

1996), software usability of dispatch systems (McCarthy et al., 1997), there are relatively few studies that attempt to model the decision making processes (Hajdukiewicz et al., 1999; Wong et al., 1998) .

A recent study attempted to integrate key features of various NDM models into a single model called the Integrated Decision Model (Wong, 2000). The resulting model was tested by using it to describe the operational decision making process of emergency ambulance dispatchers. In this study we attempted to further refine this model.

Methodology

The study involved a series of 13 cognitive task analysis interviews using the Critical Decision Method, or CDM (Hoffman et al., 1998; Klein et al., 1989; Wong et al., 1997). The CDM is a retrospective protocol analysis method consisting of an in-depth interview technique and a data analysis method for making sense of the data collected from the interviews.

Interviewees were asked to think back to a particularly memorable and usually a major incident that they have encountered in the course of their duties. Interviewees were then asked to describe the incident, and they are carefully probed, or questioned, to reveal useful insights into the decisions they made and how they made them. The interviews were audio tape recorded. Retrospective techniques are useful in situations where concurrent protocol analysis approaches such as the think aloud methods, can interfere with or endanger the safety of real-time activities. Thus, asking interviewees to articulate their thoughts and considerations while attempting to plan, dispatch and communicate with ambulance crews can distract the dispatcher and cause delays in dispatching ambulances to medical emergencies. Furthermore, there is also only a remote probability that the researcher is present during these major incidents to record the concurrent protocols. Protocol analysis refers to the systematic analysis of the interview transcripts to reveal common themes that form the basis upon which 'theories' about the phenomena can be constructed.

The CDM was originally developed to study how decisions were made in their natural contexts, or naturalistic decision making (NDM). NDM environments are characterised by time constraints, inter-dependent decisions, high stakes, uncertain and dynamic situations where the problems are ill-structured and ill-defined, and where decision makers are often working in relation to others rather than as individuals. Emergency medical dispatching at the LAS possess all these characteristics and is a good example of a NDM domain. While many other analytical methods exist, the CDM has been successfully used to specifically study decision behaviours and requirements of dispatchers in other emergency ambulance control centres in New Zealand and in Australia (Wong et al., 1996; Wong et al., 1997). It is thus considered an appropriate method to also use in the LAS study.

The data analysis for the CDM was conducted in three stages:

- a. The identification and structuring of goals to determine correspondence with the Integrated Decision Model which has been reported elsewhere (Wong,

2000),

- b. The extraction and collation of concepts that describe the stages of the decision process, and
- c. The results are reviewed to find common themes across stages that are appropriate for system design.

In the first two stages, the interview transcripts were indexed and structured to collate evidence upon which to theorise about relationships between identified concepts and themes. A Grounded Theory (Glaser & Strauss, 1968) approach to data analysis was used to ensure that the results were grounded in the observations about the process of decision making in EMD. The analysis led to the identification of human-system interaction strategies as well as strategies for maintaining situation awareness during control. Through the process, a number of usability problems were also identified, though not reported in this paper.

Results and Discussion: the Decision Model

Six broad decision making concepts were initially identified during the analysis of the interview transcripts. These six decision-related concepts were based on observations about how decisions were made during major incidents and also during the transition phase from working with routine emergencies to the major emergencies.

These decision concepts were reviewed against the Integrated Decision Model, or IDM (Wong, 2000). The IDM integrates key features from a number of naturalistic decision making models. The key features of the IDM include an emphasis on situation assessment, a planning and selection course of action (CoA) process that is based on the time available and familiarity with the type of situation, and a real-time co-ordination and control process. These processes were embedded within an awareness of the situation in and around the sector. These six concepts are:

- a. One over-riding *goal* which is to get the right ambulance to the right place at the right time,
- b. Three *priorities and constraints* that resulting actions need to conform with. They are (i) to minimise disruption to the rest or other sectors, (ii) to pay attention to other critical incidents, while (iii) controlling other ambulances simultaneously,
- c. Three decision processes of
 - i. *Assess the situation*, which requires
 - a. an assessment of the problem, and
 - b. an assessment of the resources available to deal with the problem
 - ii. *Plan and select a course of action*, and
 - iii. *Co-ordinate and control operations* in real-time

- d. One phenomenon called *situation awareness* that provide situation-specific guidance to the decision making process. This has been elaborated in detail elsewhere (Wong & Blandford, submitted).

Figure 1 models the relationship between these decision concepts.

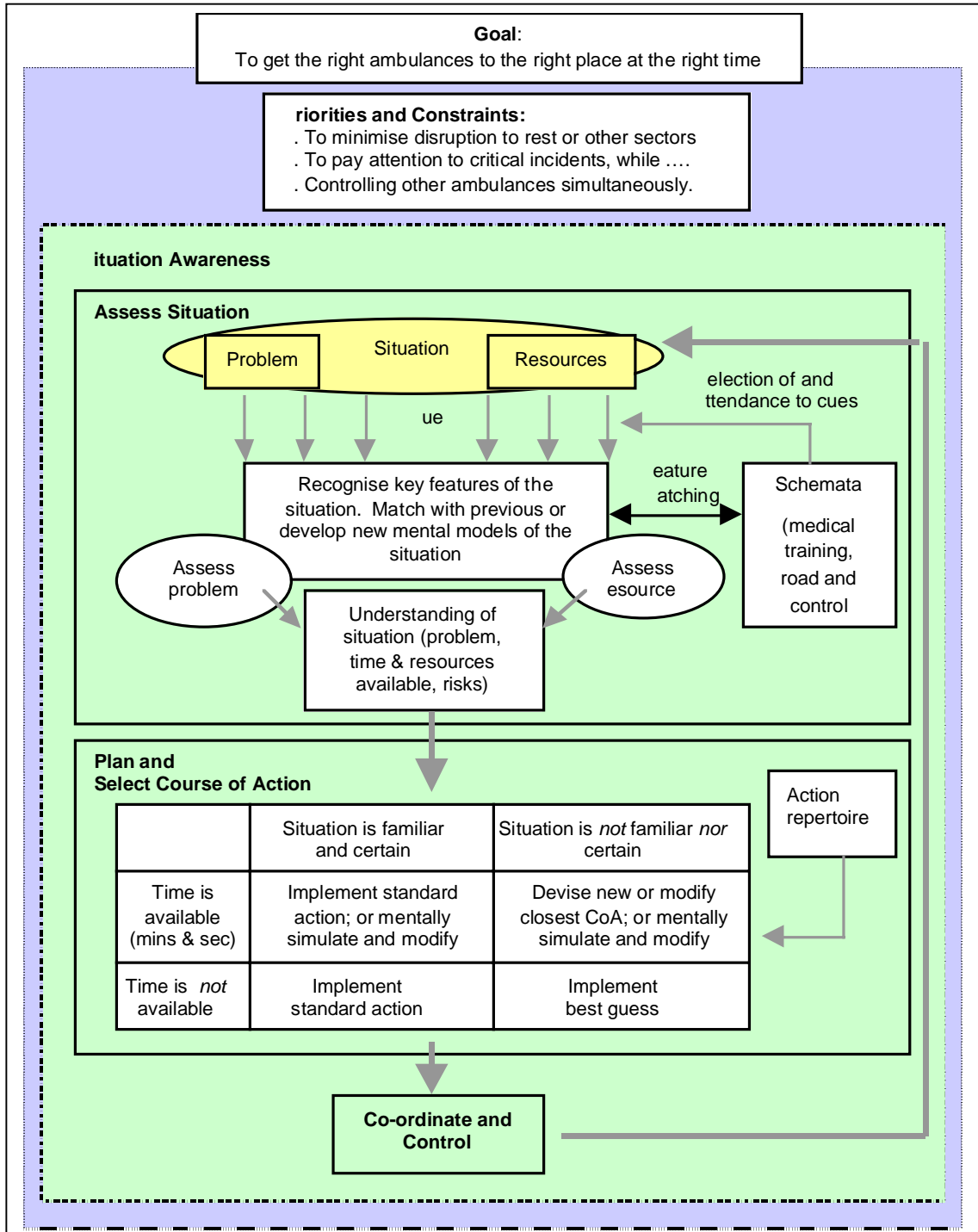


Figure 1 Relationship between decision concepts based on IDM model.

The general decision processes were further analysed using the following structure:

- a. *Activities*, i.e. what dispatchers did during each process,
- b. *Cues, sources and considerations*, i.e. what information was or needed to be attended to, where the information came from, and what considerations were made,
- c. *Knowledge and experience*, i.e. describes the knowledge and experience that were used in this part of the decision making, and
- d. *Difficulties, likely mistakes, and consequences*, i.e. the problems the dispatchers had with the systems and the things that made it harder for them to achieve their goals or likely to lead to them making mistakes and the consequences of those mistakes.

This structure was useful for providing a systematic framework for interpreting the interview transcripts in a manner that would describe how dispatchers made decisions in EMD.

Assess Situation: (A) Assessment of the problem

Activities

Allocators build a mental picture of the situation to explain what is going on.

“... you can't see what's going on, it's very difficult. You can only go by what they're saying ... You have to have a picture in your head ... of what's going on” (1/1187)

“... we just try and picture everything...you know, everything has to be a picture in your head of what's going on.” (1/1174)

While building this mental picture is difficult, it is a necessary and important step in helping them understand the problem and hence determine the course of action and what further can be done to facilitate the situation.

Another reason why building the mental picture of the situation is difficult is because allocators are often faced with information from different callers that describe variations of the same incident which they need to collate and make sense of.

P: ...as in Brixton, and one...one caller will say, oh there's a woman bleeding from her hand.... One caller will say, oh there's a man lying on the floor and I think he...he's not moving. Um...one caller will say, oh there's broken glass everywhere and I think it's hit a few people. Everybody will tell you different. (5/953-959)

This goes on until a single reliable source is available, usually a report from the first vehicle arriving at the scene.

until you get a report from scene, you have to collate all this information and try and get an idea of, you know, what they're telling me (5/993)

Another activity that takes place here is the verification of information with other dispatchers, especially when an incident occurs at or near the boundaries between sectors.

I'd have stood up, I'd have spoke to the other sector, the other sector opposite me were receiving calls. I said to them, are you receiving calls, they said yes. Basically asking the other sector what information they were getting. Trying to ascertain how many casualties we got. (1/281-283)

Another key activity in this process is assessing the authenticity of calls, i.e. is it a hoax? One problem is that "... [the LAS] get a lot of hoax calls." (5/181). In the Brixton bombing, one of the key indicators of a hoax is the small number of calls,

"if you've got something that big supposedly, with one call, then the chances are it's gonna be a hoax." (5/190-191).

The next observation about the authenticity and severity of the incident, is the high call rate,

"And what tends to happen when you've got something major, first of all the call rate goes up. Instead of no calls waiting to be answered, all of a sudden there's twenty calls waiting to be answered (5/200-202) ... the chances are it's something big." (5/231).

The final confirmatory observation is the summary of CAD numbers on the computer display,

"So on this case, what happens is all these calls are being taken all to the same location, my screen just suddenly becomes a mass of red" (5/236) "...So the chances are then, it's real ... we're not talking about hoax here, it's real." (5/242).

Such an assessment was observed to be made during the Paddington train crash as well,

"the tickets are coming out for ever [call], ... people ringing from the phone, people on the train ringing on their mobile ... So ... you got hundreds of people phoning and you know its real when that sort of thing happens." (1/125-128).

Finally, an important step in assessing the situation is estimating the number of likely casualties.

You have to start thinking how many casualties is that gonna involve, and the type of things that's gonna be wrong with them (1/160)

Cues, sources and considerations

The information used to help make an assessment of the situation is the incident information contained in the ticket. In addition to representing calls from the public, the tickets also convey additional information from external agencies such as the police, and fire brigade. In major incidents, the call rate on the electronic wall display often increases dramatically, while the computer screen would show a mass of red CAD numbers in the sector the incident is for. All dispatch staff would also frequently refer to the call details screen to keep up to date with new details on a ticket.

Allocators build a picture of the situation by piecing together key pieces of information associated with the CHALET report – Casualties, Hazards, Access, Location, Egress and Time.

I: How did you build up that picture of what was going on?

P: Umm...through the information that we're given, basically, um...the information that came back. We're...as soon as the information was started to come through, we was able to start drawing a picture, and that picture got wider and wider and wider, became more informative, and as sor....and as more informative got, we could see, without being there, what was going on, so you know, you can see...it's not just a mental picture. It's a simple diagram that can explain so much. ... You don't have to go into great detail, make it over-complicated. Little

things, where everybody understands what's going on, what they resemble, and you've got a picture.

I: What do you need to know in this diagram?

P: What's the most essential ...bit of information. Um...what they call a CHALET report, ... [with] that information you can draw that picture and you can start planning. (7/2458-2490)

Knowledge and experience

All experienced dispatchers talk about the concept of 6th sense, the feeling they cannot articulate why the information about an incident 'just doesn't look right'. Further probing of interviewees suggest that this 6th sense is based on experience and medical knowledge. It becomes part of their knowledge or mental model of how type of injury correlate with type of situation. For instance, in calls for serious road traffic accidents, one would expect major traumatic injuries. Whereas one would not expect such extensive injuries from a call from a home. "When you handle so many calls ... you get a feel for the calls, how they're written out, what happens, you know." (4/1269). In another example regarding the Waterloo Station train crash,

P: That's what we got...a broken window on a train that came in...that just started with the first call. (4/23) ... Um...it didn't seem right that they would phone up for a broken window. (4/64) ... *We were ringing it back just to check* when we got the rest of the calls coming in. (4/108) ... Um...and before we are able to do that, we start getting further calls in, saying, oh there's a train crash. (4/156-158)

Allocators use this 6th sense to mentally evaluate the calls, and if a call does not look right, they may anticipate by checking back with the source or warning potential ambulances that they might be sent to an incident.

Difficulties, problems, likely mistakes and consequences

Uncertainty of information. Allocators are often faced with cues that do not make sense, or with different information from different callers.

P ... you just don't always know from the telephone conversation what's going on. (1/151)

P ... all the members of the public will tell you different. (5/996)

P ... because the information was confusing at the beginning, it started off as what we thought was gonna be a minor incident and it turned out to be a major incident in the end, cos we had about 40 casualties. (6/58-60)

This makes it difficult to assess the situation accurately, and hence why allocators sometimes rely on their 6th sense to make the assessment and plan for the worst as the following example shows. In this example, the allocator had recognised the type of incident and considered other likely escalation of severity and anticipated what needs to be done.

P: ... Plan for the worst, you know. You've always gotta have something going on in the back of your mind, I mean, when...if you get a situation where, erm, say an RTA...an RTA comes in and it's quite serious. ... send two ambulances, say, and then I start thinking, right, who am I going to send next if I need someone... Perhaps I'll go through and warn them, I might have to be sending you to a serious RTA. (1/153-162)

Are the calls for the same incident?

P: I have to keep going from one to the other, because bearing in mind in between this ... there's normal calls coming in, so you have to keep flicking from one to the other, because I'm still getting calls from the public about different addresses. (5/582-587)

The lack of visual differentiation or explanatory information on the calls summary display makes it impossible to ascertain whether two CAD numbers relate to the same incident. The allocators and dispatchers have to access the call details on another screen, read both basic descriptions of what the call is about and the details of the call, and then go back to the summary screen to access the next screen of call details, and so on until all the call details have been compared. This process of moving between screens is known as 'flicking'. They have to hold all this information in their short term memory, and make mental comparisons of the information. They also do this to determine whether the calls are duplicate calls, i.e. are they tickets for the same incident? Alternatively, some wait till the tickets are printed out and then perform a visual comparison of the information printed on the tickets, and physically group related tickets together as incidents. This repetitive action is illustrated in the extracted transcripts below.

I'm normally flicking from one to another to look at it...because I'm also looking for other calls, unrelated to the incident in between. (5/928-932)

I: How did you know thatall of the numbers that came up in the screen were of the same incident?

P: Just by flicking through really, you have to sort of flick through them to see. ... Well when they're on my screen, I press F1 to view the calls, ... and I'll view it and I go that's the same. Flick on through it, that's the same, cos they have all got a train crash or the same location, but in all of that I might have had someone in a house that has fallen down the stairs, that's why it is very important to check through and make sure that the tickets are all the same. (1/1392-1406)

P: ... so what you would do is, depending on how many calls you have on the screen, using the cursor keys, you could flick through and look at the calls and as you look at the calls, see where is it, and then you look at your box, which is next to you, which is with vehicles and depending on the status of the vehicles, where they are, well start making judgements ... of things. (2/121-125)

Until the ticket prints out, you can keep flicking through the calls, cos obviously several calls come in at once and you wanna make sure that they all get out within a certain time. (2/130-132)

And that takes a while, and you have to keep flicking back to all the sector screens, and when you get a major incident going on, and you've got normal calls coming in, and you don't know on the screen unless you look. (1/1147-1149)

What you do is, ...you've seen them on the screen ... you look at one, you say, oh well that's a different call, ...then you move on to the next one. If they are same, you go on to the next one. You keep flicking right the way through, when there's a lot of calls on there, it's hard, and that's the only way you can do it. The only other way to do is to wait until they come out of the printer and look at the actual tickets. But that could be delayed. (4/276-274)

Although individually each flick takes only a few seconds, cumulatively and when seconds makes a difference, these actions do add to the overall activation time. Furthermore, while this is being done, the operator cannot attend to other activities without stopping this action. The frequent swapping between screens also unnecessarily increases the number of data retrieval transactions. Calls from police and fire brigade are not differentiated from calls from the public. A further complication with the summary display is that additional information from the

police, fire brigade, and any other external agency, all come through on the calltaking system and is presented just as a CAD number. The summary display does not differentiate such information well.

P: Well, you see, what happens is, as well as ringing us, the public are also ringing the police. ... (5/386) And again, that [call conveyed through the police] comes up on my screen, just like any other call. Obviously it says NSY on it. ... All the calls, whether it's from the public, the hospitals, fire brigade, all come through on the receiving end of the room (5/395-397)

P: On the first screen is only the fact that there is a call. ...it gives me no indication...whatsoever of what it is, other than there is A call, and then I actually have to go in and look at what these individual calls are. (5/569-578)

As previously described, it is difficult to distinguish between calls in the summary of calls display for the same incident and for other incidents that may have occurred in the vicinity. While the computer can quite easily tie up calls coming from the similar addresses or postal codes, operators have warned that this could be potentially dangerous. Computers should instead flag the possible link between these calls.

there's always the chance if you do that, somebody might have been knocked over by a bus right *outside* Waterloo station, and it's being taken with the other ones [i.e. the train that crashed *inside* Waterloo Station], and you're not looking at it in time (4/1373-1373)

This oversight might happen by assuming that calls coming from the general vicinity are for the same incident. Current procedures stack all tickets from an incident together and are classified as 'duplicate' calls.

we've had road traffic accidents ...we've tied them up together as the same job, then you get somebody come back and saying, we haven't got an ambulance yet, where's the ambulance, and you start thinking, you mean call the ambulance up there, they're on scene. Do you know what I mean? You look at the ticket, a hundred yards apart. (4/1387-1390).

By spreading out the paper tickets on the desk, the operator is often able to quickly scan and compare the call information and determine the ticket that should not be there. Thus, instead of automatically tying tickets electronically, it has been suggested that calls from similar addresses be *flagged* instead, which reduces the search effort, while leaving the operator with the responsibility to verify and to electronically stack the calls.

Assess Situation: (B) Assessment of resources

Activities

The checking of the allocator's box for ambulance availability usually takes seconds. This is because operators know what to look for and where that information will be displayed.

I: Ok, and how did you decide that Poplar was gonna be the nearest one?

P: Cos I know it. Cos I know my area.

I: [laughs] So you didn't really have to check there?

P: I had to check if I've got one. I know who's the nearest to Brick Lane, but I have to check if I've got my nearest, if they're not out doing something else... which takes seconds.

(5/1360-1370)

... all you got to do is glance, all you do is look in the box and you should be able to see where all your vehicles are ... (6/584)

The computer provides the first clue of where an incident will be. Once the address is ascertained, the operator very quickly scans the box for ambulance availability.

P: so what you would do is, depending on how many calls you have on the screen, using the cursor keys, you could flick through and look at the calls and as you look at the calls, see where is it and then you look at your box, which is next to you, which is with vehicles and depending on the status of the vehicles, where they are, well start making judgements and () of things. Initially it would come through and you'd say oh right that vehicles is closest to that, so I'll send that vehicle. (2/121-126)

P: Right, ok um...right, so um...the call comes up on my screen. I then obviously press the F1 function key to see what it is. I then look in the box, see my nearest ambulance, realise I don't have one... (3/755-757)

First check the box to see what's available. If none available, next is to do a General Broadcast, or GB, before sending another ambulance from a station further afield.

P: Right, ok. Um...right, well when the first call comes in, I'd ask...I would have a look in my box () to see whether the crew was out on the road or on station. Now the first crew, I know for a fact was out on the road. I had to do a general broadcast, because in my nearest station, weren't in, and I did a general broadcast for a baby claimed suspended, and they then called up. (3/309-312)

Cues, sources and considerations

The allocator's box is the key source of information. It contains information about vehicle availability, vehicle manning, whether a vehicle is off-road, on-station, what they are doing, and where they are headed to.

If there's no ticket in the box, then that vehicle is available, so all you got to do is glance, all you do is look in the box and you should be able to see where all your vehicles are, () on station, if they are off the road, un-manned or if they are running back from a hospital to the station. Then you make a decision which is the nearest or best vehicle to send at that particular time. (6/583-586)

...start looking at the box to see who I can send next. (1/157)

It's all in that box...it's everything you've got to remember. (1/915)

I look in the box, find the nearest one (1/1535)

you have got the ones that are in the box where the crews are already on their way (1/1546)

Information is contained in the physical positioning of the tickets in the box.

P: The only time [the ticket] would go backwards is when the crew have greened at West Middlesex [hospital]. (3/995)

Knowledge and experience

In assessing the state of one's resources, the operator needs to have a sound knowledge of their operational area. This knowledge includes the disposition of stations, their relationships with hospitals, key landmarks, and main roads and one-way systems. This is knowledge in the head. It is on this mental map that they build a dynamic state of where the resources are and what they are doing (4/1715-1734). The interviewee further explains that the lack of correspondence between the physical locations of stations and the spatial relationships between stations in the allocator's box is not as important as

knowing. Then based on ambulance availability, the operator is able to run mental simulations of which ambulances are the next nearest resource.

“... you really got to keep that knowledge in your head ... knowledge of where the incident is all the time ... and the surrounding stations. Doesn't matter what they're called. You can see them in the box, but you need to...if you've got a call in South East 16, you look, Southeast 16... Immediately on Southeast 16, Rotherhithe, have I got a Rotherhihe? No. Have I got a Detford? No Detford. Have I got a Waterloo? No Waterloo. Gotta run a Bloomsbury or an Oval of course...” (4/1715-1734)

It is also because of this knowledge in the head that operators are able to use the box as a quick reference for vehicle status. Their knowledge enables them to be selective and only check likely vehicles that can be deployed in an incident. From the transcript above, operators do not examine all vehicles, but seem to focus or zoom in to the vehicles in the area of the incident directly, e.g. stations in the SE16 area.

Difficulties, problems, likely mistakes and consequences

To determine if ambulances have been assigned to the same incident, operators have to keep taking the tickets out of the box to see if the ambulances have been assigned to the same incident.

I: How do you know which ones belong to the incident?

P: Cos they're all got their call sign....well you don't, you just know, you have to keep taking the tickets out the box (1/1548-1551)

Wrongly placed tickets provide wrong information about ambulance status.

the only reason we know what vehicles doing is there is a ticket in there and which way the ticket is facing and the only problem with that is what sometimes happens, is that the ticket may go around the wrong way, so when a vehicle is on a call, the ticket would be facing forward in their slot and when they finish the call, and we write down what hospital they're at, you turn the ticket back to the front.....then we know that that vehicle is returning from the call to whatever station. (2/620-625)

This is a problem with manual procedures and a reliance on human memory. It requires constant vigilance which can fall as workload increases or as the operator gets fatigued.

Planning and selection of course of action process

Activities

In planning and selecting which vehicle to send, dispatchers always send the nearest available vehicle.

P: Uh, I sent my first available resource to the call. ... Um...it was a Tottenham vehicle. And then, em...they arrived on scene, and reported, confirmed child in river. Then sent the first responder to standby. (8/406-416)

P: Em...if you look at what you've got in front of you, it's like, () there's a crew there, then that crew, you get that crew sent then that one.

I: Why didn't you think of some other crew?

P: Cos they would have been the nearest. You always send the nearest crew to the incident.

I: Where do you check to see if they were...?

P: Well at the time they were on station. You use your map book. Look through my map book. They were on station, and I always send the nearest crew to the job.

(8/786-803)

When planning and selecting a course of action, once it is known where the incident is, the dispatcher would have identified possible ambulances to dispatch. Dispatchers employ the 'dispatch on address' strategy to speed up the dispatch process.

P: The address...the location of the incident, of whatever. As soon as the address appears on my screen, and this particular was E1, I would have said, can you send Poplar on station to CAD 1234. (5/128-9)

In planning and selection of course of action, the dispatchers do not appear to generate and compare multiple options as is prescribed by traditional decision making models (Simon, 1977). Instead, they seem to instinctively select one course of action:

P: No...em we () the nearest ambulances, erm...no not really...I don't () any other option. I think there is only one option when something like that happens and that is to get the ambulances there. ... my first instinct send the nearest ambulances and that is what I done. (1/1328-1331)

This is further illustrated as a serial selection strategy when they select specific ambulances to dispatch. Dispatchers zero in on relevant area represented by the allocation box, eliminate from consideration those that are not available, and then select the closest available ambulance.

P: ... you could flick through and look at the calls and as you look at the calls, see where is it, and then you look at your box, which is next to you, which is with vehicles and depending on the status of the vehicles, where they are, well start making judgements and () of things. Initially it would come through and you'd say oh right that vehicles is closest to that, so I'll send that vehicle. (2/118-126)

Another mental activity that dispatchers do is mental rehearsals and refinement of plans in response to the situation. They develop an initial plan which they think through and modify the parts of the plan that do not work.

P: Well, if they have said like well we have not got this station available, we have got this one here and we got this other call coming in, so what we do is....cos you gotta cover both the calls. So you may have a vehicles that nearer to take Paddington and its Lad Grove and you send them to Paddington, the other vehicle has gotta run a long long way, so you are looking up and thinking right to get each one in the quickest time, will send that one a little bit further to get that one....so then you know that you have got both covered, but both's gonna get their as quick as possible, cos if you sent one to there with nothing and that one to a long long while to get to the second location, then it turns out it was something, then you have actually delayed them getting there. So its not actually looking at whos the nearest, cos well I got two calls to cover and I'll...to get them both as quick as possible, cos of the ..., that one there, ya get a report it. (2/413-423)

Dispatchers were also observed to modify their plans as more information becomes available. For instance, once a situation was verified as real and not a hoax call, more ambulances are dispatched.

P: Right, so we've decided it's not a hoax, it's for real. So what I do then is um...I dispatch some more...whatever vehicles I've got local available, I send. In this case, I think I dispatched about three. Three more local stations. ... again. (5/246-263)

In cases when the problem is easily recognised, dispatchers respond with a standard course of action. For example, for patients with suspended breathing, it is usual practice to dispatch two ambulances.

P: ... I then sent a second ambulance, because it was given as baby suspended (breathing), and obviously on any suspended patients I put a call in to send two, two vehicles, so that's what I done. (3/75-79)

Another important activity that takes place during planning is thinking ahead. Operators using their assessment of the situation, develop probable scenarios and contingency plans. Some may anticipate it by deploying resources while still ensuring that other emergency work is still catered for.

they will start thinking ahead and they will start looking in their box and think to themselves right, they are gonna be short in that area now...all that area.....well start moving some vehicles down to cover their other emergency work. (1/739-741)

Cues, sources and considerations

The dispatcher has to consider the dynamic state of the ambulances in deciding which ambulance is the nearest. The dynamic state describes where the ambulances are, where they are moving from and to in relation to the incident location. It also involves knowing who will be available in the next five to ten minutes. They describe this sense of awareness of where their resources are as a "... picture in your mind." (8/997). This notion of being aware of the dynamic situation has been described in detail elsewhere (Wong & Blandford, submitted).

P: It is, it is important, cos you've got to decide what ambulance goes on what job, if it's the nearest ambulance, if they're gonna pass another vehicle on the way. Cos say I've already given one...I'm the allocator and I've asked the radio operator to give this job out to that crew, if they were in a certain area, but then another job come in, they might be on top of that job, be going past it to get to the next one, then you've got to start thinking (), swap things around and who do I give that one to, cos it's your job to make sure that you get an ambulance on each job.

I: But how do you know that, uh...there's an ambulance coming back from there that might cross this ambulance going out?

P: Because you know the areas. If you know they're coming back from a hospital, and this job maybe like, around the corner from the hospital, and you're sending one from a long way, from a station, and you know that that ambulance is gonna be nearer. A lot of it's local knowledge within the area. You know where the hospitals are, and the stations are. Obviously some of the main roads you get to know quite well.

I: Right

P: And places you go to quite often. You get a sort of picture in your mind where the areas are, and who's gonna be better.

I: What picture in your mind?

P: Um...it's like a sort of a little map of where all the stations are and the hospitals, and then you start, you know the running times back from hospital to the station, like in ten minutes, five minutes. (8/973-1003)

Nearness of incident to a station allows allocators to trade-off number of ambulances to send with time

P: Um...if it been...if the ambulance hadn't been very near to the...if I hadn't been very near, I would have probably started more vehicles, just...but because they're only two minutes away, from here to Waterloo, it's sort of two minutes, they was gonna get a call quite quickly. Um...you have to make a judgement. If...if it looks if it could be something nasty, and then

the vehicles gotta run a long way, then you'd start more than one. You could always cancel them. If it's right virtually on top of where the first ambulance is gonna be, then you ask for a report, as soon as it gets on scene, what's happening. But in the main...meantime you can be planning that if it is a major, you know where you're gonna get your vehicles from. (4/221-228)

Information for planning ahead is a combination of current ambulance status and 'experience'.

I: And what information do you use to plan ahead?

P: What we've got on the box really, and what I know from my experience.

(1/172/174)

Vehicles may be dispatched from further afield once an initial response has been sent to a major incident. This is to avoid depleting a sector. In the Waterloo Station train crash, the initial response was a motor-bike and an ambulance from Waterloo ambulance station. Once the first crews arrive and provide a situation assessment, further ambulances were dispatched from Deptford, Oval and Rotherhithe.

P: Yes, but um...if you work out Central area is Waterloo, you'd have the Central East, it's just down in Shoreditch, you've got the North...um...the Northwest, which is just at Fulham, places like that. [*these are nearby stations in neighbouring sectors*] So they're not far for people to run in to. Rather than deplete the resources of the whole of the central sector, we try to run in vehicles from different parts to assist. (4/ 508-511)

P: The nearest...they're [Deptford, Oval, Rotherhithe] the nearest areas. They're in the sector, and they don't take long getting there. (4/476-477)

P: It's just...it's just that...a decision you have to make, and you know, if I'd sent um...three from the Oval, then I wouldn't have had any cover at all in that area. And I sent one from the Oval, one from Rotherhithe, one from Detford, I still leave (enough) vehicles on them stations to cover (other emergencies.) (4/581-584)

Knowledge and experience

Knowledge of area plays an important role in reducing planning time by eliminating the need to refer to a map and to match the incident location to the nearest station. This is illustrated in the Brick Lane bombing, and the Paddington train crash. The operator selected Poplar in the Brick Lane case, and Fulham and North Kensington in the Paddington case, simply because he or she knows that it is the nearest station to the incident scene.

I: Why Poplar?

P: Because it's the nearest ambulance station to Brick Lane.

(5/130-132)

I: how did you sort of, erm...decide that you send from Fulham, from North Kensington?

P: Just by knowing. I know...I know that area, because it's the area I work on, and I know what resources are available to me... (1/789-794)

Difficulties, problems, likely mistakes and consequences

None identified.

Co-ordinating and controlling

Activities

One of the key activities in co-ordinating and controlling is the management of the tickets. The ticket of the original call is copied for subsequent ambulance assignment. Duplicate calls are the other calls for the same incident. Duplicates for the same incident are re-numbered and tied together

P: ... The copies are not renumbered. Copies are one job, one copy, one ambulance. ... The original calls as they...there's the one original call ... All the secondary calls that are coming in are duplicated calls. ... Are all tied up with the original call... So the original vehicle that goes on the call has all the rest of them all packed up behind it, so they'd be numbered one, two, three, four, five. Doesn't matter about the CAD ...irrespective of the CAD, they are tied up to the first CAD. ... That makes sure that you don't, you know, got more calls than you have. (4/1067-1092)

The original ticket represents the incident. Copies of the original ticket are printed and are used as the job ticket for all other ambulances assigned to the incident.

P: ...every vehicle, what...what we do is every vehicle needs to have a ticket. ... So what we do is we run off more copies off the printer...of the uh... of the same ticket. Um...then we just try and change the times that we give them on the same ticket, everything stops on the same um...(CAD) number. ... No matter how many more come in, they all stop on the original (CAD) number, so they can be tied up together properly. (4/232-246)

Tickets for the same major incident are re-numbered and tied up together.

P: Yeah, we renumber them with...against the first cab. So the first CAD is number one. ... And all the rest are numbered up backwards, from one up to whatever have come in. (4/365-373)

The allocators constantly flick through the CAD numbers display and job details display to identify major incident calls and other calls.

P: Yeah, right...you try to...you look at one, you say, oh well that's a different call, you try and arrange...then you move on to the next one. If that the same, you go on to the next one. You keep flicking right the way through, when there's a lot of calls on there, it's hard, and that's the only way you can do it. The only other way to do is to wait until the come out of the printer and look at the actual tickets. But that could be delayed(4/280-284)

P: You just...you just, you know, you just flick on the...press that and press F12, go on to the next one, then you keep going...you get right through it, it's quick. (4/296-7)

Another activity is the communication of relevant information to crews as quickly as possible. These information include patient updates and scene safety information.

To give [the ambulance crews] the correct information clearly and concisely. (8/1666)

to keep them informed of the situations (8/1670)

get updates from the police or the patient, condition might have deteriorated or police have no units to assign (8/1674)

You're looking after the crews' safety as well, and what they're doing (8/1688)

During busy times when there are few resources left, e.g. when all or most of the vehicles are attending to calls, it is helpful to array the tickets on the desk and to compare their AMPDS dispatch priorities i.e. Red 1,2,3 etc and then allocate based on these priorities.

P: No, when youwhen all the vehicles are actually out you put them down so that you can read them....

I: You put them down where?

P: On your desk in front you and then you make a big space and I personally look for the diagnosis and see which ones which ... now we have got this AM PDS which is this great thing which is very helpful in a lot of things, so immediately you can go to red ones, twos and threes and the amber and the green ones you just get someone to say I'll bring them back and if you haven't got anybody – you still have to mark all you vehicles out on your ticket, do a general broadcast, so and then you just look at the tickets and as the vehicles come up green, you have to start dishing the best way you think, from the AMPDS. (6/860-871).

Allocators have to do this presently due to the system not being able to distinguish between the dispatch sub-priorities on the summary display.

Vehicles are allocated across sectors in a very fluid and quick way.

"I asked them if they've got a C7 for a call here. They say yes. So, I pass them the ticket that came out of my printer since it was my call. Then I pass it to their dispatcher and then put it in my box." (P1).

In the Ladbroke Grove incident, East Central Sector sent some vehicles to NW Sector as reinforcements to under the control of NW Sector.

"We took the tabs out of our box and put them into their box. Right they are your vehicles. You use them as you see fit. If you still need our help, just shout across in case we have something in the area ... they are your 4 or 5 vehicles to do with for the rest of the shift ... and we'll leave them off our map, and they'll work on their [radio] channel." (P2)

When attending to priority calls from ambulance crews, first the priority call alarm goes off on radio operator's desk when ambulance presses 'Priority Call' button in the ambulance. This pushes up their position in calls to be answered to top of queue, and an audio alarm goes off. People on the sector dek then pay some attention to the alarm to determine if it is relevant to them ('control ears'). The allocator then also instructs dispatcher if necessary, 'Ring West Middlesex. Details just coming in.' Radio operator records detail of the priority call on the ticket, reads back what's been written to confirm details. Allocator is listening in and while radio operator is completing the call, is already instructing the dispatcher to pass on the details to West Middlesex hospital. (P3)

Cues, sources and considerations

Allocators refer to a variety of information sources including bundles of tickets during major incidents, the box and in particular the physical placement of tickets in box, placement of the desk, the computer display, the radio operator and the dispatcher. Cues attended to during Priority Calls that help establish general awareness of the situation.

Between RO and Allocator:

- a. Verbal cues - instructions and verbal feedback with ambulance crew
- b. Visual cues – details on the ticket
- c. Physical cues – ticket being passed from RO to Allocator and then to Dispatcher.

Between Allocator and Dispatcher:

- a. Verbal cues – instruction to “Priority call to West Middlesex”.
- b. Visual cues – details on the ticket.

Physical cues – attending to physically receiving the ticket.

Knowledge and experience

Knowledge of area allows mental simulations

Difficulties, problems, likely mistakes and consequences

In the summary screen, not all CAD numbers displayed for a major incident are red, and not all reds are major incidents as well. No visual, spatial or explanatory information to distinguish between CAD numbers. Colours only distinguish between call priority rather than incident. This imposes an extra burden on the operators to constantly flick between the summary screen and the call details screen. Only when they read the content, can they distinguish between tickets.

P: Or yeah, we go...you always, if you see a red on there, you'll always look at the red first. ... Cos that's a priority call. You look at the reds. You flick and look at the reds, and then you go back and look at the ambers and then the greens, you know, in that sort of order as we're going along.

I: Ok, ok. But the reds, green and ambers um...

P: Mixed.

I: ...are mixed. They're not sorted out?

P: No.

I: Ok, and the other thing I was wondering is that all of the reds regarding...regarding the major incident are also mixed together with other reds or other...

P: Yeah, but not all the reds in a major incident...not all the calls on a major incident will be red... . Some will be ambers, some will be greens, depending on what the person being questioned says to them.

(4/429-453)

Incidents cannot be easily transferred between sectors via computer. Tickets are walked across from one sector to another if there is a need to transfer control of an incident between sectors.

P: ... They [CENTRAL CONTROL] would get the first ticket – the first information and they would give that to me and because of the process of control, () the other tickets still come up on the computer [IN THE CENTRAL SECTOR] and you print out – the allocator would bring them [THE PRINTED TICKETS] over to me. (6/95-97)

When transferring calls between sectors –they prefer to print out the tickets, sort out and ensure that calls are duplicate rather than another incident, then hand them over to other sector. The information on the summary screen does not permit them to identify the calls.

P: There is a way you can [flick the ticket across to me from another sector]. I mean I think that started last year. You press a button and it come on my screen, but when you are busy like that...cos what they actually do it get the ticket out and put it to one side, cos also you have to confirm when these tickets are coming out, you get an RTA for instance, where you get () on mobile phones, you might have fifteen calls on an RTA. But () those calls

coming out, you still gotta watch for calls on other areas. So you have to physically sort out.....you also gotta be careful of is that they are all actually duplicate calls and because like, people () different locations to where they actually are, you have to confirm to yourself that they are all the same call. (6/349-356)

In addition to that, the calls have to be dispatched acknowledged through the system.

P: So although you have got all these calls coming out fairly quickly, you got to watch out...cos as you know, it all comes up on the screen, you still got to acknowledge that you have dispatched them. So you got to be very aware watch them.... (6/380-382)

This suggests that incidents originating from outside a sector, but could end up being controlled by the sector. Control of the ticket (incident) and the ambulances that originate from outside the sector therefore need to be transferred smoothly.

Another problem in maintaining control is in keeping track of resources and events.

P: To loose track of who was going where and what was going on, 'cos its hard as an experienced allocator, that its.....that would be the hardest thing to do...to keep track of who's going, who's on their way, who else is going.....and get it correct on paper work (1/1611)

Operators keep track of developments in an incident by writing down on the back of the ticket all that occurs during an incident. This is a tedious and time consuming affair. Furthermore, because it is written by hand, the information is not easily retrieved or correlated. The information cannot be easily shared and disseminated.

...you gotta try and write things down ... like we write on the backs of the tickets (1/1621-1624) ... you turn the ticket over and write a time on it and write whats going on. Bascially the back of the ticket should read like a book (1/1629-1630). ... The time goes in and remark and the initial of the person that wrote it, so everything they tell you should be written on there and they say that it should read like a book (1/1641-1642)

Other real-time mistakes include

P: ... putting priority calls into the wrong hospital by misdialing (3/1499)

P: people tend to panic if...because of the call, like, baby suspended. ... So they would send a vehicle from station that could be miles away, but it's their nearest vehicle on station, by looking at their ...dispatch box. They might not do a general broadcast to ask for a crew that are nearer, that might be sitting at hospital just filling in their paperwork... (3/1408-1419)

Tendency to over-react and send more ambulances than is needed rather than waiting two minutes for a 'report on arrival' by the first ambulance the extent of the incident. This has the effect of drawing away ambulances that could be responding to other work.

P: I think the temptation, when you're either new or very into major trauma ...is to um...get it all out of proportion before you start. Um, for example, I could look on the screen, it says explosion on Brick Lane, I could say, Paul we've got a bomb on Brick Lane, get the duty officer, go...get a crew running (5/2323-2329) ... The temptation to send every vehicle you've got when you know that your first crew is going to be on scene in two minutes. (5/2358-2359) ... dispatches ... twenty ambulances that you might not need, when they could be doing other work which is going on. There is a temptation to forget about the rest of the work ... (5/2365-2366)

Another potential source of mistakes is the ambulances that the system recommends. Sometimes the geographically closest ambulance is not the nearest ambulance to an incident. Instead, one that seems further away could be nearer due to one-way streets or the river itself.

if you take like Barnhurst area and Woolwich, they're giving allocation points over the River...so some people cos they didn't know the area, when they were sending vehicles

across the water.....as opposed to the () station which is only three miles down the road. (6/1019-1022)

The allocation box is vital to the smooth running of the sector. All allocation and control decisions depend on it. Failure to update it or if updated incorrectly can lead to costly mistakes. Such mistakes "...doesn't happen often, but it can happen. Usually when it's very busy." (9/1150)

P: I think the allocation box. Make sure the allocation box is updated regularly. Sometimes, by mistake tickets will be put in the wrong tag, um...they'll be turned around the wrong way. The cr...they might not be updated, and the crew...on the changeover time. If those things ain't done, um...things can fall apart, because we'd be trying to get ahold of crews which are not there, or trying to call up crews who are off duty, and that's something...basically the allocation box is the main thing which helps the sector run smoothly. (9/185-190)

I: How do you make sure that things don't happen?

P: Um...by making sure that you're aware of it and you change the box as often as you can.

(9/1150-1155)

Finally, one of the most demanding task that dispatchers have to perform is keeping track accurately of who is doing what and where.

P: I think the biggest, hardest thing is losing track of who's going and who's doing what....ermmmm. I don't know how you would.....(remember).....it's experience I think. ... It's through experience you gain it, I don't think you can just make someone.....you can't make some learn experience – experience is something gained during the time and I think a lot of it is experience. (1/1654-1661)

Summary of the EMD Decision Process

The descriptions of the decision processes are tabulated in Tables 1-4, and are summarised below.

Assessing the Situation

The first major process in EMD decision making is assessing the situation. The dispatcher receives cues about the situation through the computer system, the job tickets, the ambulance crews and other dispatchers. The dispatcher first needs to understand what is the problem (assess problem) and whether they have the resources to deal with it (assess resources).

In assessing the problem, dispatchers build a mental picture of the problem or incident by collating and integrating situation and incident information from many sources. The key information they need is represented by the acronym CHALET, Casualties, Hazards, Access, Location, Egress and Time. They also corroborate available evidence with others in order to assess if the incident is real, as well as the severity of incident. The information that dispatchers attend to in assessing the problem is often distributed across a number of different sources, and include:

- a. Initial information that describes the incident is contained in the call details screen which is then printed onto a ticket.

- b. Information that describes the scene and the situation may be in original call details screen, in another ticket because the information was recorded from another call, or from reports received from the crews at the scene.
- c. Information from police and fire about an incident is usually reported on separate tickets.
- d. The call rate display in the control room gives them warning signs of a major incident.

In assessing resources available to deal with the problem, dispatchers determine location of an incident, and determine ambulance availability in and near the incident location by checking allocation box, doing a general broadcast that asks for available ambulances, or look further afield, e.g. outside their sector for potentially available ambulances.

The main source of information for assessing resource availability is the allocator's box. This is a slotted metal box which holds the tickets that have been assigned to the ambulances operating in a particular sector. From this box, dispatchers can determine vehicle availability, vehicle manning, off-road, on-station, current job, where they are headed to. The physical positioning of the tickets, inserts of temporary cards, also act as cues to vehicle status. Additional information about the realtime status of ambulances from the radio operator is also reflected in the allocator's box.

The knowledge that is used in assessing resources constitutes knowledge in the head of the operational area. This includes a knowledge of the disposition of stations, spatial relationship to hospitals, key landmarks, main roads and one-way systems. Upon this 'structural mental model' of their area of operations, they build a 'dynamic model' of events and and vehicle movements. By combining both structural and dynamic models, they run mental simulations as to which is the nearest resource. This knowledge is used to selectively focus on likely resources that may be used for an incident.

What information is attended to and how the information is considered, is dependent upon the schemata that dispatchers have. This schemata is made up of their ambulance training, medical and road experience. The schemata enables dispatchers to recognise patterns in the presented cues that help them diagnose the situation (Lipshitz & Ben Shaul, 1997). Situational cues that violate these expectations set off alarm bells that relate to what dispatchers' refer to as *6th sense*. This is often verbalised by the dispatchers as "it just doesn't look right". The outcome from this process is an understanding of the situation, i.e. the demands of the problem and the availability of resources to deal with it.

Planning and Selecting a Course of Action

Having understood the problem, the dispatcher plans and selects an appropriate course of action. Unlike classical decision making models such as (Simon, 1977), dispatchers do not appear to generate all possible options to evaluate. Instead, selection of a course of action is largely dependent upon the dispatcher's familiarity with the situation, the certainty about the information, and whether time is available. Familiar situations usually result in standard actions, e.g. send ambulance X which is the nearest to incident Y. Less familiar situations or situations where the information is uncertain, e.g. do all these calls

relate to the same train crash? and, say, when time is not available, lead to the adoption of partially standard first responses, such as send a minimal first response while awaiting confirmation of incident severity and while organising reinforcements from stations further afield.

The information used and considerations made during this part of the process include:

- a. Location of incident with respect to stations and resources,
- b. A map of the incident area to plan access and exit routes,
- c. Plans need to avoid depletion of coverage and for spreading of remaining ambulances to maintain an even coverage.

Dispatchers' need to refer to a map is dependent upon their familiarity with the area, and by the expected complexity of the incident. For incidents that have high area familiarity and low incident complexity, allocators do not refer to the map. They use knowledge in the head as described earlier. For tasks that have either low or high area familiarity, but with high expected incident complexity, dispatchers refer to a map to help plan and co-ordinate access and egress routes, RV (meeting) points, and triage areas.

Co-ordination and Control

Once the course of action has been selected, the ambulances are directed to the scene. The activities of the ambulances are then co-ordinated and controlled in realtime, making changes to plans dynamically as the situation changes. These activities include:

- i. Manage tickets as a means of managing the incident. Involves reading, tying up related tickets, recording events by hand.
- i. Act as an information hub, communicate with crews, others in the CAC and other agencies as quickly as possible.
- i. Regulate the use of resources.
- i. Facilitate the transfer of control, e.g. gold control, transfer of incident to another sector. This transfer is usually achieved very fluidly by taking the tickets out of the box and transferred to new designated controllers.

Dispatchers constantly flick between summary and job details screens to keep up with developments. When there are multiple calls for an incident, they re-number and bundle 'duplicate' tickets in order to manage the incident. They also track the case history of each ambulance by writing notes on back of the tickets assigned to the ambulance. Dispatchers also receive police and fire reports, calls from public, and reports from scene via radio operator during this time, and the dispatchers need to sort through the data. Physical cues that the dispatcher attends to include physically receiving, acknowledging and passing tickets between desk members as an acknowledgement of changes in ambulance status. In order to smooth the process of co-ordinating and controlling the ambulances, the dispatchers need to have a good knowledge of the area of operations, and a sound knowledge of the procedures for dealing with events. Control experience assists dispatchers by helping them to keep track of and juggling between incidents, task and crew priorities.

Table 1. Summary of Assessment of Problem Process

Activities	Cues, sources and considerations	Knowledge and experience	Difficulties, likely mistakes, consequences
<ol style="list-style-type: none"> 1. Build a mental picture of the problem by integrating situation and incident information. 2. Collate information from many sources. 3. Corroborate evidence with others. 4. Assess if the incident is real. 5. Assess severity of incident (number of casualties). 	<ol style="list-style-type: none"> 1. Information that describes the type of incident – call details screen. 2. Information that describes the scene and the situation (e.g. for crew safety reasons) – could be in original call details screen or could be in another ticket. 3. Information from police and fire – on separate tickets. 4. Call rate. 5. Key cues expected - CHALET 	<ol style="list-style-type: none"> 1. "Just doesn't look right" or 6th sense – developed from experience and medical (on road) training. This knowledge is used to assess the situation. 	<ol style="list-style-type: none"> 1. Uncertain information. 2. Determining if calls are duplicates – flag calls with similar addresses rather than tie in on locations 3. Flicking between summary and details screens to read, collate, compare and mentally integrate information – effortful process, highly memory intensive and therefore requires full attention. Summary display lacks visual discriminators or explanatory information. 4. Information from police and fire not differentiated on summary display.

Table 2. Summary of Assessment of Resources Process

Activities	Cues, sources and considerations	Knowledge and experience	Difficulties, likely mistakes, consequences
<ol style="list-style-type: none"> 1. Determine location of incident. 2. Determine ambulance availability in and near the incident location by <ul style="list-style-type: none"> - checking allocation box - doing a general broadcast - looking further afield for potential ambulances. 	<ol style="list-style-type: none"> 1. Allocator's box <ul style="list-style-type: none"> - vehicle availability, vehicle manning, off-road, on-station, current job, where they are headed to. 2. Physical positioning of the tickets, inserts of cards, as cues to vehicle status. 3. Information about real time status of ambulances from the radio operator should be reflected in the allocator's box. 	<ol style="list-style-type: none"> 1. Knowledge in the head of operational area <ul style="list-style-type: none"> - disposition of stations, spatial relationship to hospitals, key landmarks, main roads and one-ways. - upon this 'structural mental model' of their area of operations that they build a 'dynamic model' of events and and vehicle movements. - combining both structural and dynamic models, they run mental simulations as to which is the nearest resource. - this knowledge is used to selectively focus on likely resources wrt an incident. 	<ol style="list-style-type: none"> 1. Constantly having to verify that the box reflects the correct status of play, i.e. <ul style="list-style-type: none"> - have ambulances been assigned to the same incident? - are tickets placed the wrong way round? 2. This process is highly reliant on memory and vigilance which can falter as workload increases or as the operator gets fatigued.

Table 3. Summary of the Planning and Select Course of Action Process

Activities	Cues, sources and considerations	Knowledge and experience	Difficulties, likely mistakes, consequences
<p>1. Having identified candidate ambulances to be dispatched to the incident location, planning decisions now is how their deployment might benefit the situation. Decisions include</p> <ul style="list-style-type: none"> - ambulance is the only one and nearest one available - nearest station has more than one available - nearest ambulances are available from two or more places (there may be trade-offs in terms of time, speed, and maintaining coverage) - avoid depleting an area <p>2. Plan ahead for possible contingencies.</p>	<p>1. Location of incident wrt to stations and resources.</p> <p>2. Refer to map of area to plan access routes etc.</p> <p>3. Send minimal first response while awaiting confirmation of incident severity and while organising reinforcements from further afield.</p> <p>4. Plans need to consider avoiding depletion of coverage and for spreading of remaining coverage, e.g. ambulances 'greening at hospital'.</p>	<p>1. The need to refer to a map is defined by two factors:</p> <ul style="list-style-type: none"> (i) familiarity with area, and (ii) expected complexity of the incident. <p>For tasks that have high area familiarity and low incident complexity, allocators do not refer to the map. They use knowledge in the head. For tasks that have either low or high area familiarity, but with high expected incident complexity, allocators refer to a map to help plan and co-ordinate access and egress routes, RV points, triage areas, etc.</p>	<p>Not identified.</p>

Table 4. Summary of the Co-ordinating and Controlling Process

Activities	Cues, sources and considerations	Knowledge and experience	Difficulties, likely mistakes, consequences
<p>1. Manage tickets as a means of managing the incident. Involves reading, tying up related tickets, recording events by hand.</p> <p>2. Act as an information hub, communicating with crews as quickly as possible, the CAC and other agencies.</p>	<p>1. Flicked screens, re-numbered and bundled tickets, case history by each ambulance on back of tickets.</p> <p>2. Police and fire reports, calls from public (via CAD display), reports from scene via radio operator.</p> <p>3. Physical cues – attending to and physically receiving, acknowledging</p>	<p>1. Knowledge of the area of operations.</p> <p>2. Knowledge of procedures for dealing with various events.</p> <p>3. Experience determines the mental capacity to keep track of and juggling between incidents, task and crew priorities.</p>	<p>1. Lack of visual differentiation and explanatory information on the CAD summary display.</p> <ul style="list-style-type: none"> - not all CAD numbers displayed for a major incident are red, and not all red CAD numbers are for major incidents. - cannot easily distinguish between CAD numbers for one incident to

<p>3. Regulate the use of resources. 4. Facilitate the transfer of control, e.g. gold control, transfer of incident to another sector. This transfer is usually achieved very fluidly by taking the tickets out of the box and transferred to new designated controllers.</p>	<p>and passing tickets between desk members. 4. Radio operator and dispatcher provide information access to the crews and external agencies.</p>		<p>another. - colours only distinguish between call priority and not incidents. This places huge burden on memory and limits attention, and reduces the usefulness of the display and the effort that has to be expanded anyway. 2. Incidents cannot be easily transferred between sectors via computer. Consequences include allocators preferring to print out the tickets and walk the tickets to the new sector, and difficulties in dispatch acknowledging the ticket once ticket is handed over. 3. Case history for each ticket is written by hand. As such the information cannot be easily retrieved, referred to by others, correlated with information from other tickets, nor easily disseminated. This makes it harder to keep track of resources and what they are doing. 4. Tendency to over-react in major incidents, rather than wait a couple of minutes for a 'report at scene'. 5. Mis-dialling hospitals. 6. System-recommended nearest available ambulances does not take into consideration obstacles such as the River and one-way systems, which can significantly increase mobile to scene time. 7. The high level of manual updating of the allocator's box can lead to costly mistakes that though, "... doesn't happen often, ... can happen ... usually when it's very busy."</p>
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Decision Strategies: Portraying EMD situational information in the LAS

Next, the analysis of activities, cues, knowledge and difficulties, are consolidated to reveal how people work in the EMD. This consolidated description is known as operator strategies and will have implications for the design of how situation and process information is *represented* or *portrayed*, such that the presentation facilitates the rapid assimilation of situational information.

Decision strategies in assessing the problem

Developing an understanding of what's going on is a vital aspect of dispatch management. Allocators build an understanding of the situation by collating and integrating different pieces of often uncertain information from a variety of sources over a period of time. They often have to compare and evaluate information from between different and within the same incidents to assess the overall situation, and the severity of the incident to gauge the number of casualties they can expect. Incident information on the tickets need to be compared visually. The computer system does not facilitate the less effortful visual comparison of information, and instead relies heavily on the more effortful memory to make comparisons during the time consuming flicking' process. They verify the information with others in assessing the authenticity or the extent of the incident. A helpful guide to ensure that all important information is considered is summarised as CHALET – Casualties, Hazards, Access, Location, Egress and Time. Allocators use “6th sense” to help them verify the authenticity of information. 6th sense may be described as expertise based on their training and experience. This develops a set of expectations for managing incidents and it is the violation of these expectations that constitute the 6th sense. They use this knowledge to assess and verify situational information.

Decision strategies in assessing resources

The allocator usually knows which resource is nearest to an incident location. They only need to *glance* at box to *confirm* ambulance availability in the immediate vicinity and even further afield. Despite the lack of correspondence between the geographical disposition of stations in the sector and the spatial relations in the box, allocators do not find this a problem. They know where the stations are and only use the box as placeholders for status information rather than as locational cues. They also use their knowledge of the area to help them focus on the stations to assess rather than having to assess availability at all stations.

Decision strategies in planning and selection of course of action

Reviewing operators' behaviours and thinking during the planning stage, we see the following strategies

- a. Instinctively send the first nearest available ambulance. This implies that the dispatchers and allocators have a clear awareness of what their ambulances are doing and where they are, so that when a call comes in they *instinctively* know which is the nearest available ambulance.

- b. Dispatch on address. Once the address is displayed on the CAD system, instruct the ambulance to attend the incident while further details will be communicated later once it becomes available. This strategy is to reduce ambulance activation times.
- c. Avoid depleting the immediate area. Dispatch an initial response, then additional vehicles from further afield can be sent.
- d. Serial selection and focus on immediate area. Vehicle availability is considered one at a time from those in the immediate area and then to those further afield. Vehicle availability closely corresponds to the course of action, its consideration and selection.
- e. Plans are modified as more information becomes available. As it is common in this domain, the dispatchers and allocators are rarely (if at all) presented with all the necessary information nicely collated at the start of the incident. Instead, plans are made based on incomplete information and these plans are modified as more information becomes available.
- f. Think ahead. Dispatchers and allocators constantly anticipate the immediate future scenario and cater for it. This involves planning the jobs that an ambulance can go on to next. This requires good awareness of the situation and knowledge of intermediate or temporal resource states.

Decision strategies for co-ordinating and controlling

Tickets are the means of managing incidents. Currently, allocators lay out tickets and bundle them into incidents. Plans are made in response to the incident rather than to an individual ticket if it is part of an incident. There is a high level of manual recording of information as a means of tracking events in the incidents. One key piece of information for controlling activities is knowing what calls there are. However, the lack of basic visual discriminating details on the call summary display has led to a number of compensating and effortful behaviours. Allocators constantly 'flick' between the call summary screen and call details to keep abreast of what calls are coming up, and whether the calls relate to a major incident. This task is highly memory reliant and therefore open to mistakes.

CONCLUSION

In this report we have described how decisions are made in the real-time domain of emergency ambulance command and control, particularly in the control of major incidents and during the transition from routine operations to the control of major incidents at the London Ambulance Service. We have seen strategies that suggest dispatchers and allocators make a significant effort to understand and assess the situation by collating and integrating information from many sources, over a period of time and across different modalities. The continued maintenance of this mental picture is known

as situation awareness and has been reported elsewhere. They have also been observed to frequently use their “6th sense” to identify important things to attend to, or to question the validity of information they receive.

During the planning and selection of a course of action phase, dispatchers do not appear to generate and compare multiple options but instead zoom in on a single plan which they refine as they think through the situation. How they think through the plan and eventually select a course of action, depends on their familiarity with the situation and the time available to work through the problem. This is very much in line with that described by the Recognition Primed Decision model (Klein, 1993). A decision is finally made and a series of actions are then carried out to co-ordinate ambulance activity.

The findings about how decisions are made in emergency ambulance command and control provide valuable insights for how systems ought to be designed to support the decision processes. The greatest difficulties faced by dispatchers and allocators are in assimilating the multi-sourced, multi-modal information that arrives over time during the assessment of situation and of resources available. What is the problem and what do I have to deal with it? Computer support is most needed in collating and tracking situational information and an ability to manipulate that information by incidents, or by time to review how a situation developed or to understand what the information cues mean in the context of a situation. Much of this situational information, e.g. the emotional state of the ambulance crew after attending to particularly traumatic cases, or the information embedded in the physical handling and spatial placement of physical artefacts such as the tickets, are not traditionally tracked by the computer systems or part of the formal entity-relationship data model of the system. Yet, it is these information that the allocators and dispatchers use routinely to make the majority of their decisions. This raises the prospect for further research into how such diverse forms of information may be captured collated, and presented to a user. We have given this concept the term *naturalistic multimodal interactivity*, or NMI. It would represent a new form of human-system interaction that supports the nature of work in naturalistic settings and where the work encompasses information that spans the different human communication modalities.

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