Information Portrayal for Decision Support in Dynamic Intentional Process Environments

William B.L. Wong[1]
Prof. Philip J. Sallis
Department of Information Science
University of Otago

Dr David P. O'Hare
Department of Psychology
University of Otago

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Abstract

This paper reports on preliminary findings of a cognitive task analysis conducted at an ambulance despatch control center. The intense and dynamic nature of the decision making environment is first described, and the decision process modelled in an attempt to identify decision strategies used by the Communications Officers. Some information portrayal requirements stemming from one of the decision processes are then discussed, and these requirements are then translated into a proposed display solution.

Keywords: information portrayal, information display design, decision support design, decision modelling, naturalistic decision making, critical decision method, ambulance service.

[1] Address correspondence to: William B.L. Wong, Lecturer, Department of Information Science, University of Otago, P.O. Box 56, Dunedin, New Zealand. Fax: +64 3 479 8311 Email: wwong@commerce.otago.ac.nz

1 Introduction

The St John's Ambulance Service is the organisation responsible for the provision of all ambulance and paramedic services in New Zealand. The services provided range from first aid posts at rugby games to ferrying patients between medical facilities, to attending to medical emergencies and accidents. The responsibility for controlling and coordinating ambulance and air-ambulance operations rests with six Regional Communications Centers (RCCs) – Auckland, Midlands, Central Districts, Wellington Free, Canterbury and Southern – situated in the metropolitan centers of Auckland, Hamilton, Palmerston North, Wellington, Christchurch and Dunedin.

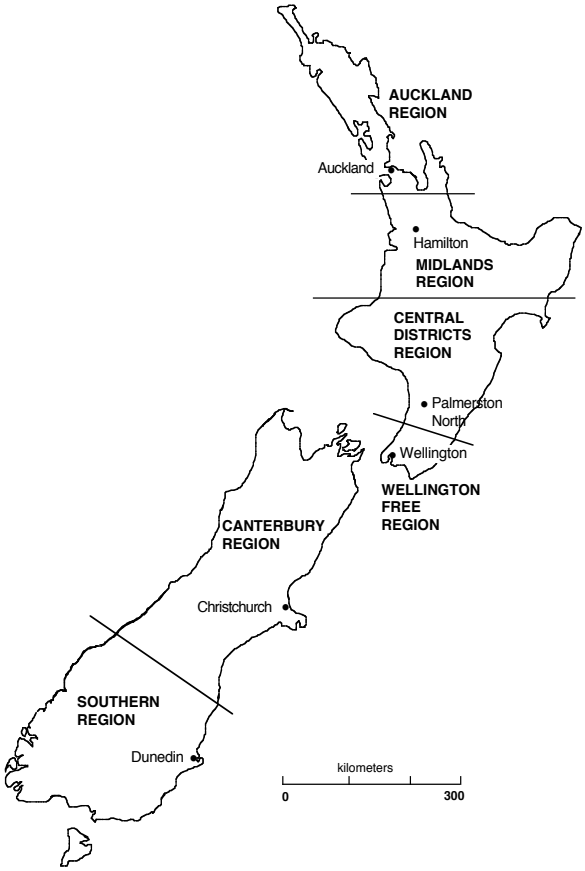

Figure 1: Approximate Areas of Responsibility

A cognitive task analysis using the Critical Decision Method [1] was conducted on the Communications Officers, or despatchers, operating the Southern RCC. The purpose of the study was to identify the information portrayal requirements for decision making in dynamic control environments through an analysis of the decision making processes employed by the despatch officers. It is proposed that human performance can be improved if information is presented in a manner that supports the way information is used in the decision making process. This represents

what Vessey refers to as *cognitive fit* [2]. Although her work tended to be laboratory-based, the notion that information uptake and hence understanding of the situation can be speeded up if we map the way information is designed to the way we think about the situation, is applicable.

The approach the study has taken is to firstly identify the decision strategies invoked by the despatchers, and then determine from these strategies how information is used in making the decision. This specification, incorporating the ideas of task and display proximity, would then represent the information portrayal requirements. This approach is further described later in this paper.

In order to appreciate the preliminary findings, it is necessary to briefly introduce the domain in which this research is undertaken. The dynamic nature of naturalistic decision making environments places additional pressures on decision makers not usually experienced in laboratory settings. These will be described in the next few sections.

2 Dynamic Decision Making

The St John's Ambulance control environment may be classified as naturalistic decision making [3,4]. Such environments are characterised by

- ill-defined problem situations.
- dynamically changing conditions such that a decision made a few minutes ago may no longer be appropriate under the new conditions.
- a series of decisions where the outcome of an earlier decision will influence the way the next decision in the sequence is made.
- time-pressure where there is a need to decide and act within minutes because of the knowledge that delays can cost lives, or because there are a large number of incidents to attend to in a short time frame.
- high stakes, or the knowledge that a wrong decision can have severe consequences and possibly loss of life, such as the recent death associated with the Melbourne Ambulance Service [5].

3 Intentional and Causal Processes

Dynamic decision making environments can be further classified according to whether they are causal or intentional. According to Rasmussen, causal processes are described as processes in which the outcomes may be predicted on the laws of nature. For instance, in the manufacture of chemicals

or petroleum products, temperature will predictably affect the rate of output, or the pressure build up in the processing chambers.

The activities of intentional processes on the other hand, are not determined by such laws of nature. Intentional processes usually refer to intelligent, self-motivating, people-based systems. The outcomes are not predictable based on these laws of nature, and instructions given to members of the system may not be carried out because of local knowledge of the situation. Command and control systems and emergency service despatch management systems fall within this category. This distinction is important because it has an impact on the way information is portrayed. While it is possible to mimic the stages of a product flowing through a manufacturing process, such a mimic diagram would not be appropriate in representing the stages of activities performed by each ambulance. This research is focussed on information portrayal for intentional process environments.

4 The Southern RCC

The Southern RCC is one of the five Regional Communications Centers responsible for controlling and coordinating ambulance operations. In this Southern Region 14,000 emergency patients were attended to in 1994 as compared with 53,000 emergency patients by the Auckland Region. These numbers somewhat reflect the distribution of population in the country. The Southern RCC's area of operations encompasses the lower half of the South Island of New Zealand, extending from the Waitaki River to Stewart Island in the south. This represents an area of approximately 54,000 square kilometers.

In this region, there are 28 ambulance stations with 48 ambulances unevenly deployed. There is one dedicated air-ambulance, and several other volunteer helicopters to service the region. Ambulance officer qualifications range from entry level through to paramedic qualified personnel.

The Communications Center is staffed by ambulance officers who are rotated through periods of ambulance operations and despatch control duties. This is considered necessary as many of the emergency calls that they receive require the despatcher to make some initial diagnosis of the criticality of the patient's medical condition in order to send appropriate ambulance resources to the caller. Incorrectly classifying a critical case as non-life threatening can result in the loss of life. On the other hand, classifying a non-serious case as life threatening is a waste of limited resources which could have been despatched to a more deserving situation.

5 Methodology

In the initial part of this study, eight Communications Officers from the Southern Regional Communications Center were interviewed using the Critical Decision Method (CDM) [1]. CDM employs a retrospective technique which directs the interviewee to cast his or her memory back to a particularly memorable incident he or she had experienced during the course of their duties. Having established a frame of reference, specific probes are then asked of the interviewees to investigate the cognitive processes invoked during that incident. Because the incidents recalled often had made such an impact on the Communications Officers, many of the Officers interviewed were able to recall seemingly minor details, as the following example shows. The interviewee remembered that it was seven minutes after receiving the initial call that he remembered to inform the doctor.

W: When did you call the Palmerston doctor?

T: Oh uhh, seven minutes after initial receiving the call.

W: How did [you remember it] so detailed?

T: But I remembered. Because I forget all about it. I was certainly assessing everything I had going, was just sitting there in the chair going, that's going, that's going. Great, Palmerston doctor. Oh shit!!

The retrospective approach was taken rather than a concurrent protocol analysis approach because the environment is simply too intense for the officers to verbalise their thoughts as the emergencies occur. In one situation, two duty officers received 10 '111' calls within a short span of 9 minutes! An analysis of the verbal protocols that transpired during this time would most likely describe the events as they occurred rather than the decision processes used by the officers.

While in most circumstances, the officers have to deal with a great number of emergency calls, situations that pose a major resource allocation problem appear to occur relatively infrequently in the Southern RCC. Thus the researchers would have to be at the RCC for a great deal of the time in order to witness such an occurrence. The CDM overcomes this problem. Furthermore, it was found that events described during the CDM interviews tallied with operational tape recordings of the events as they actually occurred.

Each 60 minute interview was divided into three segments. The first segment sets the stage of the interview by asking the interviewee to describe the procedures taken upon the receipt of a '111' phone call. The second segment constitutes the CDM, investigating the critical incident, what issues

and information were considered and how the decisions were made. The final segment of the interview investigated the information portrayal needs.

The interviews were transcribed and then a content analysis was performed on the transcripts using a piece of software called NUD•IST™ [6]. The software aids qualitative researchers in handling non-numerical, unstructured data by supporting indexing, searching and theorising.

The content analysis was directed at identifying the decision processes, including what was considered and at which points in the process the decisions were made. The decision process of each interviewee was modelled to show the depth of decision making, to provide a visual estimate of the size of the solution space, the decision strategy used, and a decomposition of the tasks to associate the information used to the various stages in the decision process and actions performed by the interviewee.

The technique used to model the process is called *DIAgramming* (Decisions-Information-Actions diagrams). This technique is an extension of Tainsh's [7] operational sequence diagrams which appeared to focus primarily on the human-computer interactions. DIAgramming extends the concept of actions to include any event that triggers or generates information, or is an action that is the result of some thinking or decision. These actions range from computer related tasks to communications with the '111' callers and ambulance officers or other emergency services staff. DIAgramming has also included intermediate decision stages such as changes in the state of knowledge and considerations made in the process of making the decision. An example is briefly discussed later in this paper.

The information analysis performed on the interview data was aimed at determining the task and display proximity of the information [8], i.e. whether information used together in a decision (task proximity) is portrayed together (display proximity) to facilitate their combined or integrated use. Also by DIAgramming the intermediate stages of the decision process, we are able to determine specifically when each piece of information is required. The analysis also attempted to identify the accessibility of the required information. Shepherd [9] had found that decision makers tended to do without or make assumptions about information necessary to a decision especially if the information is difficult to access.

The remainder of this paper will briefly report on some initial observations from this study.

6 Intense and Time Constrained Environment

One scenario that is representative of the workload in the RCC during intense periods has been selected for further investigation. The workload in the first nine minutes of the situation was so intense that many of the events that occurred were not documented in the computer until later. During that short span of 9 minutes, a total of 10 '111' calls were received by two duty officers. The calls related to three major road traffic accidents and one attempted suicide. The attempted suicide was eventually handed over to the Police to deal with. Interspersed with those calls were communications with ambulances and other emergency services. The details of these nine minutes, illustrated in Figure 2, are based on a careful analysis of a routine tape recording of operations. Each vertical block in Figure 2 represents 30 seconds.

From this analysis, ambulance operations control appears to function in a very intense environment. Many activities occurred simultaneously within a constrained period of time. During this initial nine minutes, six ambulances were controlled by the RCC. Further analysis of activities in the next hour showed that up to 14 vehicles attending to 5 separate incidents were coordinated by the RCC (not shown here).

The illustration only shows the receipt of calls and the initial despatch decision. The task of the despatcher does not end there. The despatch decision is the start of a long period of monitoring the performance and coordinating the resources as they transit to the accident sites, attend to the casualties, transport them to a hospital for treatment, and then return to the station. Because of the large distances involved, each despatch task can last for as long as one and a half hours, if not longer.

Data from the interviews indicate that the timeframe in which despatch decisions are made is very short:

- within the first minute of attending a call the officer must make a diagnosis of what has happened, what is wrong, what is needed, and where to send the ambulance.
- In the next 2 - 2.5 minutes, the officer must plan and organise the resources to be despatched.
- The ambulance should be on the road within 5 minutes of receipt of the 111 call. In the previous example the first ambulance was dispatched three minutes after receipt of the call.

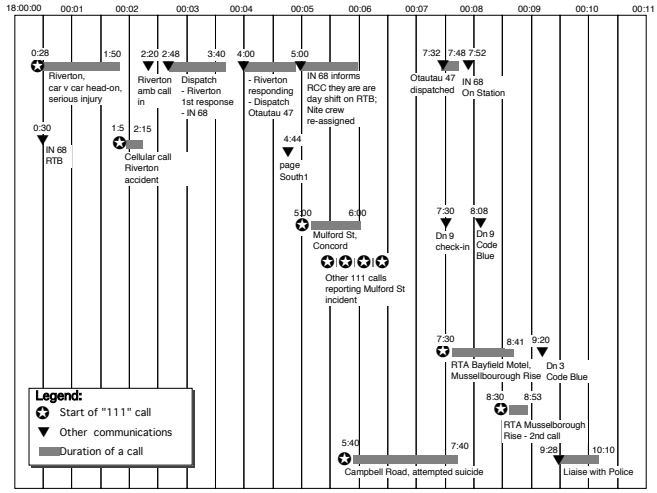

Figure 2: Summary of events that occurred between 1800h and 1810h on Friday 10 Mar 1995

Stressors during that period include the many tasks that are required of the despatcher - typing, communicating with the ambulance, communicating with the caller to ensure all necessary details are obtained (e.g. what's wrong, where is the accident, number injured, extent of injury), determining what's needed and where the resources should be sent from, and in some cases, having to instruct the caller in CPR (cardio-pulmonary resuscitation) over the phone.

> *T: Too many things are happening at once, and you if you imagine one person, being with a computer it would have sent out one command at a time, if you have got two people doing two different commands at a time, the information can go out a lot faster. ... When you are here by yourself you have to do a multi-tasks away from the computer, telephoning people, doing radio work, you are not actually on keyboard, updating the information.*

If the situation involves only one call, it is usually manageable. However, in instances when several calls are received in a short space of time, as in the above example, an additional despatch officer where available is called in to assist with routine or non-emergency calls that relate to other parts of the region that must be attended to as well. The consequences of this high stress is that often what is perceived as the least important or the more involved task will get left undone until the pressure eases.

> *T: A classic would be those vehicles arrived, before you had the job on the screen.*

It appears the task of keying in data into the computer is one such task. Data that get left until later include updating the vehicle status. There presently appears to be no serious loss of effectiveness as a result of this lack of action.

7 Problems are Ill-defined and Unstructured

Unlike laboratory experiments, the problems faced by the despatchers are largely ill-defined and unstructured. One of the first things that the despatchers do on receipt of a '111' call is to determine what has happened or what is wrong. The despatcher attempts to structure the problem by asking a series of questions to eliminate unlikely conditions. An extract from the transcript of one of the interviews will be used to illustrate this.

> *T: OK. We question him to a point. We don't let the caller rabbit on. Now , our purpose is to control the conversation. We ask the questions and we want him to answer. Sometimes we have to be forceful to get the information out of the people instead of letting them rabbiting on about information we don't really want to know or what has been happening about what's back home.*
> *... Um, for now what we ask for is what exactly happened. By that what we don't want a blow by blow description of what they were wearing or going past the incident we want to know what's happening now. A simple car accident were two cars collided someone fell off a motorbike, or someone's having chest pains, or having trouble breathing because of asthma, or might be something very basic ... at this stage.*

The diagnostic process of determining what has happened is made more difficult because often the caller is incoherent, or may be unable to identify the proper symptoms necessary for making the initial diagnosis. The following is extracted from an incident reported during another interview.

> *M: The caller was very difficult to understand. ... Umm, I was trying to find out about the person who had collapsed, were they conscious, were they breathing, and the gentleman was really difficult to understand and eventually got that the patient was flushed or red in the face, and that told me they were probably conscious, not a cardiac person who would have been blue or if they had a major bleed would they be white. So that told me that the person was probably conscious, and that took the edge off a bit.*

While a cursory examination of the interview data suggests that a person with limited medical knowledge could possibly diagnose the situation, it would be unwise at this stage to conclude without further investigation the medical knowledge requirements and their impact on the despatcher's ability to diagnose the criticality of each case. An appropriate diagnosis of whether the case is life-threatening or not, will determine the priority and the kind of medical aid, with which ambulances are despatched.

8 Small Solution Space (*m* x *n*)

The size of the solution space of a problem can be estimated by (*m* x *n*), where *m* is the number of possible alternatives and *n* the number of dimensions in each alternative. Once the diagnosis of the medical state of the patient is performed, the subsequent decisions appear to be less complex.

The cognitive task analysis of the ambulance control decision-making process indicated that a single option (*m*=1) is generated based on the despatcher's recognition of key characteristics of the situation. These characteristics are the nature and seriousness of the incident, location of the incident, and the location of the nearest stations to the accident site.

Once the nature of the incident has been determined, deciding what resources are needed is not an issue. The nature and seriousness of the incident determines the need – how many ambulances are to be despatched. During this decision process, which is almost immediate, the following factors or dimensions are considered (*n* = 3)

- type of rescue vehicle (helicopter, 4WD, or standard ambulance)
- number of ambulances needed
- type of crew needed

> *W: How do you know you needed four vehicles.*
>
> *T: Seven injuries, 3 of which were probably serious, that's, each vehicle can carry two people, so I've got seven patients, which is almost eight, which is four trucks.*
>
> *… Um so seven patients for an emergency response, and you also want if its serious three extremely qualified ambulances for a start, you want as many paramedics as you can get to the scene as soon as possible.*

The location of the incident would immediately eliminate from consideration the stations that are not in the vicinity of the accident. This process of elimination significantly reduces the number of options from the decision process.

The next stage of the process is determining which ambulances from that station or neighbouring stations are available. In most instances, this choice is limited:

- which are the nearest stations?
- what resources are available at these stations?
- can they be used or have they been committed to other jobs?

> *W: How do you know you had to take the ambulance from Oamaru?*
>
> *T: That was the closest, the closest one we've got. The Goodwood Straight is north, northern motorway, on the way to Oamaru. You've only got ambulances in Dunedin and Oamaru, there is nothing in between. So I can't pull anything from anywhere to go to it. So I'd stripped Dunedin I knew Oamaru had three vehicles and they could afford to lose one plus the one from Mosgiel. If Mosgiel hadn't been in Dunedin there would have been two trucks from Oamaru on the system, just with the time saved by having one already in Dunedin, you needed only one.*

Once the problem has been diagnosed, the despatcher only evaluates principally one option (m=1) and only on a small number of dimensions (n = 3). Thus the job of the despatch officer is characterised by an intense series of frequent decisions of small solution spaces. Therefore in terms of information portrayal requirements, information access for this task will need to keep pace with the rate at which it is used.

9 The Decision-Making Process and Strategy

The decision processes of the interviewees were modelled in an attempt to identify the type of decision making that was involved. For the purpose of this paper, one of these models will be used to illustrate the decision making process. This model represents a two car head-on collision on the Goodwood Straight, a stretch of road between Dunedin and the town of Oamaru. There were seven serious injuries. Part of the decision process is DIAgrammed in Figure 3.

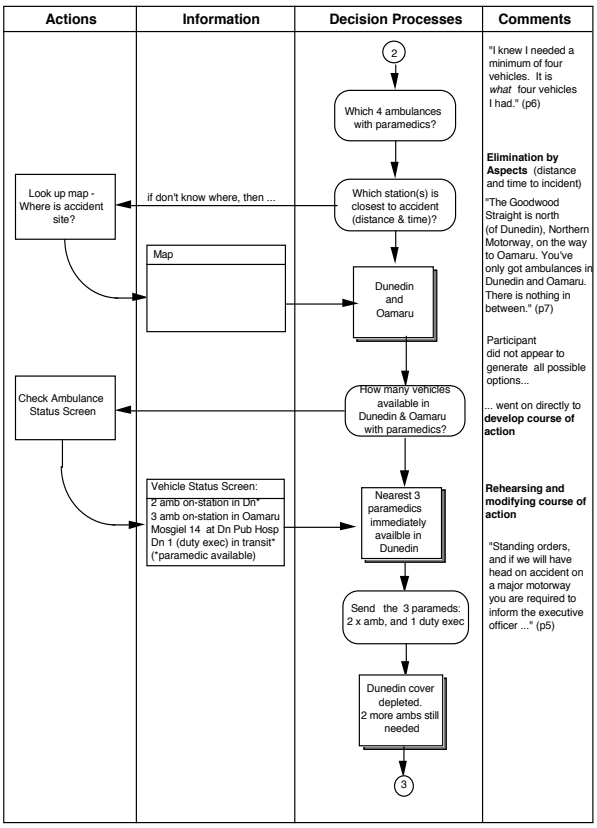

Figure 3: *DIA*gram of Decision Process of Interview #2

Following the assessment of the patients' medical state, the despatch officer had immediately assessed a need for four ambulances. Standard procedures dictate that the Duty Executive Officer from Dunedin would also be sent to the accident scene. The decision to be made was *which* four ambulances to send.

Knowing where the accident occurred, the despatcher immediately eliminated from consideration all those stations that had no responsibility for accidents occurring in that area, therefore narrowing the considerations to only what was available in Dunedin and Oamaru. Furthermore, these stations were closest to the accident.

Glancing at the Ambulance Status Screen on his computer, the despatcher first identified what was immediately available at Dunedin: two ambulances were available on station; another ambulance from Mosgiel was available at Dunedin Hospital; the Duty Executive was on his way back to the station after attending to another accident. One more ambulance was still needed, and Oamaru with three available ambulances, was the obvious choice as it was the next closest station to the accident site.

After considering the impact of depleting the ambulance coverage in Dunedin, and mentally rehearsing the plan, he made the decision to despatch all that was immediately available and to activate a recall of off-duty personnel to the Dunedin station. Several observations can be made about this decision process.

- There was no evidence that the despatch officer developed multiple options which were evaluated on the respective dimensions ($m = 1$). There was also no evidence that weights were assigned, nor any means of calculating a optimal solution was involved.
- One option was generated: Send what was immediately available from Dunedin. This option was developed based on a recognition of key aspects of the situation. This option was subsequently mentally rehearsed to see if the plan would work. As the despatcher further assessed the disposition and availability of the ambulances the plan was modified to include an Oamaru ambulance. This decision process appears to resemble Klein's Recognition-Primed Decisions [10].
- A process of elimination based on the key aspects of shortest response time and on area of responsibility was observed to have been used to reduce the number of possibilities to consider when developing the plan ($n = 1$). Such a strategy is called the lexicographic rule.

10 Implications for Information Portrayal

10.1 Accessibility and Search Strategy

The intense and time constrained nature of the decision making environment suggest that information that is critical in the decision making should be easily accessible, i.e. it should be available immediately, at the fingertips or displayed on system. The following transcript suggests this is not so.

> *T: ... most information is easy, it's just slightly involved in getting it.*

The despatcher should not have to spend more time than is necessary, or be engaged in protracted procedures, in order to retrieve information required by the decision. For example, in the current system, the despatcher has to work through five different computer menu changes in order to access the screen that gives directions on how an ambulance might travel to a particular address.

T: You actually have to drop out of it. If you imagine your main working screen is Alt-F2 and it gives you your emergency and patient screens. If you want to get into the [streets] database, you go Alt-F1 and which you lose completely in order to have that information in front of you and it just has a menu screen which you choose "Utilities". And under "Utilities" you have another five going there, and when you get there you've got to switch to the little brown boxes on the screen. So anytime you have any of these other functions you don't have access to the information on the screen. So if you're looking at the streets you don't know how its spelt, you lean over to your mate and say, "Can you tell me how the street name is spelt on the screen?".

10.2 Task and Display Proximity

Wickens' Proximity-Compatibility Principle predicts that if information is used together in the making of a decision (task proximity), then it will benefit the decision maker to have these bits of information displayed together (display proximity). Wickens identifies five levels of task proximity:

- Close proximity. Information is integrated into a common variable,
- Medium/High Proximity indicates information is used together in the same decision but not integrated,
- Medium Proximity indicates that information about two related tasks is considered together,
- Lower Proximity indicates information used in separate tasks of the same higher level goal,
- Low proximity is where the information being considered is for unrelated tasks.

The information used to determine which ambulances to despatch to the accident scene has a Medium/High level task proximity. The information is used together or combined but not integrated into a common variable. In the current system, Ambulance Status information is divided across two displays. The first display represents the more frequently assigned stations, and the second contains the less-frequently assigned stations. Hence, stations that are geographically next to one another may be displayed on a separate screen. This increases the effort required for the task of comparing ambulance and crew status between neighbouring stations, as was when the despatcher needed to decide between sending Dunedin or Oamaru-based ambulances.

Since many decisions are geographically related, e.g. an accident occurs near Queenstown, a display design based on the proximity-compatibility principle that takes geographical disposition of the stations into account has been proposed (Figure 4). Each box contains information about ambulance status at each station. The boxes are portrayed according to the relative positions of the stations as

they occur on the ground. This is to facilitate the task of visually comparing ambulance availability between neighbouring stations. The lines linking the boxes represent the highways connecting each station. These lines provide orientation information to make it clear which stations are immediate neighbours.

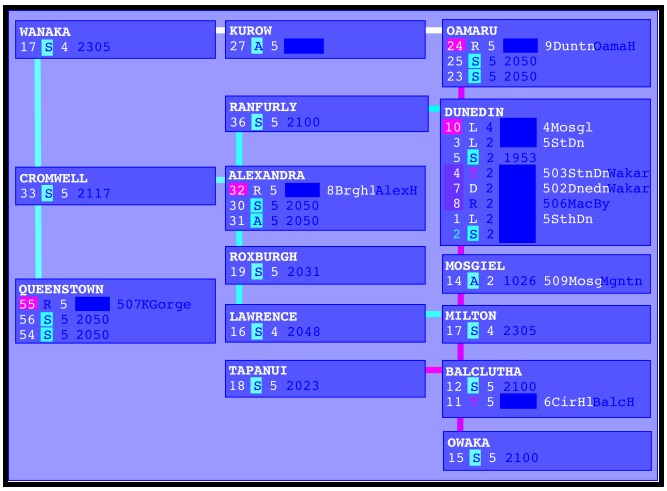

Figure 4 Proposed Ambulance Status Screen based on Relative Geographical Dispositions and Proximity-Compatibility Principle

11 Conclusion

In describing the decision making environment, we have seen that the tempo of emergency callouts, or the rate at which they occur, is very high during peaks. It is towards these intense peaks that this research programme is directed, since if the officers had all the time they needed to read and interpret required information, the manner in which information is portrayed would be of limited concern.

It is proposed that performance can be improved if information is portrayed in a manner that supports the decision strategies employed by the Communications Officers in these dynamic environments. One design approach is to display information which must be considered together in decision making in close physical proximity on the display. Further investigations will be conducted to evaluate the appropriateness of such a design.

Acknowledgments

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