A DECISION SUPPORT SYSTEM FOR HELICOPTER EMERGENCY MEDICAL SERVICE OPERATIONS

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Keywords: *DSS, HEMS, decision, support, helicopter*

Abstract

Helicopter emergency medical services (HEMS) operate around-the-clock, in all-weather conditions, and often with no fore-warning. In a time critical operation, where precious minutes may cost lives, the crew must decide which cases dictate a HEMS response and if so, whether the conditions are safe to conduct the mission.

This paper provides an overview of the current research into developing an intelligent system which is capable of supporting the decision-making processes faced prior to aero-medical operations.

1 Background

This research has been conducted in collaboration with Air Ambulance Victoria as part of Australian Research Council Linkage Project LP0347412. The aim is to develop an intelligent system to support the pre-mission analysis of helicopter emergency medical service (HEMS) operations.

Ambulance services are responsible for saving lives by providing pre-hospital medical care and transporting critically ill or injured patients to appropriate facilities for treatment. HEMS are the part of that service that utilises rotary wing assets for patient care and transportation.

The helicopter is recognised for its unique ability to reach remote areas, often in difficult terrain [1-4]. This capability has made it highly valuable in the recovery, resuscitation and transfer of critically ill patients to major hospitals and in the search and rescue of people at land and sea. In the early 1950's during the Korean War, helicopters were successfully used to evacuate wounded soldiers and their use was expanded during the Vietnam War with significant decreases in mortality. In 1968, based upon the military experience, the use of civilian helicopters to transport patients was suggested and civilian HEMS operations began shortly thereafter [4-7].

The life saving capability of the helicopter is reflected in the world-wide growth of HEMS operations [1, 2, 5, 6, 8-10]. The first dedicated Australian HEMS operation began in December 1970 servicing the Mornington Peninsula [7]. Since then, HEMS operations within Australia have grown considerably; the annual number of aeromedical transports by helicopter increasing from 1,278 patients in 1992 to 6,982 patients in 2002 [11]. HEMS now operate in all Australian states and territories except the Northern Territory.

Air Ambulance Victoria is part of the Metropolitan Ambulance Service and is responsible for aeromedical services within the state of Victoria. Air Ambulance Victoria commenced operations on 1 May 1962, with the role of supporting the Victorian Ambulance Service in the urgent and non-urgent transportation of patients over long distances. Today Air Ambulance Victoria wet leases four dedicated Beechcraft Kingair B200C aircraft and three dedicated aeromedical helicopters: one Eurocopter Dauphine N3 and two Bell 412 EP [12].

Air Ambulance Victoria's three helicopters are based Essendon, Latrobe Valley and Bendigo (Fig. 1) with the primary role being to provide:

- rapid transport of time critical, medical, surgical and trauma patients;
- rapid primary response of paramedical personnel and equipment to an incident or location; and
- access and/or removal of patients from remote or inaccessible locations [12].

Fig. 1. Air Ambulance Victoria HEMS bases

Operational safety is a central concern in the HEMS industry; weather, night time flight, spatial disorientation from the lack of visual clues, pilot training and experience, and pressure to take the flight are all risks associated with HEMS operations [1, 5, 6, 9, 13-17]. Safely operating in this high risk environment calls for the systematic evaluation and management of the risks [13].

A recent study found that in America the risk of death for a HEMS crewmember (per hour engaged in the activity) was similar to that of rock climbers and skydivers [16, 18]. Australian HEMS operations are not immune to risk. For the period 1992-2002 the accident rate for HEMS operations in Australia was 4.38 per 100,000 flying hours, and the accident rate for HEMS operations in the state of Queensland was 25.03 per 100,000 flying hours [11].

Australian HEMS operations are perhaps further complicated by the vast distances and the predominantly hot conditions, which challenge both aircraft and crew performance [18]. Adding to this Australian HEMS are generally required to fulfil multiple roles, performing critical care inter-hospital transfer, land-on-scene response, hoist operations and search and rescue (SAR). In North America and Europe, there is generally a distinction between hoist and SAR operators and those who undertake inter-hospital transfers and land-on-scene response [18].

2 Problem Definition

The high HEMS accident rate has prompted HEMS operators across the globe to address the management of risks inherent to their operations. In-flight decision-making, pre-flight planning, failure to follow standard operating procedures, delayed remedial actions, and misinterpretation of environmental cues are all areas that have been identified as needing to be addressed for safe HEMS operations [17].

HEMS operations are complex, being a joint exercise between the flight crew, paramedics and supporting agencies. Operations occur around-the-clock, in all-weather conditions, and often with no fore-warning. In a time critical operation, where precious minutes may cost lives, the crew must decide which cases dictate a HEMS response and if so, whether the conditions are safe to conduct the mission.

The primary goal of HEMS is to provide rapid and safe transport for critically ill or traumatised patients to an appropriate care facility. Each helicopter flight requires an initial dispatch decision with full awareness of the risk factors for the mission [19]. The decision to cancel, delay or launch must be based upon a sound and complete analysis of all available information.

This decision making process is compounded due to the disparate mission requirements, operational environment, crew capability and machine performance. Most HEMS operations are minimally planned with decisions usually being made 'on the fly' [20], with operators depending upon the crew and their experience to perform pre-flight planning. Given the operational environment and emotional stresses, HEMS operations are susceptible to human error which can ultimately produce accidents [15-17].

In an effort to reduce risk of HEMS operations the American Federal Aviation Administration (FAA) recommends and the Helicopter Association International (HAI) endorses the utilisation of an operational risk assessment tool to include dual decision-making for authorisation to accept or continue a HEMS mission [21]. Despite this, investigations have revealed that many HEMS operators lack a consistent, comprehensive flight dispatch procedure to assist pilots in determining the safety of a mission [13]. Subsequently the need for intelligent systems to reduce the likelihood of erroneous decisions in the pre-flight planning phase of HEMS operations has been identified [21-31].

Working in close collaboration with Air Ambulance Victoria this research aims to prototype an intelligent system for the pre-mission analysis of HEMS operations. This research will address the key problem of pre-mission analysis, by developing a system which will assist flight-coordinators and crew in the decision-making processes faced prior to HEMS operations.

3 System Framework

Thompson [20] emphasises that HEMS operations are inherently risky and minimally planned with decisions usually having to be made 'on the fly'. Most operators and crew adopting an informal approach, doing it on the run, often using experience and 'gut feel' to make decisions. The high level overview of the current decision making process is presented in Fig 2.

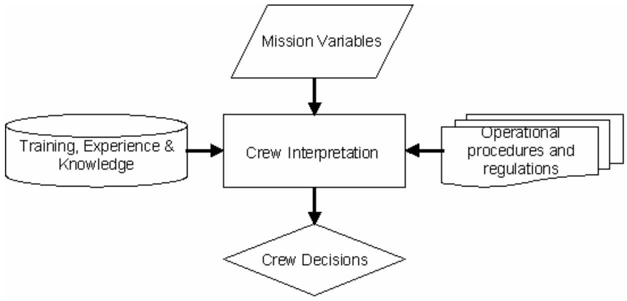

Fig. 2. Current decision making process

Intelligent systems are mathematical, computationally intensive problem solving tools and methodologies which utilise computers to emulate various aspects of human intelligence. Intelligent systems generally fulfil two roles: (1) they function as intelligent assistants to augment human expertise; and (2) they act as a substitute for human expertise that saves cost, time, and life. Intelligent systems have demonstrated that they are ideally suited for tasks such as search and optimisation, pattern recognition and matching, planning, uncertainty management, control, and adaptation [32]. They offer an advantage in that they are generally reliable; they do not become tired or bored, call in sick, or go on strike. Intelligent systems consistently pay attention to all details and so do not overlook relevant information and potential solutions [33].

Intelligent systems are embedded in almost any application where information needs to be processed to provide a usable output [32]. Intelligent systems are already used to assist in decision making, planning and scheduling [34-43]

The need for decision support systems (DSS) comes from the well-known limits of human knowledge-processing. Humans are limited to manipulating about seven pieces of knowledge at any one time; and the stress, errors and oversights that can result from being overloaded with knowledge are just as detrimental as not having enough knowledge [44].

Since the early 1970s, DSS have evolved significantly; progressing from advancements of theory to serious applications [45, 46]. DSS are used extensively in transportation, the military and space to assist in decision making, planning and scheduling [34, 37-39, 41, 47, 48]. Defence Research and Development Canada (DRDC) have developed SARPlan, a DSS for overland aeronautical SAR mission planning. The system aids the SAR mission coordinator in planning the search mission more efficiently and produces an optimized plan for deploying the available search effort that maximizes the probability of success [47]. Another scheduling DSS is SYNOPSE which has the ability to evaluate cargo airline flight schedules, with respect to cost, revenue and contribution to profit [39]. Likewise, TurboRouter is an optimization-based DSS for vessel fleet scheduling [48].

Sinha et al. [22-31] developed a conceptual framework for an intelligent system for pre-mission analysis of HEMS operations in order to reduce the probability of errors in the pre-mission analysis phase. This work suggested that available mission capabilities be compared against required mission capabilities to quantitatively determine the probability of mission accomplishment and to suggest actions to address the shortfalls in the required mission capabilities.

This work provided a foundation on which to base this research and develop a system that can assist AAV's flight-coordinators and crew in the pre-mission decision-making process. In conjunction with AAV this previous work has been developed and revised in order to accurately reflect the decision making process. Consultation with pilots, crewmen, paramedics, flight coordinators and AAV management has been undertaken to establish tangible and achievable requirements for the system which allow the original framework to be developed into functional system. Top level factors identified for consideration in pre-mission analysis for AAV operations are presented in Table 1.

Table 1. AAV pre-mission analysis factors.

Analysis Factors	
Medical	Operational
• clinical urgency • clinical details • clinical requirements • paramedic crew	• meteorological conditions • location & landing areas, including alternates • range & fuel • lowest safe altitude • flying/recovery crew • resource performance

Aven and Korte [49], contrast two different approaches to decision making: (1) Decision-making as an exercise of modeling alternatives, outcomes, uncertainty and values, and choice of the alternative which maximises/minimises some specified criteria. (2) Decision-making as a process with formal risk and decision analyses to provide decision support, followed by an informal managerial judgment and review process resulting in a decision.

Following the review of AAV operations, a framework which augments human expertise and aids the decision-making process has been adopted Fig.3. The system is to be work-centered, in that it will find, fuse, format, present information, and respond to user requests [50].

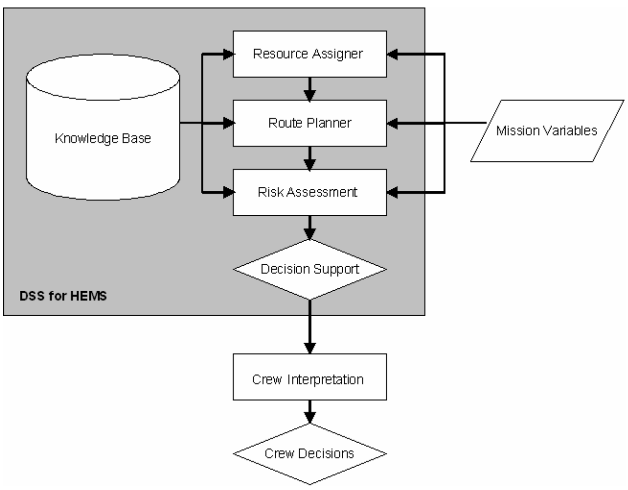

Fig. 3. Proposed decision making process

3.1 Resource Assigner

This new framework is divided into three primary modules, a "resource assigner" module a "route planner" module, which reflect the two distinct phases in AAV's pre-mission decision making process, and a risk assessment module. In each module rule-based algorithms exist that reflect AAV operating procedures and safety regulations, and notify the flight coordinator/pilot of non-compliance.

The "resource assigner" establishes a priority for each mission, based on the patient's location and condition, and assigns the most appropriate resource to the mission, based upon resource availability, priority, time and level of care. Using their judgment the Flight Coordinator has control to change the level of priority and/or assign any available resource.

3.1 Route Planner

The "resource assigner" passes information to the "route planner" which creates a flight path tailored to the mission. The flight path is segmented and bounded by mission defined points. These include accident scenes, helicopter landing sites, airfields, hospitals and refuelling points. Based upon the patient location and injuries the route planner will automatically define the flight path, with the operator having control to edit or change any or all of the specified points. Based on the flight path the route planner informs the pilot, of expected meteorological conditions, NOTAMs, estimated arrival times, fuel consumption and IFR lower safe altitudes for the mission. Following a review of this briefing the pilots must use their judgment to make a decision as to the safety and success of the mission.

3.3 Risk Assessment

The risks associated with HEMS operations must be identified, assessed and managed, to ensure they are mitigated, deferred, or accepted according to the operator's ability to do so within the regulations. The FAA and HAI recommend the utilisation of operational risk assessment tools, such as risk matrixes, in the pre-mission analysis of HEMS operations. Yet, recent investigations have revealed that inadequate risk assessment may have contributed in many recent fatal HEMS accidents [51].

To provide HEMS organisations with appropriate risk management tools, the FAA EMS Task Force, with the assistance of the air medical community, developed Notice N8000.301 "Operational Risk Assessment Programs for Helicopter Emergency Medical Services." This notice encourages the use of weighted risk assessment and management processes matrices but emphasises that individual HEMS operators should consider their own operational and environmental needs in developing and implementing risk assessment tools [51, 52].

At present the system is designed to find, fuse, format and present information pertaining to the proposed mission. The pilot must then review this information and use their judgment to make a decision as to the safety and success of the mission.

Research is currently focusing on incorporating and automating either a procedure-weighted or training-weighted risk assessment matrix into the system. This will allow the system to judge the level of risk for a particular mission and alert dispatchers and flight crew if it is beyond operational limits.

Difficulties exist however as there is no "one size fits all" matrix and individual HEMS operators need to consider their own unique operational and environmental conditions in establishing the specific weighting of risks. There is also some concern that pseudo-quantitative numerical risk scores and matrices can be easily manipulated to obfuscate the real risk level [20].

4 Discussion

Previous research efforts have been directed towards developing functionality and methodologies capable of meeting these requirements and module objectives. This has included the ability of the system to:

- convert map references to GPS coordinates,
- cross cross-check icing level with lower safe altitude,
- determine case priority,
- automatically prepare flight plans including refuelling,
- determine the required level of patient care,
- re-task resources to higher priority missions,
- co-ordinate a multiple resource to response (i.e. rotary and fixed wing), and
- calculate lower safe altitudes.

Research and development continues on integrating all of the above into a prototype decision support system, capable of supporting both the resource allocation and flight planning phases of AAV's HEMS operations. This prototype will then be tested in conjunction with AAV to measure the merits of such a decision support system and to provide feedback for the future commercial development of such a system.

5 Concluding Remarks

HEMS are hailed for their life saving ability, having been shown to improve the survival of many patients with medical and trauma emergencies [1, 3, 5, 53-58], yet the high accident rate threatens the very existence of HEMS operations [59]. This research targets an operational capability deficiency in HEMS operations, and focuses on an identified application.

Intelligent systems are an emerging field offering benefits to a multitude of applications. The research forms a comprehensive investigation of the application of "intelligent systems" to the pre-mission analysis of HEMS operations. The research will culminate in the development of a prototype intelligent system capable of assisting in the pre-mission analysis of HEMS operations. The system will support flight coordinators and crew in the decision-making processes faced prior to HEMS operations and deliver improved emergency medical services to the Australian community.

An initial dispatch decision must be made with full awareness of the risk factors for the mission. The system will reduce the risk of HEMS operations by assisting operators during the decision making process. The system provides a consistent, comprehensive flight dispatch procedure to assist in determining the safety of a HEMS mission. Ensuring the go/no-go decision is not based on feelings but on facts and confirming adherence to regulations, industry safety recommendations and operating procedures.

It is important to ensure that HEMS resources are appropriately utilised. Studies confirm that inappropriate use increases cost and risk of injury and results in potential transport delay or unavailability of the aircraft for other requests [53]. The system will assist HEMS operators in managing the utilisation of their resources and ultimately improve the efficiency of HEMS operations by streamlining the pre-mission analysis and decision making processes.

The HEMS community has acknowledged globally, the need to develop systems, to address the pre-flight planning and effectiveness of HEMS missions. The approach taken to developing the system with Air Ambulance Victoria means that it can be easily adopted by other HEMS operators for integration into their flight dispatch procedures.

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