AIR MEDICAL EVACUATION AND SURVEILLANCE SYSTEM

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The helicopter and trained paramedics operating in the rural areas of Arizona in 1969 and 1970 in a multidimensional role as an airborne force to provide definitive treatment and reduce patient transport time for highway accidents (the evacuation mission) and as a deterrent force to reduce traffic accident potential (the highway surveillance mission) were demonstrated and evaluated. When they were used in patrol and surveillance operations, there was a statistically significant reduction in driver behavior characteristics that are accident-related. The helicopter must be evaluated with regard to its total operating capability of performing medical evacuation, patrol and surveillance, and general law enforcement. It cannot be economically justified when used to perform only 1 type of mission.

•A HIGHWAY accident is a multidimensional problem composed of man, machine, roadway, environment, and their interrelationships. The traffic accident fatality rate per 100 million vehicle-miles has decreased by a factor of 3 in the last 40 years and has stabilized between 5.2 and 4.7 for the last 10 years. However, in 1971, 54,700 persons lost their lives, 2 million persons were injured, and 170,000 of the injured suffered permanent physical injury (1). Arizona had 1.6 million registered motor vehicles in 1971 and over 13 billion vehicle-miles of travel (VMT). This VMT represents an increase of more than 10 percent since 1970. The fatality rate in 1971 was 5.73, which was somewhat higher than the national rate. There were 751 traffic deaths and over 28,000 traffic injuries in 1971 (3).

This unfortunate situation has developed although vehicles, highways, training, and law enforcement have improved throughout the nation. More effort must be devoted to giving accident victims more chance of survival and recovery and less chance of permanent injury.

One contribution of the Air Medical Evacuation System (AMES) has been in accident prevention but its most important contribution has been in its postaccident activities that improve the rate of survival for those involved in highway accidents.

The experience of the U.S. Army indicated that air evacuation of the wounded was a most significant factor in reducing the death rate from 4.5 per hundred wounded in World War II, to 2.5 per hundred wounded in Korea, to less than 1 per hundred wounded in Vietnam. During World War II, no wounded were evacuated from the battlefield by air; in Korea, 15 percent of the wounded were evacuated from the battlefield by air; and, in Vietnam, 90 percent of the wounded were evacuated by helicopter to sophisticated medical facilities (6). It was thought that this method, which caused a dramatic decrease in the military death rate, might be applied to assisting the victims of motor vehicle accidents.

CONCEPT

It was planned that AMES would be used for roads and recreation areas with high accident histories. There would be helicopter rescue teams on ground alert, others on airborne surveillance, and computer-assisted dispatchers. When an accident occurred, one of the AMES teams would be directed to the scene.

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At the scene of the accident, a specially trained 2-member team would rescue, sort, and treat the injured by need. The injured would be evacuated to the nearest medical facility capable of providing definitive treatment. The AMES team would have direct radio communication with a medical consultant who could advise on emergency treatment measures to be taken at the scene or en route to the hospital. After the casualties had been delivered to the hospital emergency room, the AMES helicopter would return to the accident site, to another patrol route, or to the base.

Primarily, the system was to provide quick response to an accident particularly in rural and remote areas. Secondarily, AMES was to be an alternate means for highway patrolling and law enforcement; an aid to improved accident investigation; a base for civil defense and disaster systems; and a model for use by other states or communities.

OPERATIONS

The AMES mission was derived from a combination of the assigned missions of the U.S. Army Air Ambulance Operations, the U.S. Air Force Rescue and Recovery Service, and the definition of the AMES concept originally established by the study team. The 3-part mission of AMES was to

1. Rescue in the shortest possible time persons injured in motor vehicle accidents or other accidents within Arizona, especially in rural and remote areas;
2. Preserve the lives of injured persons through competent emergency first aid at the accident scene; and
3. Transport the injured from the accident site to the nearest medical facility capable of providing definitive treatment.

Although AMES was developed primarily for evacuation missions, general law enforcement operations and accident prevention operations that resulted from surveillance operations were also tested. Operational plans, therefore, included all AMES missions.

The range and speed limitations of the helicopter and the need to reach casualties as quickly as possible limit the distance over which it can operate effectively. The environmental conditions that limit the operational effectiveness of AMES are the size (341 by 396 miles) of Arizona and its topography. Helicopters considered for the AMES mission had an operational radius of approximately 150 miles at a constant altitude of 5,000 ft. The realistic average range of the AMES helicopter would be 150 miles although there might be a wide variance in range for a given time. It then became apparent that 1 centrally located AMES group could not serve the entire state because the maximum area the helicopter could cover would be only about 71,000 square miles of the state's total of 113,600 square miles.

EVALUATION

This portion of the planning activity involved developing procedures to measure the effectiveness of the AMES operations in accomplishing specified objectives.

Some of the benefits expected of the AMES program during the original study conducted by R. L. Sears included a reduction in patient incapacitation from injuries received in motor vehicle accidents (days lost from normal activity because of hospitalization, immobilization, or pain and diminished functional or cosmetic results because of delays in treatment); a reduction in motor vehicle accident mortality rates; and a reduction in the number of motor vehicle accidents (6).

It has been generally accepted that people die or are subjected to more serious injury because of delay between injury and competent medical treatment. Air medical evacuation and specially trained paramedic teams offer real potential for reducing this problem.

Determining which remedial program, or combination of programs, to implement in a state like Arizona should be based on the relative cost and effectiveness of various programs. The AMES demonstration provided cost and operational data for a particular level of implementing a helicopter evacuation system. From these data, estimates were made for the cost-effectiveness of different levels of AMES implementation.

Cost-effective implies that the benefits derived from a system must be measured in dollars. It is difficult to assign monetary values to the cost of a life or to assign a value to mental suffering. In a classical analysis of cost-effectiveness comparative, not absolute, cost-effectiveness figures are used. If these same relative values are used in measuring the effectiveness of all systems being studied, the relative worth of each system can be judged with some validity.

To determine the reduction in patient incapacitation, the following data were collected on each injured person evacuated to a medical facility by an AMES helicopter:

1. An estimate by the attending physician of any time delay in definitive treatment that may have resulted in 5 or more days of increased hospitalization;
2. Difference in time between arrival of the AMES helicopter at the scene of the injury and the estimated arrival of a ground ambulance at the same scene;
3. Difference in time between the arrival of the AMES helicopter at the receiving hospital and the estimated arrival of a ground ambulance at the same hospital; and
4. Difference in time between the arrival of the AMES helicopter at the receiving hospital and the estimated arrival of a ground ambulance at the hospital nearest the scene of the injury.

To determine whether an AMES mission saved a life, the same data collection procedure was used. If the difference between the mission time of AMES and the estimated mission time of a ground ambulance would have resulted in death according to the physician, then the AMES demonstration was credited with the possible saving of a life. The number of possible saved lives was another measurement of the benefit of early arrival on the scene of injury or at a hospital and would assist in the determination of acceptable air or ground ambulance response times.

Highway patrolling by AMES was limited by helicopter capabilities and costs to 8 or 10 hours of flight per week. The natural variability in accident frequency over relatively short stretches of road, at restricted times, is such that any observed change during the hours of patrolling could not be attributed solely to AMES. The observed rate might have occurred purely by chance. AMES effectiveness was analyzed by considering causation factors as discussed in the surveillance section.

The following are tasks, other than those involving medical evacuation, that were also performed by AMES:

1. Location and rescue of lost or trapped persons;
2. Transfer of patients between hospitals when movement by ground ambulance would be hazardous to their survival;
3. Delivery of critically needed medical supplies—drugs, whole blood, or blood products;
4. Transfer of premature infants to special nurseries; and
5. Traffic control, fugitive searches, and general law enforcement.

The value derived from each mission depended on the time required to accomplish the mission, the cost of accomplishing the same mission by some other means, and the possible savings in human suffering. Although the frequency of any 1 type of mission might be small, the total benefit proved significant because the helicopter flew many types of missions. Care was taken to avoid including, in a final tally of benefits, missions that could have been accomplished economically and within allowable time limits by other means.

A cost and operation effectiveness evaluation was conducted to develop the following:

1. A cost model of an air medical evacuation system;
2. A measure of system use for different types of missions; and
3. A measure of the operational effectiveness of the system.

DEMONSTRATION

Actual flight operations were conducted for a period of 9 months. The categories of flight missions were

1. Evacuation,
2. Transfer of patients, including premature infants that required special care,

from 1 hospital to another;

3. Search for missing vehicles, missing persons, and criminal suspects;
4. Surveillance of major roads for traffic violations, unsafe conditions, and unusual happenings; and
5. Other (training, public relations, demonstration, and support).

Data for evacuation and transfer missions are given in Table 1. The largest number of missions flown (81) was for highway accidents and the largest number of hours flown (134) was for hospital transfers. Highway accident flights averaged 1 hour and hospital transfer flights averaged 2.28 hours. Average flight time for the 213 evacuation/transfer missions was just under 1.5 hours. Total cost for evacuation and transfer was slightly less than 26 percent of the total cost of the program. Average cost per patient evacuated was $288. The highest costs for transporting of sick and injured persons were in hospital transfer operations. Many of these people had been injured in highway accidents and were in such critical condition that they had to be moved to special care centers in Phoenix or Tucson. A total of 225 persons were carried in the AMES helicopters. The distribution of these persons by type of mission is given in Table 2.

A summary of all missions (824) flown during the AMES program is given in Table 3. The flight phase of the program involved 1,185 hours of flight time and cost $251,220. According to distribution of flight activity by type of mission, over 63 percent of all flights and over 64 percent of all flight time involved surveillance. Medical evacuations and hospital transfers accounted for just under 26 percent of all flights and all flight time. Search and other missions accounted for the remainder.

The operating cost of the total system depends on the number of flight hours per month. To operate a system equivalent to the demonstration project would cost $212 per hour for 150 flight hours per month. If flights were increased to 200 per month, the cost per hour would be $200. But the real value of the AMES role in medical evacuations lies in time savings. An average of 41 minutes per patient was saved compared to the time necessary for conventional ground ambulance service.

The high initial investment, personnel requirements, and operational characteristics of helicopter systems combine to make this type of program unsatisfactory if its only purpose is evacuation.

SURVEILLANCE

Objective

The original objective of the AMES surveillance program was to determine the helicopter's effect on accident rates. But, because of the limited number of patrol hours and the random occurrence of accidents, an emphasis on this effect would have had little significance. It was decided, then, to concentrate on the following:

1. Determining the cost of patrolling by helicopter in comparison to the cost of patrolling by present means, and
2. Analyzing traffic incidents that are illegal or hazardous or both and determining whether the helicopter has an effect on them.

Accident Causes

The cause of an accident is difficult to define. Many factors, such as the use of alcohol or inattentiveness of the driver, can contribute to the cause. So, the following incidents that are illegal or hazardous were selected as evaluation criteria:

1. Excessive speed—Although it is debatable that excessive speed is the major cause of accidents, it is a factor in accident severity. Excessive speed was defined as 10 mph or more over the posted speed limit. The AMES patrolling might measurably reduce speeds on patrolled roads as a result of motorists seeing a helicopter marked Arizona Highway Patrol; widespread publicity that certain roads will be patrolled by helicopters; and motorists being stopped by ground patrol units and charged with violations that had been reported by helicopter patrols.
2. Following too close—This always represents a potential accident. Following

Table 1. Evacuation and transfer missions.

Type	Missions Number	Missions Percent	Hours	Cost[a] (dollars)
Evacuations				
Highway	81	38	81	17,172
Nonpatient	42	19.2	47	9,964
Nonremote, nonhighway	24	11.7	29	6,148
Remote[b]	11	5.2	15	3,180
Transfer	55	25.8	134	28,408
Total	213	99.9	306	64,872

[a]$212 per hour.
[b]Areas inaccessible to ground ambulances because of terrain or absence of roads.

Table 2. Patients evacuated and transferred.

Type	Missions	Persons Number	Persons Percent	Persons per Mission
Evacuation				
Highway	81	116	52	1.42
Nonremote, nonhighway	24	25	11	1.04
Remote	11	12	5	1.09
Transfer	55	72	32	1.30
Total	171	225	100	

Table 3. All missions flown.

Type	Missions Number	Missions Percent	Hours	Cost (dollars)
Evacuation	158	19.2	172	36,464
Transfer[a]	55	6.7	134	28,408
Search	21	2.5	30	6,360
Surveillance	520	63.1	765	162,180
Other	70	8.5	84	17,808
Total	824	100.0	1,185	251,220

[a]Transfer missions were flown only during the last month of the demonstration.

too close was defined as traveling within 30 ft of another vehicle when the operating speeds were more than 50 mph. If a vehicle closed to pass another and the passing maneuver began within these limits, it was not included.

3. Illegal passing—This was defined as passing on the left in a no-passing zone. Vehicles that completed passing within the first 100 ft of the solid line were not included.

4. Unsafe passing—Unsafe passing was defined as passing with less than 100 ft clearance of an oncoming vehicle or cutting off the passed vehicle.

5. Improper lane position—This was defined as encroaching on the centerline or the shoulder or as traveling on the wrong side of the road.

6. Driving too slow.
7. Littering.
8. Stopping on roadway.
9. Obstructing right-of-way—This was defined as parking to fully or partially block a right-of-way.
10. Driving while under the influence of alcohol.
11. Driving with equipment that needs repair.
12. Driving with inadequate vision.
13. Pedestrian or livestock on roadway.
14. Other (e.g., improper turns, improper stop).

Although it was doubtful that the helicopter could reduce the number of incidents in several of the criteria, they were included because they represent duties that would be performed by a ground patrol vehicle and because they are readily identifiable from the air.

Selection of Patrol Routes

The first step before beginning helicopter patrols was determining routes, their length, and the patrol schedule. Routes were determined by considering their proximity to the helicopter base; accident history, geometric characteristics, and traffic volume of the routes; limitations of personnel availability; and cost.

Based on these determinations US-87 and I-10 were selected. In 1968 the summer average daily traffic (ADT) for these routes was 1,800 and 9,000 respectively. US-87 is a 2-lane route through hilly terrain and has one of Arizona's highest accident rates (2.86 per 100 million vehicle-miles). I-10 is a 4-lane divided highway and has a low accident rate (approximately 1.2 per 100 million vehicle-miles).

The length of route to be patrolled was determined by the number of flight hours possible before refueling would be required, location of the base of operation, flight pattern, evacuation capabilities during a patrol, and desired sample size. The helicopter is limited to about 3 hours of flight time before refueling is required. Therefore, a short surveillance period (1 hour on station) was selected to allow a maximum flying radius in case an evacuation occurred during a patrol mission. A loop was flown in both directions along the roadway during the patrol. In this manner approximately 80 miles of road were patrolled on a 1-hour round trip.

The time of day and day of week for patrolling were determined by helicopter crew availability and by the past accident history of the routes. The schedule provided that a surveillance mission was not to be flown unless there was a standby helicopter. If an evacuation mission occurred during the mission and the surveillance helicopter was not to perform the evacuation, the surveillance helicopter was to return to base.

On US-87, the procedure was to fly the helicopter intermittently for 4 patrols on alternating days of the weekend. A helicopter would fly on Friday and Sunday of 1 week and then on Saturday of the following week. Data were collected by ground observers on all 3 days. In this manner the effect of the helicopter could be determined by examining the criteria under patrol and nonpatrol conditions.

Data were collected on I-10 by ground observers before helicopters flew patrols over this route. After sufficient data had been collected, concentrated patrols were flown over similar hours and days of the week as on US-87.

Informing the motorists of the patrols was done by posting signs on the patrolled routes and by using newspapers, radio, and television. Portable signs were used on

US-87 and were placed only when the helicopter was scheduled to patrol. Permanent signs were used on I-10 after the background data were collected.

Ground data were collected from a fixed point on both routes. The ground observer sections were located at approximately the one-third point on the route with visibility of more than ½ mile in each direction.

The ground observers fixed intervals for speed determination by using a stopwatch. These sections were about 0.2 mile. Clocking was done on only those vehicles that appeared to be traveling unusually fast. When a speeding vehicle was passed, both vehicles were counted. When several vehicles were traveling at apparently the same high speed, all vehicles were counted. The helicopter observer gathered the same data as did the ground observer except that the helicopter observer determined excessive speed visually.

Surveillance Patrol Results

All of the evaluation criteria, separately and combined, were examined by using the analysis of variance technique (4, 5). A 2 by 3 grouping of the experimental data was made based on the helicopter flying status and volume. The statistical analysis of the evaluation criteria before and during airborne surveillance was made by using an error of the first type (the error of rejecting a true hypothesis—probability that the statement, "the AMES effect reduced the criteria," is false) of 0.10.

US-87—Data were collected on US-87 for 31 hours, including 13 hours when helicopter patrols were flying. This route is predominantly used for recreational travel. The directional split of traffic, as a percentage of total westbound traffic (toward the Phoenix metropolitan area), was 34.3 percent on Friday, 58.5 percent on Saturday, and 79.4 percent on Sunday. The range of this directional emphasis was 70 percent. A count made on the trucks, buses, and trailer-car and boat-car combinations was 14.3 percent of the total volume observed. This route also serves several recreational areas north of the Phoenix area.

The F value for rejecting the hypothesis that the variance or standard deviation of the criteria are equal when the helicopter is and is not flying is $F_{0.10, 1, 22} = 2.95$. Based on this test the hypothesis can be rejected because the helicopter patrol did have a significant effect in reducing

1. Excessive speed, $F = 4.69$;
2. Illegal passing, $F = 4.23$; and
3. All criteria, $F = 4.95$.

I-10—This 4-lane divided highway is predominantly traveled by intercity traffic between Tucson and Phoenix and through-state traffic on this southern Interstate route. The volume of traffic observed was relatively constant and had no major directional emphasis. A total of 30 hours of data were collected before signs were placed and helicopter patrols begun. Ground observers collected 22½ hours of data while the helicopter was patrolling. And, a special 1-hour patrol was made over a 2½-mile section that was near the ground observation location. This special patrol resulted in a marked decrease in the number of speeding vehicles. This indicates that the helicopter has a zone of influence much larger than that of ground enforcement vehicles. Four and one-half hours of data were collected when the signs were in place and the helicopter was not patrolling. Statistical analysis of these data indicates that the signs themselves have no effect as a deterrent.

The F value for rejecting the hypothesis is $F_{0.10, 1, 47} = 2.82$. The helicopter had a significant effect in reducing

1. Excessive speed, $F = 18.55$;
2. Improper lane position, $F = 2.84$; and
3. All criteria, $F = 15.17$.

SUMMARY

If a vertical takeoff is required, there is no substitute for the helicopter. For straight traffic control, however, a fixed-wing aircraft can orbit a point as well as a helicopter and at about 1/10 the cost.

Ground patrol units are the most economical means of traffic control and surveillance and are a necessity for enforcement. But, they have several important disadvantages. For example, only a small segment of roadway is visible to them at a time; in rough terrain visibility perpendicular to the roadway is restricted; and enforcement and surveillance take place in this restricted segment, which can vary from a few feet to several miles.

Operating speeds of the helicopter are about 2½ times as fast as those of a ground unit on normal patrol. Under almost all circumstances the helicopter can patrol a route faster than any other mode. The helicopter's landing and fast evacuation capabilities can be made available in combination with trained medical personnel. There were several missions during the project when the helicopter was the first official vehicle at an accident scene. The pilot was available to direct traffic movement or to aid the observer-paramedic in treatment. Ground units are limited in enforcement and movement when the traffic is heavy. This is particularly the case on 2-lane routes. But, violators can be detected but not stopped by a helicopter. This, and high operating costs, are the main disadvantages of the helicopter.

A ground unit and helicopter combination was used in issuing warning tickets on both routes. On the Interstate, the primary violation was excessive speed. On US-87, the helicopter aided the ground patrol units in detecting and apprehending illegal passing and centerline violators. In a 1-hour period 12 of these violations were detected from the helicopter over an 8-mile area, and all were apprehended by 1 of the 4 ground units in the area. The advance notice given to patrol units was a key factor in apprehending all violators detected. Under similar heavy traffic conditions, if ground units detected these violations, apprehension would not always be possible.

The AMES performed the functions of both a ground ambulance system and the Highway Patrol operation. Cost models for AMES, a Highway Patrol operation, and a ground ambulance operation were developed on the basis of 24 hours per day for a year.

On the basis of time, a helicopter operates at an average of twice the speed of a ground ambulance or Highway Patrol car. AMES performed 171 medical missions in 154.5 hours, less time than it would have taken a ground ambulance for the same missions. This time saved cannot be measured in dollars, but the 41 minutes saved per patient constitutes the real value of AMES in its medical evacuation role.

It is estimated that the AMES is equivalent to 3 times the capability, in terms of area serviced, of the Highway Patrol operation or ground ambulance operation. Operating 3 Highway Patrol groups would cost $205,617. Six ambulances would cost $329,835. The total annual cost of these 2 systems is $535,456. The annual AMES cost would be $379,000.

These comparisons show that use of a helicopter, when it is operated in a rural area, can be justified on a cost basis as a supplement, not a replacement, for existing law enforcement and ambulance services.

CONCLUSIONS

A major time savings was demonstrated by AMES when used in medical emergencies in rural areas. The greater the distance is from a base of operation, the greater the savings are in time. When used only in evacuation, AMES costs of operation are over 3 times those of ground ambulances. But, in a multiple role, the cost-effectiveness of AMES can be justified by providing a valuable supplement to existing law enforcement and ambulance services. The multiple use of surveillance and evacuation was demonstrated successfully. Functioning in a patrol and surveillance role, AMES significantly reduced driver behavior characteristics that cause accidents, especially excessive speed and illegal passing.

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REFERENCES

1. Accident Facts. National Safety Council, 1972.
2. Air Medical Evacuation System (AMES) Demonstration and Evaluation Project. College of Engineering Sciences, Arizona State Univ., Tempe, Rept. ERC-FH-11-7090, May 1970.
3. Arizona's Traffic Accident Summary for 1971. Traffic Safety Division, Arizona Highway Department.
4. Hicks, C. R. Fundamental Concepts in the Design of Experiments. Holt, Rinehart and Winston, New York, 1964.
5. Winer, B. J. Statistical Principles in Experimental Design. McGraw-Hill, New York, 1971.
6. Sears, R. L. A Systems Approach to the Development of a Concept of Operation for an Air Medical Evacuation System (AMES) in the State of Arizona. Arizona State Univ., Tempe, Engineering Rept., 1967.