Modeling for Optimal Ambulance Patient Compartment Layout

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Keywords: Ambulance patient compartment design, modeling and simulation, ergonomics, safety.

1. INTRODUCTION

In 2010, there were more than 250 U.S. ambulance crashes that were reported in the news media. During such accidents, emergency medical technicians (EMTs) who ride in the ambulance patient compartment while caring for patients are at high risk of suffering injuries. Restraint systems are the first line of defense against injuries or death; however, using restraints makes it difficult to access equipment and supplies and to treat the patients. An ideal patient compartment layout facilitates efficient clinical care and ensures the safety of both patients and EMTs.

The General Services Administration's KKK-A-1822F and the National Fire Protection Administration's NFPA 1917 standards do not specifically address patient compartment design [1], [2]. New designs for patient compartments are needed that balance the safety and mobility needs of EMTs. We used an online survey to solicit design needs that will be verified by practitioners and manufacturers and used to determine design requirements and design concepts. We will evaluate the design concepts through modeling and simulation (M&S) of clinical care activities in the ambulance and provide recommendations for U.S. design standards.

2. PROBLEM STATEMENT

EMTs work in a moving ambulance and perform physically demanding tasks [3]. Because the patient compartment is a confined workspace, a number of concerns arise. The concerns are, mainly:

- safe and easy mobility inside the compartment
- accessibility of equipment and supplies
- secure equipment mounting
- seat type and orientation
- usability of restraint systems
- internal and external communication mechanism.

3. NEEDS AND REQUIREMENTS ANALYSIS

We examined and compared the NFPA 1917 standard with three other standards: Alberta Ambulance Vehicle Standards Code, Australian/New Zealand Standard 4535, and British Standards Institution BS EN 1789 using SysML. Through a requirements gap analysis of the standards as well as ride-along trips, experts' interviews, and the industry survey, we identified design needs in different areas:

a) Seating

The ambulance seats while satisfying the needs of EMTs from diverse populations should allow an EMT to:

- easily access the patient
- easily access the equipment, supplies, and medicines
- have face and eye contact with the patient
- ride and perform tasks safely and ergonomically

b) Work Environment

The ambulance work environment should provide the capability to:

- transport and care for more than one patient safely
- provide appropriate lighting and comfort
- facilitate appropriate communications
- supply the required power and power outlets
- secure equipment and supplies
- move around the ambulance freely and safely
- ingress and egress safely and easily
- eliminate hazards such as head strike zones

c) Restraint Systems

The ambulance restraint systems should allow an EMT to:

- buckle and unbuckle easily and quickly
- access the patient from a restrained position safely
- access monitors and supplies safely
- perform patient care safely, effectively, and ergonomically

The restraint systems should also satisfy the needs of EMTs and patients from diverse populations.

4. DESIGN CONCEPTS

User needs and requirements will be analyzed to develop design options. The development of interior layout design concepts is complex as it is constrained by factors such as space limitations and clinical equipment designs. Since it is not feasible to develop a single design that fulfills all the requirements, alternative optional design concept based on given criteria, will be developed that satisfy as many of the requirements as possible.

The design options will be systematically evaluated using virtual-reality simulation models of EMTs performing a range of emergency care activities. This type of simulation has several benefits over traditional physical mockups.

Human factors and physical layouts can be modeled and evaluated simultaneously.

To evaluate different layout designs we will build and integrate models of the EMTs, the patient, and the patient compartment. The conceptual design of the compartment interior and accessories will be modeled using a 3D geometric modeling tool. Simulating the EMT activities and patient care requires a human simulation tool to accurately depict all movements and tasks. For example, the tool must have a feature to measure and display distances between two points. It must also have mannequins that can duplicate all body movements and the actions of limbs and digits. The simulated human body should be an articulated figure composed of different segments, capable of being manipulated into the different postures and positions that an EMT would assume to perform various tasks.

Experiments can be carried out by varying a number of factors to evaluate EMT and patient safety, and performance of clinical care. Some of the factors include:

- size, gender, stature of EMTs
- interior dimensions of the ambulance
- type of ambulance and layout of furniture
- location of equipment, supplies, and medicines
- clinical care activities and restraint systems

5. RESULTS OF EVALUATION

In preliminary experiments, two patient compartment designs with different seat layouts were examined. Each experiment simulated EMTs trying to reach a simulated patient's mouth and right arm from seated and restrained positions. The first experiment used a common layout of a bench seat to the left of the patient and a captain's seat at the patient's head. This experiment showed that it is impossible to reach the right wrist of the patient without unbuckling and that the patient's mouth is readily accessible from the captain's seat. In a second arrangement, three seats are located side-by-side to the patient's left and the middle seat can slide forward and backward to permit closer contact with the patient. In this case, the model showed that the EMT is able to reach the patient's right wrist.

6. CONCLUSION

This paper discusses problems associated with balancing efficiency and safety of emergency medical care in an ambulance and identifies gaps in existing standards and needs for new designs of the ambulance patient compartment. Physical layouts are modeled using a 3D geometric modeling tool. EMT tasks are modeled using a human modeling tool for a range of medical care activities. This paper has shown that M&S can evaluate alternative designs and scenarios to obtain optimal ambulance patient compartment layout. The results of M&S will guide recommendations for future ambulance design standards.

ACKNOWLEDGEMENT

The US Department of Homeland Security Science and Technology Directorate (DHS S&T) Human Factors/Behavioral Sciences Division sponsored the production of this material under Interagency Agreement HSHQDC-11-X-00049 with the National Institute of Standards and Technology (NIST).

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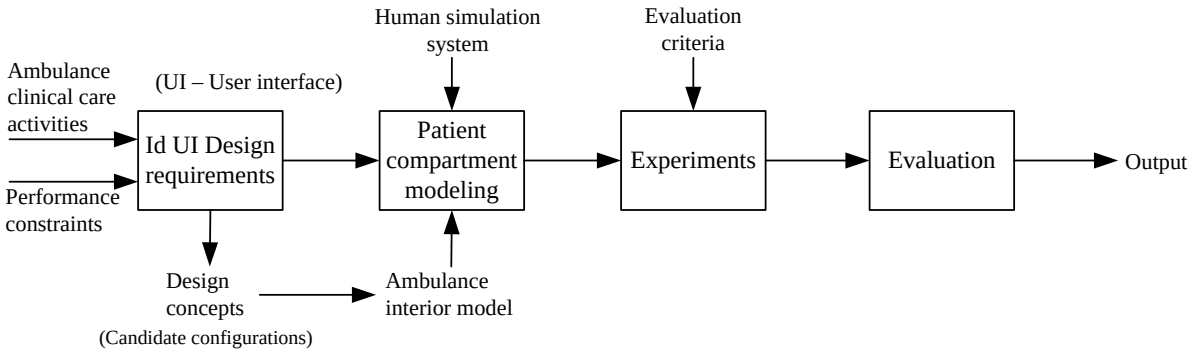

Figure 1. Modeling and layout design evaluation process