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Characterizing the Workday of Ambulance Crew Members

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Abstract

The work of ambulance crew members is highly variable and unpredictable. Decisions made based on an oversimplified understanding of the workday may result in crewmembers struggling to meet unrealistic demands and subsequently lead to fatigue and burnout. Manually collecting work measurement data using traditional techniques is costly and time-consuming, while the resulting estimates may quickly become obsolete. Fortunately, most of today's ambulance service systems involve technologies that capture data throughout operations. This research capitalizes on such data to support the quantification and visualization of the workday of ambulance crews in real time. Physical data collection efforts focus on filling the gaps between available process data and work measurement, to the extent allowed by cost constraints. Using such data, we characterized the workday of a crew as the amount of work time incurred up to a specific point in time, given observed process data as well as information on work dynamics and process variability. Cumulative work time curves with uncertainty bands are proposed to visualize and analyze the workday in terms of expectations as well as human capabilities and limitations. Such information will be useful for the support of real-time operational decisions, retrospective analysis of workload, and prospective analysis of decisions in terms of their impact on the workers' wellbeing.

Keywords

Work measurement, data analytics, ambulance, fair day's work, cumulative work time.

1. Introduction

Emergency medical services (EMS) consist of processes intended to address emerging medical needs from the general population, often materialized as calls to 911. Such calls are random in nature and their response needs can range from well-defined transportation requests to unanticipated life-saving procedures that have been deemed "impossible to predict" [27]. Ambulance crew's job involves evaluating and stabilizing patients' condition prior to reaching a hospital to receive medical attention [1]. Given the flexibility required, EMS systems are human-centered and require a varied set of skills at different stages of the emergency response process. These characteristics make most EMS work systems complex systems that can only be understood in hindsight, and for which capacity planning and evaluation can represent a challenge.

Today, most EMS systems are equipped with networks of computing systems interacting directly with personnel as well as indirectly with other pieces of equipment and tools during the process. Such information systems are intended to help understand the status of the system in real time and support operational decisions. The main EMS variables monitored in real time are the location and availability of ambulances. This information, along with general information about time of the day, weather and traffic patterns, allow for deciding which ambulance to send to specific calls in order to achieve the desired performance. The main performance measures used to evaluate EMS systems include: the time it takes to process a 911 call (call processing time), the time it takes for the appropriate team of first responders to arrive to a call (response time), and the number of calls served or transported per the total number of unit-hours available in the period of interest (commonly known as the unit-hour utilization, UHU))[2]. Performance measures related to equity [3], [4], carbon emissions [5], patient survival rates [6]–[8], and patient prioritization [9] have been proposed in the literature but have been rarely adopted in practice. These measures focus on evaluating performance from the point of view of the customers served by or communities affected by the system. In general, no direct measures of workload from the perspective of the humans directly delivering the emergency medical services are formally monitored or have been proposed to support operational decisions or system evaluation. Therefore, there is no information on what constitutes a workday for emergency medical workers and thus it is not clear what constitutes a fair day's work in this work environment.

The service time and the UHU are usually considered the main indicators for workload in EMS. Nevertheless, these measures present several drawbacks when used as the sole indicators of ambulance crew workload. For example, the service time is recorded using the available information technologies. This service time measure is recorded using the time at which the crew is dispatched and the time at which the crew is available to serve another incoming call. Nevertheless, there are other activities that take place during the ambulance crew workday that are not recorded in the available information systems, but that still contribute to workload. Similarly, the UHU is a productivity measure that does not accurately represent the traditional concept of utilization given that it does not include up-to-date measures of service time and that attempts to provide a single number to describe the performance of a highly variable system. While there is no standard or widely accepted way to measure workload, any workload measurement technique would require an understanding of the time needed or spent performing the different activities associated with a work system. The goal of this research is to outline the components of the workday of ambulance crewmembers in a specific EMS system, to identify the best sources of work measurement data for the different components, and to perform a pilot work measurement study that will help further understand the capabilities and limitations of traditional work measurement techniques in establishing a fair day's work in such environments. Section 2 presents a brief overview of the Industrial and Systems Engineering literature involving workload in EMS systems, particularly from the operations research and ergonomics perspectives. Section 3 summarizes the methods proposed to understand and measure the EMS crew workday. Section 4 presents the results of the data collection and analysis efforts of a pilot study and illustrate the proposed work system characterization. Section 5 presents the conclusions and future research.

2. Literature Review

The purpose of this literature review was to gain a general understanding of how EMS work systems are viewed from the perspective of the Industrial and Systems Engineering profession. We particularly reviewed articles from the Operations Research and Management Science literature, focusing on designing and improving EMS operations as well as articles from the Ergonomics and Task Analysis literature, focusing on understanding the workload imposed by these systems on the frontline workers providing emergency care to patients.

The Operations Research literature review found that most articles focus on ambulance redeployment, while some focus on ambulance location/positioning/districting, ambulance dispatching, and allocating patients to hospitals. In general, the analyses propose a strategy to better support such decisions and most use some form of simulation to evaluate the potential performance of their proposed strategy (e.g., using simulation-based evaluation, simulation optimization and heuristics, and trace driven simulations). We only came across one article explicitly using some measure of workload in joint location/dispatch decisions [10]. Other articles reviewed did not explicitly use workload as a performance measure to optimize, but as a secondary measure. In most of these articles, the term "workload" was used as a system level measure referring to some stratified call volume [11]–[15] (per geographical region or per team). General comments related to workload as it pertains to the workers included: "unsystematic redeployment potentially increases workload and causes fatigue for EMS personnel" [16], "a balanced workload implies that personnel operating ambulances are able maintain proficiency while treating patients" [9], and "workload is an important future research area" [4].

The Ergonomics literature review included articles about traditional ambulance services that focused on the perspective of the front line first responders (e.g., paramedics, emergency medical technicians, and ambulance nurses, among others). This line of research mainly aims at identifying factors leading to stress [17]–[22], emotional distress and workplace violence [23], [24], occupational injury and physical exposure [1], [25], and noncompliance with safety procedures [26] in workers. [27] explains that mismatches can occur when the job demands are too high or when workers capacity is too low. According to [22], EMS workers experiencing stress are more likely to experience job dissatisfaction, depression, anxiety and hostility among other effects that may also affect patient interaction. Thus, it is important to not only identify when workers are experiencing physical and psychological stress but to prevent stress in the first place. Most commonly discussed solutions to identified stress and fatigue rely on assessment, training and general management support. However, no targeted interventions to improve the experience of EMS workers under specific circumstances were outlined. This could be partly due to the difficulty of providing a single picture of an EMS workday. Still, there is some information that could be used in monitoring work to help EMS systems adjust their crews' loads throughout a work period. For example, [28] found that patient acuity is a determinant of paramedics' physical demands. Such information could be used to predict or retrospectively assess physical demands using process data. A few of the articles collected and analyzed task duration data [1], [27], [28], for which they reported descriptive statistics of driving, off-load delay, time on-scene, lifting tasks, and overall call duration. No paper characterized the workload experienced by EMS workers throughout a workday.

3. Methods

This research proposes to characterize the workday of ambulance crewmembers using the concept of cumulative work time, which is like the concept of cumulative uptime used for tracking availability [29]. The corresponding curve has a slope of 1 when the system is busy, i.e., it accumulates one hour of work time per scheduled hour. When the system is idle, the slope is 0 (see Figure 1).

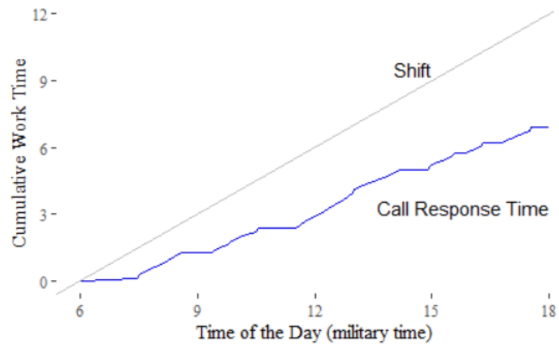

Figure 1. Sample workday for a specific ambulance crew when considering only the direct call response time stamps recorded in the system.

This representation could help identify not only the overall available time at the end of the shift, but also the breakdown of idle periods throughout the shift (represented by the horizontal line segments). The main challenge in building a cumulative work time function lies in ensuring that all work is accounted for in the analysis. Figure 1 shows an example of a workday for a sample ambulance unit when considering only the direct call response time recorded in the system. This study used direct observation to identify the nature and dynamics of other indirect tasks performed by ambulance crews during the workday. We then used a combination of pilot work measurement studies and Monte Carlo methods to quantify and visualize key characteristics of a workday. We restricted our data collection efforts to methods that can be applied by shadowing one crew at a time. The traditional work sampling approach was excluded from the scope of this pilot because of the wide range of locations at which a crew may be at any point in time during the day, making it difficult and costly to physically track one or more ambulances using traditional techniques with the resources available. Self-data collection methods were also excluded to avoid adding workload to the crews under study. A team of two students and a faculty member thus rode along EMS crews while tracking the different activities they performed without interfering with direct patient care or other critical activities. Actual system dispatch data was then complemented with collected data to visualize the estimated workload of a specific crew during a recorded day, along with the uncertainty in the estimations. The Monte Carlo simulation approach was used to obtain many potential realizations of a workday and a percentile method approach was used to illustrate the uncertainty in the assessments. All simulations and analyses were done in RStudio Version 1.2.5033.

4. Results

EMS crews' tasks and data collection requirements are shown in Table 1. We use the term "routine work" to refer to the service analogous of repetitive work. The EMS example of routine work is "call documentation", in which details of each call must be recorded on a standardized application. However, the details may significantly vary for different calls. We define mission work, as those unique bundles of tasks that are started and completed in one attempt, whether they are strictly completed or not. Anything not done within the mission is either shed or becomes part of a new mission. These classes, along with the anticipated frequency of the corresponding tasks, led us to recommend different approaches for work measurement. The only work component that could be directly studied using available data was "direct call response" time. Time studies are traditionally applicable to repetitive work, such as shift start activities, particularly if they occur at a predictable time of the day. We also used a time study approach to quantify the duration of documentation work, given that its frequency is directly dependent on the frequency of calls and have a high priority. Still, we are aware that a single standard time is not sufficient to fully characterize it and that variability needs to be incorporated into the workday analysis. We defined a "perpetual" frequency for those tasks that are not required to be completed during a single shift, such as housekeeping or administrative computer tasks. These kinds of tasks are usually performed whenever there is enough available time but have no completion expectations and depend on the discretion of the crews. In such case, we would need to perform a work sampling study that considers the time allocation to these tasks depending on the availability allowed by the other tasks performed in a shift. Including only tasks that have high priority within a shift will provide an idea of how much work time is left to realistically perform these other peripheral tasks. In what follows, we illustrate our analysis using a sample ambulance crew and data from a day shift running between 6:00 am and 6:00 pm.

Table 1. Generic tasks performed by ambulance crews, in priority order. Available time: total time that can be dedicated to the corresponding task. T: shift time. Duration estimation: recommended work measurement approach.

i	Task	Available time, T_i	Frequency	Class	Duration estimation
1.	Direct call response	T	Random	Mission	• Process data • Driving to post estimates.
2.	Repositioning	T	Random	Mission	Work Sampling
3.	Call Documentation	$T - T_1 - T_2$	Call dependent	Routine	Time study
4.	Shift start activities	$T - T_1 - T_3$	1	Repetitive	Time study
5.	Gas fueling	$T - \sum_{i=1}^{4} T_i$	1	Repetitive	Time study
6.	Administrative	$T - \sum_{i=1}^{5} T_i$	Perpetual	Routine	Modified Work Sampling
7.	Housekeeping	$T - \sum_{i=1}^{5} T_i$	Perpetual	Mission	Modified Work Sampling
8.	On-duty training	$T - \sum_{i=1}^{7} T_i$	Perpetual	Mission	Modified Work Sampling

4.1. Direct Call Response Time

Based on direct observation of call responses, we conclude that personal allowances (e.g., time needed use the restroom) and delay allowances (e.g., time needed to clean up the cot and replenish supplies) are included in the system time stamps. Fatigue allowances are not included. In addition, a crew changes their status to available once these activities are done and right before they start driving back. Therefore, the system time stamps do not include the time spent driving back to the post. A crew may be assigned to a call as soon as they become available, leaving no time to drive back, or may have time to drive back to the post to perform other tasks while they wait to be dispatched to the next call. Thus, the difference between call response time and shift time in Figure 1 represents the time available to drive back, perform other tasks and recover from the fatigue associated with the different types of work. We used Google Maps to obtain estimates of driving times between the patient destination (e.g., hospital) and the corresponding post, as well as historical "driving to" time distributions for calls with no discernable address. We imputed the minimum between the estimated drive-back time and the time to next call.

4.2. Call Documentation

Each call response is associated with some documentation, even if the call results in no actual care or transportation being provided. While ideally such documentation should take place immediately after the call, the actual documentation time varies depending on the workday and the actual workers. The team was able to collect documentation times for 20 calls. We observed two main components of documentation: "demographics" (collecting patient data) and "care documentation" (information about patient needs and care provided). While demographics data is almost always collected in parallel with the medical services provided, "care documentation" takes place after the patient has been stabilized and transferred to the ambulance. We observed two methods to finish the documentation: 1) as much as possible in the truck (about 80% of observed crews tried this approach) and 2) all in post. The policy of the EMS organization is to give patients priority; thus, they support the discretion of EMS workers in documentation strategies. In addition, some crewmembers expressed not being able to perform documentation on a moving vehicle in a small tablet due to dizziness. On the average, those attempting to perform some documentation in the truck spent about 30% of the total documentation time. The rest was performed on the post. Because calls have priority, documentation is often interrupted. In general, it took on average 3.25 attempts to finish documentation for a single call. Documentation time in post was found to follow a Normal distribution using a Kolmogorov-Smirnov test (p-value > 0.15) with mean 17.9 and standard deviation 8.284 minutes. This estimate includes the effect of interruptions.

4.3. Shift Start Activities

Shift start activities take place at the beginning of the shift, if possible. The purpose of shift start activities is to prepare truck for the shift, make sure it is clean, free of mechanic issues and full of supplies. Our pilot study had 16 observations (out of 30 times data collection was attempted). The variable nature of the work makes it a challenge to anticipate a total study time for a desired sample size. Sometimes, crews had finished everything before the official shift start time, received a call and left without being able to finish their regular routine, or they did not do the task because the truck was not used within the last 12 hours. The 95% confidence interval for the observed time of shift start activities in the pilot was 22.8 ± 2.19 minutes (standard deviation: 4.48). If an error of 10% was desired, then the recommended number of observations would be 18.

4.4. Workday Representation

Figure 2 updates the representation of the workday depicted in Figure 1 when considering the results from the data collection study and basic fatigue allowances of 4% as recommended by the International Labor Organization. If crews have two paramedics, documentation workload was divided by two to better reflect the observed division of labor that takes place. We plotted the median of 100 simulation runs as well as the 5th and 95th percentiles of work time incurred throughout the workday. The original EMS crew utilization estimate for this workday, interpreted as the crew's proportion of busy time, would be 0.575. The updated estimates indicate that the median utilization would be of 0.89 (5th percentile: 0.85, 95th percentile: 0.93) when considering shift-start, evenly split documentation work, driving back times, and allowances.

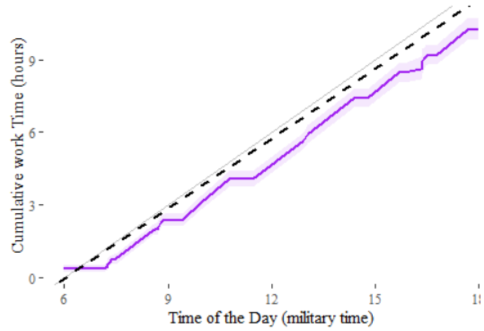

Figure 2. Estimated work time for sample day including shift start activities, driving-back time, and documentation. The dashed black line represents the available time when considering allowances.

5. Conclusions and Future Research Directions

This paper presented a pilot study of the workday of ambulance crew members. While traditional work measurement techniques alone are insufficient and inappropriate to measure all EMS crews' work, there is a need to develop a shared understanding of the demands placed on first responders. Our study provides a first step in better representing highly variable work systems requiring real-time tracking. There are several limitations to our study. The workday representation excludes several work components. In addition, the workload estimates provided apply only to the crew under study on the day of analysis. The same crew may experience different workload levels on a different day and different crews may experience different workloads. Furthermore, the analysis assumes that both crewmembers are always performing the same level of work, which may not be an accurate representation of reality.

These results and limitations motivate further research to establish a fair day's work for EMS crews. A comprehensive representation of work time incurred that includes most of the tasks performed by EMS crews should be obtained, including appropriate allowances that are specific to the nature of the tasks performed. Furthermore, estimates of workload per crewmember are also needed to guide team configuration decisions. While both members are together for the whole duration of the shift, work distribution among crewmembers affects the effort exerted during the shift and thus the need for recovery and associated allowances. Answering these questions will require further data collection on how available time is allocated to repositioning, administrative, housekeeping, and on-duty training tasks, which require alternative work measurement techniques. Once a reliable workday representation is defined, then real-time and historical data can be used to predict remaining workload and design strategies to balance workload within shifts as part of system status management.

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