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# Coping with stress in emergency department physicians through improved patient-flow management

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ABSTRACT

This paper provides a method for the real-time monitoring of job stress in emergency department (ED) physicians. It is implemented in a Decision Support System (DSS) designed for patient-to-physician assignment after triage. Our concept of job stress includes not only the workload but also time pressure and uncertainty. A job stress function is estimated based on the consensus views of ED physicians obtained through a novel methodology involving stress factor analysis, questionnaire design, and the statistical analysis of expert opinions. The resulting stress score enables the assessment of job stress using workload data from the ED physicians' whiteboard. These data can be used for the real-time measurement and monitoring of ED physician job stress in a stochastic and dynamic environment, which is the main novelty of this method as compared to previous workload and stress measurement proposals. A further advantage of this methodology is that it is general enough to be adapted to physician job stress monitoring in any ED. The use of the DSS for ED patient-flow management reduces job stress and spreads it more evenly among the whole team of physicians, while also improving other important ED performance measures such as arrival-to-provider time and the percentage of compliance with patient waiting time targets. A case study illustrates the application of the methodology for the construction of a stress-score, the monitoring of physician stress levels, and ED patient-flow management.

## 1. Introduction

Spain's national institute for health and safety in the workplace (Spanish acronym: NIOSH) defines job stress as the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker [1]. Higher stress levels are observed in the health services than in other comparable professions [2]. In fact, health care workers also show higher rates of substance abuse, suicide, and job stress-related depression and anxiety than employees in other sectors [3]. Emergency department (ED) providers in particular can be exposed throughout the greater part of their shifts to more severe stress levels than those faced by physicians in other hospital departments [4–6]. Owing to the stochastic nature of hospital emergencies, the ED is a volatile, chaotic, and unpredictable work environment. ED physicians working in the Hospital Compound of Navarre (HCN) in Spain specifically reported experiencing levels of stress that were both high and inequitably distributed due to an uneven workload assignment, despite the existence of apparently fair workload assignment rules (e.g. the assignment of patients upon arrival to physicians by simple rotation). Their testimony motivated the research presented in this paper, whose primary purpose is to provide a dynamic method for the real-time monitoring of physician job stress [7], and to demonstrate its use in a Decision Support System (DSS) aimed at defining new patient-to-physician assignment rules that both reduce stress and distribute it more equitably among the whole team of physicians, while also improving other important ED performance measures relating to the quality of patient care.

Basu et al. [8] present a review of studies examining stress sources in EDs. After reviewing 25 articles, they conclude that high work volume, long working hours and high work intensity are common predictors of occupational stress in EDs. Previous studies on the subject include Keller and Koenig [9] with testimonies from a sample of 104 ED physicians who name their main causes of stress as patient load, interaction with patients and families, and lack of administrative support; and Phipps [10] who identifies the main sources of stress as time pressure and the responsibility for crucial decisions on critically ill patients.

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Recently, Fishbein et al. [11] reviewed 30 articles in which electronic records are used to measure the healthcare workload, which they categorized into tasks, patients, clinicians, and units. Their observations suggest that patient-level measures are dependent on the clinical condition of the patient (e. g. Ref. [12]), the acuity of which can be inferred from the level assigned upon arrival at the ED. The number and severity of the patients being managed simultaneously by a single physician are objective predictors of the workload at the clinician level [13–16]. Acute cases are more complex and require more interventions, resources and time [17,18], while the setup time for a patient's consultation increases with the number of patients per physician [19,20]. These data can be used to obtain a workload measure.

In addition to the workload itself, work interruptions are found to be another main stressor [21]. ED physicians, particularly senior doctors, have been shown to encounter up to fifteen interruptions per hour [22, 23]. One source of such interruptions are consultations with students and medical residents, since resident supervision is an important part of the physician's workload, 7.3% of which, according to Innes et al. [14], is devoted to teaching students or residents, while Dreyer et al. [13] raise this estimate to over 10% in teaching hospitals.

Another issue is time pressure, reported in Flowerdew et al. [24] as one of the most common stress factors in ED, together with the workload, staff shortages, and lack of teamwork. Time pressure relates to the need to make snap decisions on patients whose health is at serious risk and working to performance targets set by the hospital administration or the government. One example, commonly cited in stress studies such as Flowerdew et al. [24] and Mortimore and Cooper [25], is the British government's "4-h A&E waiting time target" whereby at least 95%of patients attending A&E should be admitted, transferred or discharged within 4 h.

The selection of work-related stressors for consideration in this study is based, firstly, on those reported in other studies, and, secondly, on feedback from qualitative ED physician interviews conducted by the physician who co-authored this article. As a result, we choose to focus on workload, time pressure, and uncertainty. **Workload** refers to the number and type (severity) of patients being managed simultaneously by the physician. As patients arrive at the ED, they are triaged (their priority is determined) and immediately assigned to a specific physician who will see them through the entire health care process. This triage process varies between hospitals and from one country to another, but usually uses one of four ordinal ED triage scales [26]. The Canadian Triage and Acuity Scale (CTAS), for example, classifies patients into five distinct priority levels. The resulting workload can therefore vary over the length of a shift because both patient arrival numbers and patient health statuses vary over time. **Time pressures** refer to the upper limit for the arrival-to-provider time (APT) ("door to doc"), which is defined as the interval between the patient arriving at the ED and being seen by a physician [27], and depends on the type of patient. Delay in the first diagnosis could put the patient's health at risk, especially in very severe cases. Table 1 shows the CTAS access time limit as well as the required performance level, or target achievement rate. **Uncertainty** refers to lack of knowledge about the patient's illness and the tasks required to provide medical assistance to patients not yet seen or with test results pending. Generally, the ED healthcare process can be represented by a queue system with several stations; one each for the first and second consultation and some in between for medical tests if needed. As the patient proceeds through the different care stages, more information about their illness is revealed and the level of uncertainty subsides. RFID item-level tracking/tracing identification technology is a very useful source of instantaneous information about all patients in the hospital [28,29], which works by recording each stage in the treatment of every patient.

**Table 1**
CTAS key performance indicators.

| Category | Classification | Access Time | Performance Level |
|---|---|---|---|
| 1 | Resuscitation | Immediate | 98% |
| 2 | Emergency | 15 min | 95% |
| 3 | Urgent | 30 min | 90% |
| 4 | Less urgent | 60 min | 85% |
| 5 | Not urgent | 120 min | 80% |

Several methods have been developed for assessing stress exposures and outcomes. All 25 studies reviewed in Basu et al. [8] used questionnaires. The two most commonly used are the Job Content Questionnaire (JCQ) [30] and the Effort-Reward Imbalance Questionnaire (ERIQ) [31]. The JCQ [32] has 79 items requiring participants to self-report on their experiences in their current job, although shorter versions have been used; a 6-item version is included in the Health and Retirement Study, for example. For further information, see Kopp et al. [33]. The original ERIQ has 22 items, and a shorter 16-item version has been developed [34] to measure three work stress components: effort, reward, and "over-commitment". Further psychometric information can be obtained in Montano et al. [35] and Siegrist et al. [36].

Both measures contain items that are subjectively evaluated by users. Examples from the JCQ are "*My job requires working very fast*" and "*I am not asked to do an excessive amount of work*"; and from the ERIQ, "*I have constant time pressure due to a heavy workload*", "*I have many interruptions and disturbances in my job*", and "*I get easily overwhelmed by time pressures at work.*"

Some studies also use scales designed to measure stress in more general contexts, such as the Perceived Stress Scale (PSS) [37,38], which measures the effects of different situations on the individual's feelings and perceived stress. The 10 questions that make up this scale probe subjects' feelings and thoughts over the last month, for example, *"In the last month, how often have you felt nervous and stressed?"* Other indices have been developed as adaptations of previous ones for use in specific studies. One is the Emergency Worker Stress Inventory (EWSI), which consists of 78 items and was developed for the study by Naudés and Rothmann [39], and later used in Ansari et al. [40]. Another, the Work-Related Strain Inventory (WRSI) contains 18 items and was designed to measure perceptions of strain in occupational settings; its reliability and validity have been confirmed in various health care provider studies [41].

Some stress studies also use indices of workload and burnout. The National Aeronautics and Space Administration Task Load Index (TLX) [42] and the Subjective Workload Assessment Technique (SWAT) [43] stand out among the first category. The TLX uses six dimensions to assess workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. The SWAT considers the worker's time pressure, mental effort, and psychological stress. Both are multidimensional measures based on rating responses that are aggregates of subjective perceptions and do not consider the multiple characteristics of the clinical case.

Burnout, which is the consequence of chronic stress, is characterized by exhaustion, cynicism and detachment, and professional inefficacy [44]. The most commonly used measure of burnout is the Maslach Burnout Inventory [45] (e. g. Ref. [46–49]), which has three subscales (emotional exhaustion, depersonalization, and reduced personal accomplishment) and is used to measure burnout in service workers:. It contains 22 self-scored items on a seven-point frequency scale ranging from 0 (never) to 6 (every day) [50]. Another burnout measure used in ED stress studies is the Copenhagen Burnout Inventory (CBI; [51]) (e. g. Ref. [4,52]), which assesses personal burnout (6 items), and work-related burnout (7 items).

While all questionnaires provide a global stress and workload assessment for a period of time (e.g. a work-shift), they are not designed to adjust to work-shifts with changing working-conditions and are therefore inappropriate for measuring the changing stress levels experienced during an ED physician's work shift. Thus, our proposal is to measure stress based on estimates of the stress levels experienced by physicians in different workload scenarios. The data are then subjected to statistical analysis to obtain a function capable of measuring physician job stress in real-time. The estimated function represents the consensus view of the ED physicians with respect to perceived stress.

The stress score for a particular physician workload scenario takes into account the above-mentioned factors: the workload assigned to a physician disaggregated by patient type (severity), the stage in the patient care process, waiting time targets, and other physician responsibilities, such as teaching duties. The proposed methodology involves stress-factor analysis, questionnaire design, and a statistical analysis of expert opinions. The resulting stress index can be incorporated into the usual performance criteria used to evaluate ED patient-flow management policies. While patient care evaluation criteria, such as the time until the first consultation, the length of stay or the number of patients in the ED, are commonly used, indicators of the healthcare staff situation are disregarded.

The patient-to-physician assignment problem is analogous to the job shop problem (JSP); the jobs to be processed are the patients and the different workstations are the different medical consultations and clinical tests. Within this production management context, there are also analogies with the assembly line balancing problem (ALBP), which deals with the appropriate and balanced allocation of tasks to workstations in order to optimize throughput. Due to their combinatorial nature, both JSP and ALBP are hard optimization problems, which have been the subject of considerable research effort. Zhang et al. [53] and Sivasankaran and Shahabudeen [54], respectively, provide comprehensive reviews of the JSP and ALBP literatures. Recent research on ALBP has considered the "physical workload" as an extra constraint in the design of "ergonomic" assembly lines. Otto and Scholl [55], for instance, introduced a two-stage optimization model: with a first stage in which the line was balanced with no attention to ergonomic risk factors, and a second stage, in which the line was ergonomically adjusted. In the JSP, the number of jobs to be scheduled is known in advance and, in the ALBP, the sequence of tasks for each job is also known. In an ED, however, the care pathway is not known at the time of patients' arrival; nor are the tasks required for their appropriate treatment. The ED pathway and the tasks it will involve are revealed during consultation with the physician and as clinical test results become known. Meanwhile, the patient's health status (and priority) can change during the waiting time. Furthermore, the health care received by a patient is provided by a single physician, who has sole responsibility for the diagnosis, the clinical tests to be ordered and the treatment to be given. Thus, the ED patient-flow management problem has characteristic features that set it apart from others in the realm of scheduling problems.

In this paper, we propose the use of a DSS, which discards current patient–to-physician assignment methods, and is based, instead, on a balanced distribution of job stress among the whole team. Evidence is provided of the gains obtained by reducing the amount of stress, and spreading it more evenly among physicians, while also improving some classic ED operational measures [56] based on patient waiting times.

In complex systems with unpredictable outcomes, especially those such as health systems, in which there is a strong ethical component, new management policies are tested by means of simulation techniques (see Refs. [57,58]). This study uses historical ED patient arrival data, including all patient characteristics (treatment requirements, length of consultations, care pathways, etc.) in order to compare the key performance indicator (KPI) values achieved with the current patient management system against those obtained with the new job stress balance-based DSS proposal.

This paper is organized as follows. Section 2 describes all the phases involved in estimating the job stress function. In particular, Section 2.1 gives a step-by-step description of the preparation for data acquisition, and Section 2.2 explains the statistical data analysis procedure. Section 3 shows the results of the application of this procedure to a real ED case. The use of job stress monitoring as input to a DSS for the assignment of new incoming patients to physicians is illustrated in Section 4. Finally, Section 5 summarizes and discusses the benefits of our approach.

## 2. Methodology

In this section, we present all steps necessary to estimate a stress function denoted by $f(w)$, whose purpose is to provide a score on a global scale of the stress induced in a physician by a workload scenario $w$. A workload scenario at a given time $t$ is defined by the set of patients that are currently assigned to a physician. This pending workload includes: patient waiting for the first visit, patients in progress, and patients waiting to be transferred after finishing the medical process in the ED. They change over time: whenever a new patient is assigned to a physician, a new consultation begins or ends, a new patient's test arrives, etc.

Let W be the set of all possible different workloads:

$$f \quad : W \rightarrow R \subseteq \mathbb{R}^+$$

$$w \in W \quad \rightarrow y_w = f(w)$$

where $y_w$ is the stress induced in a physician when the workload is $w$, and $R \subseteq \mathbb{R}^+$ is the set of values in which the stress varies.

The aim is to estimate the function $f(w)$ from the statistical analysis of the stress assessment made by experts (physicians working in the ED) from a sample of scenarios representative of $W$. The methodology is divided in two phases: the first one concerns the preparation for collecting data, in which the job stress factors and their levels are first determined, and then an appropriate survey is designed for eliciting physicians' stress assessments; the second phase covers the data analysis, for which the data is depurated and homogenized, and finally, the stress function is estimated. The methodology, structured in seven steps, is summarized in Table 2.

### 2.1. Phase 1. Preparation for data acquisition

#### 2.1.1. Step 1. identifying the set of factors affecting the job stress and their categories or levels

The job stress analysis begins by identifying the set of factors, related to the workload, that affect the physician's stress. Patients, as they arrive at the ED, are triaged and then immediately assigned to a specific physician. Each physician is aware of the pending workload at any moment of the work-shift. The severity level and the waiting time for each patient is known. In addition to the patient consultation work, the physician has to supervise a resident labor during some shifts. All these elements were enumerated by physicians as stressor factors. Table 3 represents the factors we consider in our research.

Most EDs have a similar structure and way of operating and consequently similar stressors. However, if the layout of facilities or ED organization influencing on stress are different, the job stress factors summarized in Table 3 can be modified and adapted to the particular ED in which the methodology is being applied by adding more or substituting them by those job stress factors identified by its physicians.

The stress factors for physicians are grouped into two categories: training responsibility and pending patients. The training responsibility factor refers to the supervision of residents, which are medical school graduates undergoing on-the-job training and cannot assist in all areas

**Table 2**
Methodology summary.

| |
|---|
| *Phase 1. Preparation for data acquisition* |
| *Step 1.* Identifying the set of factors affecting job stress and their categories or levels |
| *Step 2.* Definition of workload scenarios and selection of a representative sample |
| *Step 3.* Drawing up the questionnaire for job stress assessing |
| *Step 4.* Selection of experts, dry run exercise, expert training, and elicitation session |
| *Phase 2. Data Analysis* |
| *Step 5.* Homogenization of experts' answers in a common scale |
| *Step 6.* Table of Data. Coherence and consistency analysis for each expert's answers |
| *Step 7.* Estimation of the job stress function based on scenario assessments |
| *Step 8.* Validation of the job stress function |

**Table 3**
Description of different categories for each stress factor.

| TRAINING FACTOR | CATEGORIES |
|---|---|
| RESIDENT SUPERVISION ($F_1$) | 0: No resident supervised<br>1: Resident supervised |
| PENDING PATIENT FACTORS | CATEGORIES |
| PATIENT PRIORITY($F_2$) | 1: High priority<br>2: Medium priority<br>3: low priority |
| PATIENT MEDICAL ATTENTION PHASE ($F_3$) | 1: Waiting for the C1<br>2: In process<br>3: Waiting for transfer |
| PATIENT WAITING TIME TARGETS ($F_4$) | 0: Time limit not exceeded<br>1: Time limit exceeded |
| NUMBER OF PATIENTS ($F_5$) | Any integer value |

of patient demands nor every patient's care needs. Physicians can be charged with the supervision of a resident during a whole shift and consequently should have more tasks such as teaching.

All factors, except the number of patients, are categorical. The factor "resident supervision" has two categories: no resident is supervised and the physician supervises a resident.

Patients in an ED can be of different priorities, which are determined when they are triaged taking into account some medical factors such as the health status, illness, etc. As it has been mentioned in the introduction, these possible priorities depend on the triage scale used by the hospital. In this methodology section, we consider an ED where patients can be of priority 1 (high), 2 (medium), or 3 (low). Patients can be waiting for the first consultation (C1), in progress -carrying out medical tests after physician's C1 and waiting for a second consultation (C2)-, or waiting for transfer to their destination (home, hospital) after the medical process in the ED has finished. Thus, "patient medical attention phase" factor has three categories.

Moreover, there are "patient waiting time targets" for the C1, which depends on the patient priority, $t(F_2)$. Two states are considered for this waiting time factor: waiting time below the limit and waiting time exceeding the limit. Finally, the factor "number of patients" can take values in the set of all non-negative integers. Table 3 summarizes the factors and their categories.

The amount of patients of each type, obtained by combining the levels of the stress factors ($F_2$,$F_3$,$F_4$), are represented by integer variables $X_1,\ldots,X_{10}$, while the supervision of residents is coded by a binary variable $X_{11}$ (see Table 4).

**Table 4**
Variables originated by the combination of the stress factors.

| Variables Description (combination of factors) | Medical attention phase ($F_3$) / Waiting time targets ($F_4$) | | Priority ($F_2$) | Variable Name |
|---|---|---|---|---|
| Number of pending patients ($F_5 = \sum_{i=1}^{i=10} X_i$) | 1: Waiting for C1 | 1: Time limit exceeded | 1 | $X_1$ |
| | | | 2 | $X_2$ |
| | | | 3 | $X_3$ |
| | | 0: Time limit not exceeded | 1 | $X_4$ |
| | | | 2 | $X_5$ |
| | | | 3 | $X_6$ |
| | 2: In process | | 1 | $X_7$ |
| | | | 2 | $X_8$ |
| | | | 3 | $X_9$ |
| | 3: Waiting for transfer | | | $X_{10}$ |
| Training Responsibility | Resident supervision ($F_1$) | | | $X_{11}$ |

#### 2.1.2. Step 2. Definition of workload scenarios and selection of a representative sample

We denote by $S$ the workload scenario defined by the variable vector $(X_1,\ldots,X_{11})$. For example, $S = (X_1 = 0, X_2 = 0, X_3 = 1, X_4 = 2, X_5 = 0, X_6 = 2, X_7 = 1, X_8 = 3, X_9 = 1, X_{10} = 0, X_{11} = 0)$, means that

- There is only a priority 3 patient exceeding the upper limit waiting time ($X_1 = 0, X_2 = 0, X_3 = 1$) and other two priority 1 and two priority 3 patients waiting for the C1 ($X_4 = 2, X_5 = 0, X_6 = 2$).
- There are 5 patients waiting for the C2: one of priority 1, three of priority 2 and one of priority 3 ($X_7 = 1, X_8 = 3, X_9 = 1$).
- No patients are waiting for transfer ($X_{10} = 0$)
- No resident supervision ($X_{11} = 0$)

A workload situation $w$ will be represented by a vector $S$. Because the number of patients assigned to a physician is, theoretically, not capped, the number of different scenarios is also infinite. Furthermore, although the maximum number of patients assigned to a physician was limited by an upper bound, for example fixed according to the maximum value observed in a real ED, the number of different scenarios would also be huge. Fig. 1 shows the increase in the number of scenarios depending on the maximum number of pending patients. For one pending patient, there are 24 different scenarios, but for 15 patients, which is a realistic figure in peak arrival hours, there are over 15 million different scenarios.

Let $\Omega$ be the set of possible scenarios $\Omega = \{S_i\}_{i=1}^{\infty}$ and $f$ the stress function:

$$f \;:\Omega \;\rightarrow R \subseteq \mathbb{R}^+$$

$$S \;\rightarrow y_S = f(S)$$

where $y_S$ is the stress induced in a physician when the workload w is described by scenario S, and $R \subseteq \mathbb{R}^+$ is the set of values in which the stress varies. Without the loss of generality, we will assume that $R = [0, 100]$, with 0 associated to a no stress situation and 100 to a maximum level of stress.

The function $f$ will be estimated from the statistical analysis (see *Phase 2*) of the stress assessment made by physicians working in the ED on a small number of selected scenarios in $\Omega$. The cardinality of $\Omega$ prevents an exhaustive assessment of all scenarios $S$ in $\Omega$. To overcome this difficulty, a "D-Optimal" design of experiments, which is a popular criterion that maximizes the determinant of the information matrix, is carried out.

Furthermore, this design has to consider that certain combinations of factor levels may be theoretically possible but very unlikely to be observed in practice. For example, physicians could report that they have never been assigned more than 25 patients. Thus, a set of constraints on the stress variables are imposed on the set of selected scenarios for the design of experiments.

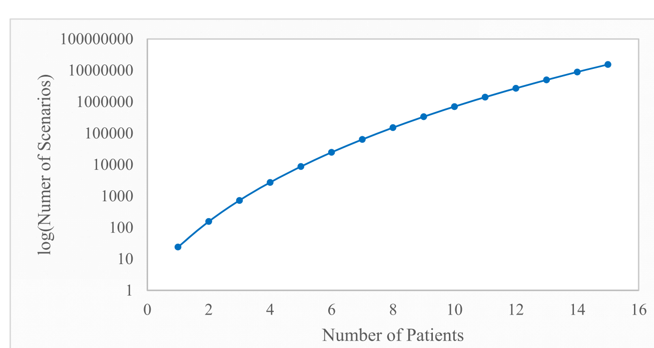



**Fig. 1.** Number of possible scenarios depending on the number of pending patients.

$$\sum_{i=1}^{10} X_i \le L_0 \qquad \sum_{X_j \ s.t. \ F_2(X_j)=i} X_j \le L_i \forall \, i=1, \ \ldots, 3 \qquad X_{10} \le L_4$$

$L_0$ is the upper limit for the total number of assigned patients and $L_i$ is the upper limit for patients of priority $i$, $i = 1, \ 2, \ 3$. This set of combinations and their associated upper limit values should be suggested by experienced physicians working in the ED. They could vary from one ED to another ED because they depend on the mix of patients attending the ED and other characteristics. This D-optimal design can be obtained by using the software JMP® (SAS Institute Inc., Cary, NC [59]), which uses an iterative computational method called "coordinate exchange" [60]. The covariance matrix determinant of the model coefficient estimates is minimized in the D-optimal design, thus, the effects are precisely estimated with minimum standard errors [61]. The outcome of the design of experiments provided us the necessary scenarios to estimate the main contribution for each factor and first order interactions.

**Including extra scenarios as anchors**. In many situations, people make estimates by starting from an initial value that is adjusted to yield the final answer, which is biased toward the starting point. This phenomenon is what Tversky and Kahneman [62] call anchoring. In this questionnaire, we will anchor or benchmark experts' answers by defining additional reference scenarios for likely situations in the ED at both ends of the stress scale. The physician included in the research team defined some realistic scenarios for which the majority of their colleagues would give a very high stress score, called red scenarios, and others for which the majority of their colleagues would give a very low stress score, called green scenarios. These green and red scenarios will serve as anchors. A formal definition of such anchor scenarios is provided in Appendix A1. In each set of scenarios given to an expert for stress evaluation, there will always be one red and one green scenario, which are supposed to be rated at both ends of the scale.

### 2.1.3. *Step 3. Drawing up the questionnaire for job stress assessing*

It is known from the work of Miller [63] that there is a limit to our information-processing capacity as the immediate memory span can approximately handle just seven items, and that there is also a span of attention that encompasses a finite number of objects. These considerations lead us in the design of the questionnaire (included in Appendix B2). We proposed a questionnaire that consists of four cards, each one with a set of four scenarios such as the one represented in the left side of Fig. 2. That is, each expert is asked to rate the stress in 16 different scenarios. Each card contains an anchor and three other scenarios provided by the D-optimal design of experiments. A number $M$ of different questionnaires are designed in such a way so that no scenario is repeated in a questionnaire, and all scenarios selected by the design of experiments are included throughout several the various questionnaires.

The visual presentation of the scenarios is also important. For example, they should feature a native look, just like the physicians' patient portfolio in reality (color code, structure, etc.). In Fig. 2, the right-hand side depiction is a capture from the computer screen where a physician consults the pending patients, and the left-hand side represents a scenario as it is included in the questionnaire (see *Application to a Case Study* in Section 3). Below each scenario, there is an empty box in which the experts have to enter a score on a scale from 0 to 100, where 0 would represent "no stress" and 100 would mean "absolute stress".

Similar to Greller and Parsons's [64] effort to develop a psychosomatic measure of work stress, but in terms of workload perceptions, we develop a scale of adjectival items to describe the stressfulness of the job situations (e.g., "no stress", "slight stress", etc.). This stress scale (see Fig. 3), visualizing different stress ranges with a qualitative description, was included in the lower half of the questionnaire card.

### 2.1.4. *Step 4. Selection of experts, dry run exercise, expert training, and elicitation session*

The selected experts should be physicians who work in the ED and are accustomed to handling their patients' portfolio in the ED computer screen (whiteboard) - represented in the questionnaire as workload scenarios. First, some experts should be shown the proposed

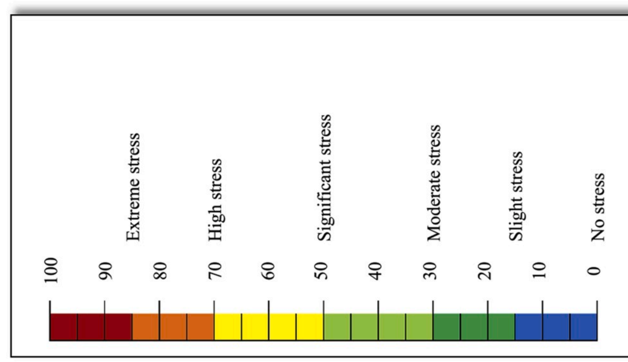



**Fig. 3.** Stress qualitative scale.

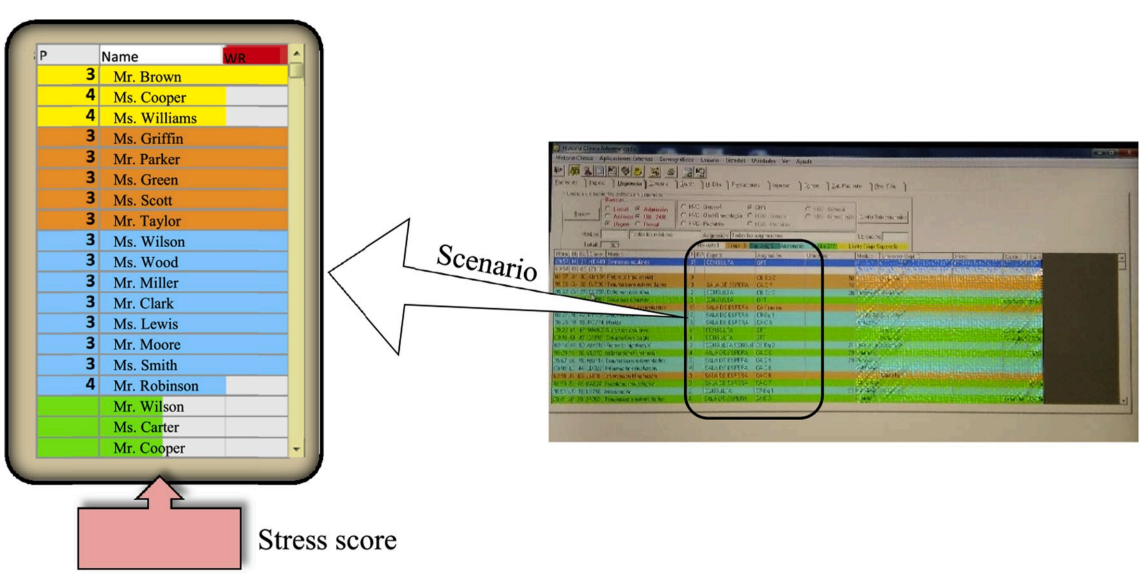



**Fig. 2.** Example Scenario of the Questionnaire - Physicians' portfolio of patients in reality.

questionnaire to express their remarks and queries. This should help to improve the presentation of the cards and instructions provided in order to make them clearer for a final improved version.

Then, it is necessary to create a training session for the participants in which the objectives of the study and every part of the questionnaire can be clearly explained. It is helpful to provide the experts an instruction sheet - to refer to in case they had doubts while they are filling out the questionnaire - including some guidelines with advice on how to complete the questionnaire (see Appendix B1 and B2).

### 2.2. Phase 2. Data analysis

#### 2.2.1. Step 5. Homogenization of experts' answers in a common scale

One of the problems of general scales is that different raters tend to use different portions and amounts for the scale, which is influenced by personality [65]. Thus, the issue of standardizing the opinions of several physicians whose subjective perceptions of stress could differ widely should be addressed. Different raters may use numbers of a scale in different ways: some experts with a higher threshold for stress may rate all the scenarios in his/her questionnaire, even the most adverse ones, with the maximum score being 50 in a [0,100] scale, while others tend to crowd themselves into the highest segment of the scale. Meanwhile, there could also be experts who spread their score values across the whole scale.

This issue is addressed by a linear transformation of the physician's scores in order to spread them all over the scale range. This transformation is determined by the scores of the green and red scenarios together with the conservation of the ratio differences of workload scenarios (see Appendix A2 for the mathematical details). After the transformation, the scores from different physicians are comparable.

#### 2.2.2. Step 6. Table of data. Coherence and consistency analysis for each expert's answers

In this step, the internal coherence and consistency among raters are analyzed. Stress scores coming from no-coherent or inconsistent physicians have to be discarded. Coherence and consistency indices, based on the Kendall's tau-a and tau-b, are defined to assess coherence and consistency of physicians (see the mathematical details in Appendix A3 for the mathematical details).

#### 2.2.3. Step 7. Estimation of the job stress function based on scenarios assessments

Once physicians' scores for scenarios have been rescaled when necessary, and coherence and consistency controls have been carried out, the stress function is estimated by regression techniques.

The rescaled – when necessary - stress felt by a physician *i*, $Y_i(S_j) = Y_{ij}$, in the scenario $S_j$, can be expressed as

$$Y_{ij} = f(S_j) + \mathscr{E}_{ij}$$

where $f(S_j)$ is the stress induced by the scenario $S_j$, which could be interpreted as the consensus score [66], true score [67], or universal score [68] for the workload of $S_j$ over the population. The residual $\mathscr{E}_{ij}$ carries the unique effect for physician *i*. This personal component, $\mathscr{E}_{ij}$, is due to the person's reality perception, personality, years of experience, capability, etc. It is assumed that, $E(Y_{ij}) = f(S_j)$, and then $E(\mathscr{E}_{ij}) = 0$.

In order to keep the stress scores in the range [0, 100], a multiple linear regression with a logit link for the stress score is proposed. The independent variables are the stress variables $X = \{X_1, \ldots, X_{11}\}$.

$$logit(Y(S)) = \log\left(\frac{Y(S)}{100 - Y(S)}\right) = g(X) = \beta_0 + \beta_1 X_1 + \ldots + \beta_{11} X_{11} + \varepsilon$$

Then, the stress associated to a scenario $S$ is $Y(S) = 100 \times \frac{\exp(f(X))}{1+\exp(f(X))}$, and can be calculated from the values of the 11 variables $X_i$.

#### 2.2.4. Step 8. Validation of the job stress function

The regression model must be statistically validated by checking that all statistical assumptions are met. Furthermore, the ED physicians must qualitatively validate the job stress function obtained by their scenarios assessment as it will be used to fairly distribute patients among them, or as a performance measure of their ED, etc. Thus, the statistical significance of each identified stress factor, as well as the relative importance of them, must be shown to the physicians.

If there is no acceptance and consensus, the first training session must be repeated to modify the questionnaire or clarify its instructions as well as the objective of the study, stressors, and the stress scale. If there have been some no-coherent or inconsistent physicians, there must also be organized a discussion session about the stressors and the structure of the scenarios among participants to get them to improve their assessment. Finally, experts should fill out the questionnaires reassessing all scenarios to repeat the described process and reestimate the job stress function.

## 3. Application to a case study

This proposed methodology was applied to analyze the stress of physicians in the ED of the CHN, which is located in Pamplona (Spain). It serves a population of half a million people, and the number of annual patients exceeds 140,000. This ED is staffed 24 h per day with 43 board-certified emergency physicians.

### 3.1. Phase 1. Preparation for data acquisition

**Identifying the set of factors and their categories. Definition of workload scenarios and selection of a representative sample.** We widely discussed with the ED physician staff in order to define every factor affecting stress, as well as all their possible combinations to pinpoint the job stress variables. Then, we created the design of experiments imposing some constraints provided by them, e.g., no more than 16 patients being managed simultaneously ($\sum_{i=1}^{10} X_i \leq 16$), no more than eight patients waiting for the C1 simultaneously ($\sum_{i=1}^{6} X_i \leq 8$), etc.

The "D-optimal" design provided us 72 different scenarios to assess. Furthermore, we designed 12 extra scenarios as anchors – six for high stress levels and six for low stress levels. We designed six different questionnaires containing four cards with four different scenarios on each one (see Appendix B2).

**Drawing up the questionnaire for stress assessing.** As we have mentioned in Section 2, the scenarios of the questionnaire should imitate the ED physicians' computer screen (see Fig. 2). Each scenario shows the list of patients a physician has been assigned. Each patient has a priority (left part of each scenario panel: high, medium, and low - in this case, coded as 3, 4, and 5 respectively) and is in a specific medical attention phase with possible waiting time targets (color code). The length of each color bar indicates the patient priority. There is an indicator in the top right corner that shows if the physician is also supervising a resident (red) or not (white).

We grouped the 72 scenarios in six sets of 12 scenarios to form six different questionnaire models. Each questionnaire was complemented with two green and two red scenarios (one for each card) to augment variability with extreme scenarios on both sides of the scale. The 16 scenarios of a questionnaire were divided into four cards each one containing an anchor, and three other scenarios.

**Selection of experts, dry run exercise, expert training, and elicitation session.** The questionnaire was presented and provided to the 43 physicians of the ED in a training session. After two weeks –with a reminder in the middle of that period-we got 70% of the ED-physicians staff to answer the questionnaire (30 ED-physicians). They found the questionnaire reasonable and the scenarios very similar to their usual work situations.

We finally collected a total of 472 stress scores for the 84 scenarios (there were two instances where the last card of the questionnaire was overlooked - four scenarios on each one), and each scenario was rated by a minimum of four and a maximum of six different physicians.

### 3.2. Phase 2. Data analysis

**Homogenization of stress scales.** We calculated the stress score for green and red scenarios (both extreme sides of the stress scale), and we obtained 3 and 80 as the lower and the upper limit of the common scale range, respectively. Based on these values, we only rescaled the physicians' opinions whose minimum score was over the minimum limit or the maximum below the upper limit.

**Coherence and consistency of raters.** We first analyzed each physician's response in order to detect "incoherent" experts. They all scored with a higher stress value in the scenarios which dominate others, so we did not discard any physicians due to his/her incoherence.

Then, we calculated the consistency with the group index (see consistency indices in *Appendix **A3***). Only one physician showed inconsistent results respect to his/her group, who significantly ordered his/her questionnaire's scenarios differently in terms of stress. As a result, we didn't take into account his/her questionnaire. Table 5 shows the results of the group with the inconsistent physician (11), which has a low CGI value:

However, the rest of the groups did not present inconsistencies. As an example, Fig. 4 shows the scores that physicians gave to the scenarios in questionnaire model 2.

**Estimation of the job stress function based on scenarios assessments.** The data from 29 physicians were taken into consideration to run the multiple linear regression with the logit of the job stress score as the dependent variable (see Table 6). We obtained that all types of patients were statistically significant for the dependent variable (p-value<0.01).

However, supervision training, which had been mentioned by physicians as a relevant factor for stress, has a high p-value (0.238) not showing statistical significance. However, we included it in the model to calculate the stress as the physicians insisted on its relevance.

The chosen model yielded a determination coefficient of above 0.70, and the regression function was the following:

$$Y(S_j) = Y_j = 100 \times \frac{\exp(f(X))}{1 + \exp(f(X))}$$

$$f(\mathbf{X}) = -3.378 + 0.726X_1 + 0.458X_2 + 0.410X_3 + 0.313X_4 + 0.280X_5 + 0.207X_6 + 0.189X_7 + 0.155X_8 + 0.182X_9 + 0.113X_{10} + 0.0778X_{11}$$

$$X_1, \ldots, X_{10} \in \mathbb{N}$$

$$X_{11} \in \{0, 1\}$$

This model allows us to assess every possible situation in the ED through the workload information of the physicians' whiteboard. Fig. 5 shows the stress associated to different workload scenarios ordered from least stressful to most stressful.

**Validation of the job stress function.** This model was validated both statistically and qualitatively by physicians. All statistical assumptions for this regression were met. For example, Fig. 6 shows that residuals are normally distributed. We use the Anderson-Darling statistic with a 95% confidence level.

Model validity was also checked by the ED physicians. Table 6 clearly shows the factor's influence on physician job stress through the variable's coefficients. Patients, who have not yet been seen by a physician for the first time, have the highest coefficient ($X_i$, $i = 1,\ldots,6$). Within that group, patients whose waiting time has been exceeded ($X_i$, $i = 1, 2, 3$), contribute to higher levels of stress than the others ($X_i$, $i = 4, 5, 6$). This result supports theories that state that uncertainty and time pressure are some of the most prevalent causes of anxiety, which is a symptom of stress [69–71].

As patients have fewer process stages left, their contribution to the physicians' overall stress decreases ($\beta_i > \beta_j > \beta_{10}$, $i = 1,\ldots,6$; $j = 7, 8, 9$). Moreover, within all these groups of patients that produce a high amount of uncertainty and time pressure, the most severe a patient is the more stress he/she logically produces for the physicians.

As we mentioned, although supervision training did not show statistical significance, physicians wanted it to be included in the validated model to contribute to the total stress.

**Table 5**
Consistency of physicians belonging to Group 3.

| | Physician | Kendall's tau-b | p-value | CGI |
|---|---|---|---|---|
| Questionnaire Model 3 | 11 | 0.38 | 6.40E-02 | 0.07 |
| | 12 | 0.69 | 3.29E-04 | 0.74 |
| | 13 | 0.63 | 1.46E-03 | 0.58 |
| | 14 | 0.70 | 3.97E-04 | 0.50 |
| | 15 | 0.80 | 3.54E-05 | 0.61 |

## 4. Using the stress monitoring to balance the physicians job stress

The developed stress score allows us to assess the physician's job stress in every possible situation of the ED through the workload information of the physicians' whiteboard. The job stress score changes dynamically as the workload assigned to a physician also changes during the work shift (existing patients' health status evolve, new patients arrive, etc.). As an example, Fig. 7 represents the instantaneous real job stress level of six physicians during their work shift (historical data from a Monday from 8:00 to 15:00 in the ED of the HCN).

Currently, patients are assigned to a specific physician rotationally as they are triaged after arriving at the hospital ED, without considering their complexity, their priority, or the physicians' pending patients. This workload assignment rule causes significant differences among physicians' job stress, which is neither healthy nor fair. There are situations in which a physician could have accumulated many patients as they were all very complex and required a lot of medical care, while other physicians are idle as they were only assigned very mild patients.

The job stress measurement confirmed the feelings of stress and workload inequities among physicians reported by the HCN-ED physicians. This result motivates the investigation to change the patient assignment rule in order to reduce job stress variability among physicians during the work shift. As an example, the assignment of a patient upon arrival to the physician with the lowest stress score achieves a better stress balance among physicians. Fig. 8 represents the job stress of the six physicians the same Monday of Fig. 7 by using this new assignment rule based DSS during the work shift. It has been reproduced the same demand and patients' characteristics, that is, it has been used the information of all patients that arrived that day (necessary treatments, length of consultations, care pathways, etc.) and events have been reorganized considering that patients were assigned to the physician with the lowest job stress level.

We have considered a sample of 50 days (including that represented in Figs. 7 and 8) and as a result, the variability in the job stress experienced by physicians has been decreased by more than 60%. It has been quantified by using the Mean Absolute Error (MAE),

$$MAE(t) = \frac{1}{n}\sum_{i=1}^{n}|x_i(t) - x(t)|, \quad t = [0,\ t_{END}]$$

where $n$ is the number of physicians, $x_i$ the stress being experienced by physician $i$ at time $t$, $x$ the average of stress per physician at time $t$, and $t_{END}$ is the time when the work-shift ends. A paired $t$-test for testing differences between paired observations of the mean $MAE$ during the work shift has been performed with a confidence interval of 95% (p-value<0.01).

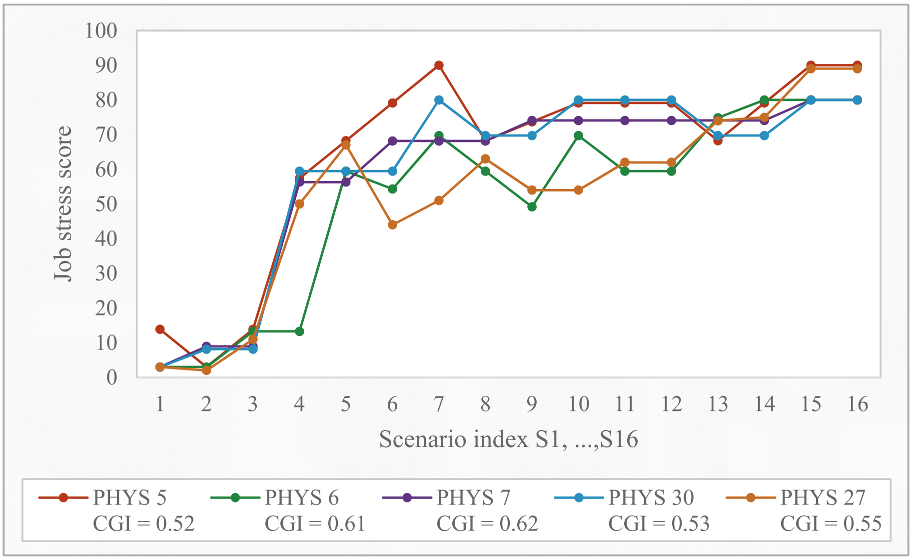



**Fig. 4.** Group 2 scenarios' score.

**Table 6**
Regression coefficients.

| Model variables (combining stress factors) | | Coef. | p-value |
|---|---|---|---|
| Number of patients in each care situation | | | |
| Waiting for the C1 ($F_3 = 1$) | | | |
| Time limit exceeded ($F_4 = 1$) | | | |
| Number of Priority 1 patients | $X_1$ | 0.726 | <0.001 |
| Number of Priority 2 patients | $X_2$ | 0.458 | <0.001 |
| Number of Priority 3 patients | $X_3$ | 0.410 | <0.001 |
| Time limit not exceeded ($F_4 = 0$) | | | |
| Number of Priority 1 patients | $X_4$ | 0.313 | <0.001 |
| Number of Priority 2 patients | $X_5$ | 0.279 | <0.001 |
| Number of Priority 3 patients | $X_6$ | 0.207 | <0.001 |
| In process ($F_3 = 2$) | | | |
| Number of Priority 1 patients | $X_7$ | 0.189 | <0.001 |
| Number of Priority 2 patients | $X_8$ | 0.155 | <0.001 |
| Number of Priority 3 patients | $X_9$ | 0.182 | <0.001 |
| Waiting for transfer ($F_3 = 3$) | | | |
| Number of patients | $X_{10}$ | 0.113 | 0.005 |
| Training supervision | | | |
| Resident supervision | $X_{11}$ | 0.078 | 0.238 |

However, it has been reduced not only the variability of stress across physicians but also the amount of stress experienced. The average stress per physician and the maximum stress per physician have been reduced by almost 5% and 10%, respectively, when using the new proposed assignment rule based on the stress score during the work shift, see Fig. 9. A *t*-test has been performed on each measure with a confidence interval of 95% (p-value<0.01 for both).

Moreover, it has been taken into account time-related KPIs linked with patients, which have been significantly improved. Welch et al. [72], Welch et al. [27], and most recently Vanbrabant et al. [56] list various metrics by which ED performance can be measured, such as the APT, mentioned in the Introduction. This important time interval is widely used in emergency healthcare services, since many illnesses are time-dependent, and a delay in the diagnostic evaluation by a qualified medical provider could be a health risk for the patient. Thus, the APT limit is used as a KPI. Furthermore, most EDs define a maximum waiting time for each acuity level and set performance goals related to them, as explained in Table 1's CTAS. In this study, the ratio of patients whose APT exceeds the time limit is also considered a KPI.

A 2-sample *t*-test has been performed for the APT with a confidence value of 95% obtaining a reduction of 3% for P3 (p-value = 0.028) and 10% for P45 (p-value<0.001). These improvements also have a significant impact on the proportion of patients who exceed the APT limit (see Fig. 10, where proportions have been represented as percentages). A test of two binomial proportions has been performed, which shows a reduction of 12% for P3 (p-value = 0.002) and 23% for P45 (p-value = 0 < 0.001).

## 5. Conclusions

The medical literature recognizes that a better distribution of work among professionals reduces stress levels and thereby mitigates burnout, which is a frequent phenomenon in the health field and potentially detrimental to the health care received by patients. In fact, several studies claim that high workload and stress levels contribute to increasing human and system error rates (e.g. Ref. [73]). It is therefore important that indicators of physicians' working conditions be included in patient management criteria sets. Thus, the results presented in this paper have implications for the improvement both of physicians' working conditions and ED patient-flow management.

In this paper, we have introduced a methodology that enables real-time monitoring of physician stress due to workload volume and the evolving characteristics of the work-shift. The factors considered include not only the number and priority level of the patients but also their stage in the care process, waiting time, etc. Physicians' consensus views with respect to the importance of the different stress factors are also considered in order to obtain an overall factor score indicating each patient's contribution to the physician's total job stress. Our job stress conceptualization includes not only the workload but also the associated time pressure and uncertainty. For example, once a priority 1 patient is assigned to a physician, his or her contribution to the physician' stress will vary between the following situations:

- Situation 1: waiting for C1 for 2 min.
- Situation 2: waiting for C1 for longer than the time limit for a priority 1 patient.
- Situation 3: waiting for the release of test results ordered by a physician in C1.

In situations 1 and 2 there is uncertainty: the physician has not yet

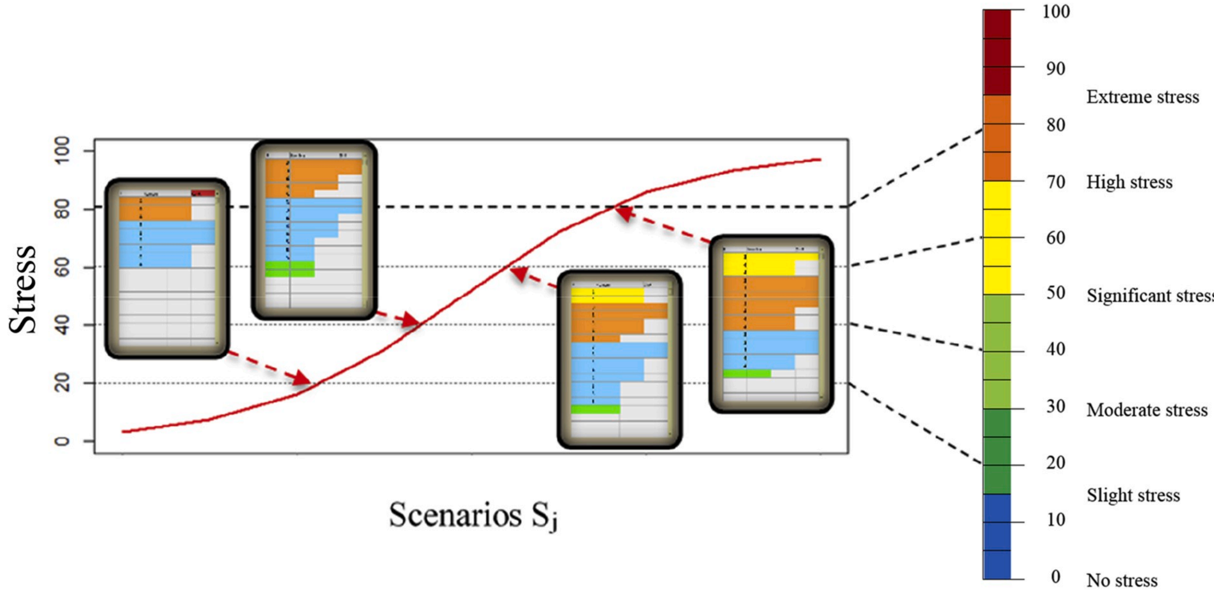
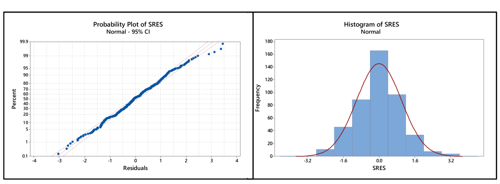



**Fig. 5.** Graphical representation of the stress assessment function. The four scenarios included are among the 84 designed scenarios for the questionnaires.




| Statistic | Value |
|---|---|
| Mean | 0 |
| StDev | 1 |
| p-value | >0250 |
| AD | 0.625 |

**Fig. 6.** Probability Plot and Histogram of residuals.

seen the priority 1 patient and does not know what medical care will be required, the severity of the patient's condition, or the nature of the accompanying circumstances, etc. Situation 2 is worse again in terms of stress than situation 1, as the maximum target waiting time for C1 has been exceeded, and the patient's health status may have altered or even deteriorated (time pressure).

All these nuances can be perceived with this method because it is based on the elicitation of experts' opinions and experience. Self-reported respondents have conscious awareness of experiencing stress and are presumably able to describe how it feels.

The importance of the qualitative validation of the ED physicians' estimated stress function must be emphasized, as it will be used in the workload assignment. The results of the statistical analysis of the stress-factor importance levels recorded in the case study largely matched physicians' expectations. Patients who have yet to be seen are a source of physician stress, which is all the stronger if the patients have already waited beyond the target waiting time. It is remarkable that, although all ED physicians reported during Phase 1 that resident supervision was a major stressor, this factor proved to have no statistical significance in our analysis. Nevertheless, in the validation phase, it was agreed that it must be included in the regression function for the sake of fairness in the workload distribution.

In addition to its aforementioned value as an important KPI for assessing any ED patient-management flow rule, the resulting job stress score can be used as an ED patient-flow management criterion.

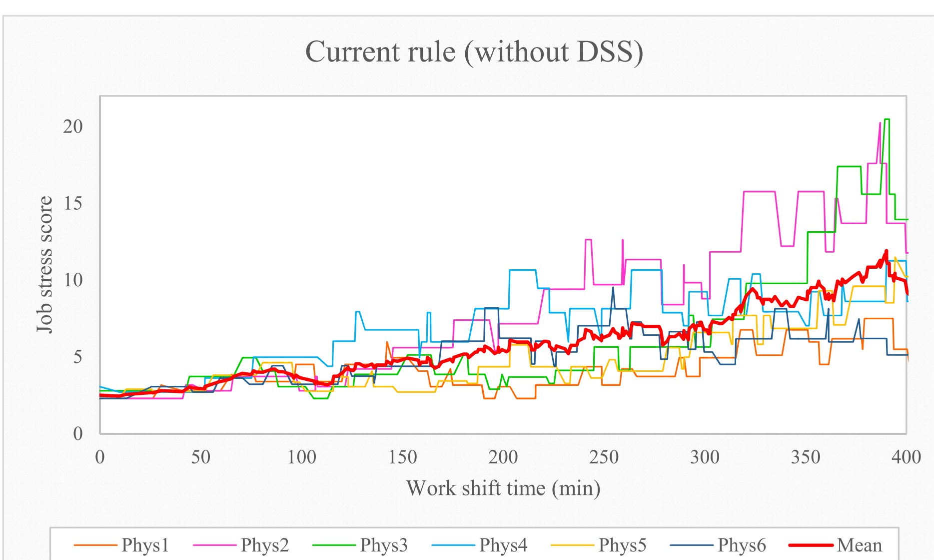



**Fig. 7.** Stress associated to each physician during a specific work shift with the current assignment rule.

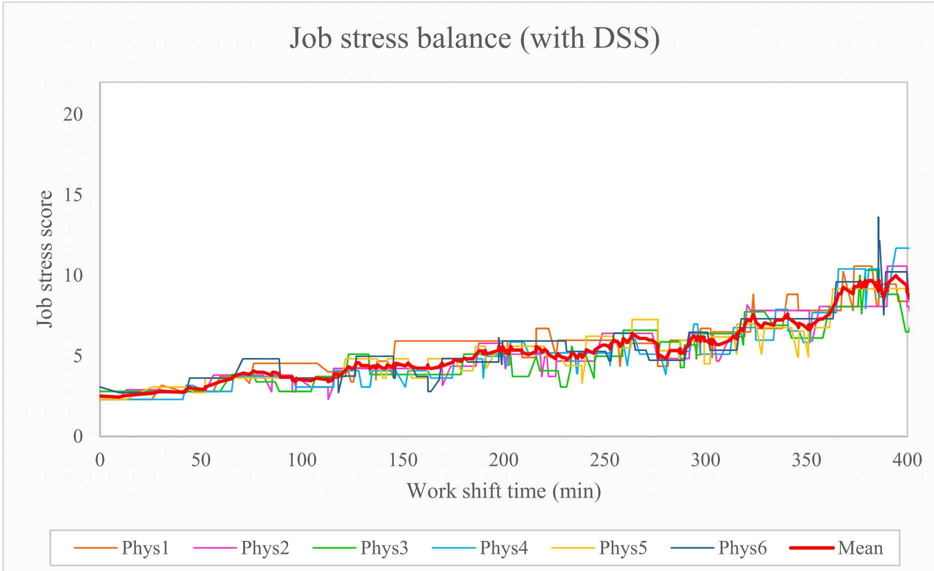



**Fig. 8.** Stress associated to each physician during a specific work shift by using a DSS based on the minimum stress score assignment rule.

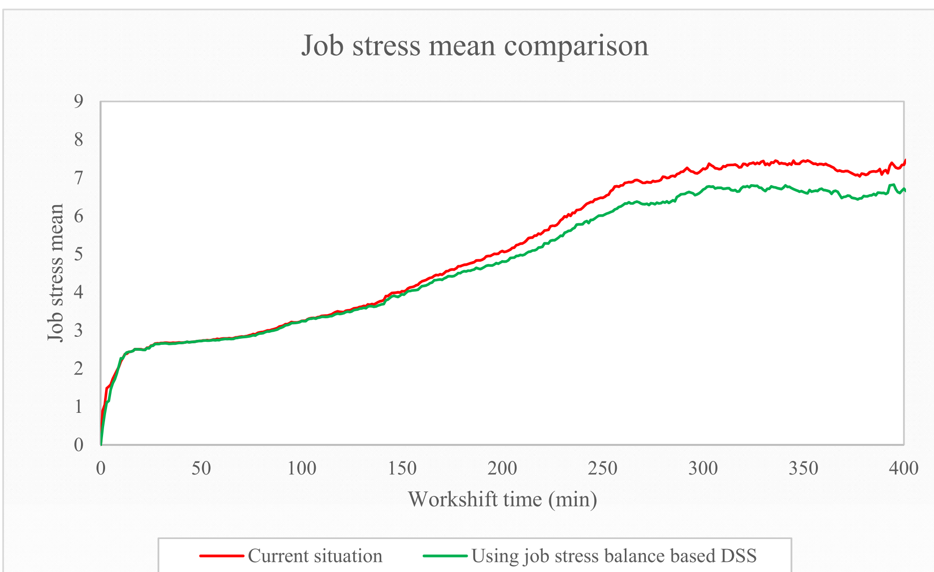



**Fig. 9.** Average of stress per physicians during a work shift by using the current rule and the new job stress balance rule.

This paper has demonstrated the advantages of using a DSS based on this dynamic, balanced job stress score, which is easy to calculate and to implement in ED patient-to- physician assignment after arrival and triage. We propose a new patient-flow management rule based on the balance of job stress among the whole team of physicians. The results show a reduction of more than 60% in the variability of stress levels among physicians and a 10% decrease in mean stress levels, as well as a reduction in APT and an improved APT target achievement rate. A simplified version of the described DSS has been implemented in a real-life context via the Electronic Health Record system, which takes into account only the patient's acuity. Physicians perceive a more even spread of job stress under the new workload distribution and less difference in the number of patients they are each managing simultaneously at the end of the work shift. The electronic records also show KPI improvements in line with those reported by the simulation model. However, given its practical interest, a full discussion of this intervention and its results is being prepared as a research article for a medical journal.

The methodology for assessing physician stress was developed in the context of a public hospital where physicians are salaried and there is no clinical productivity component or overtime. Therefore, the stress factors were determined after analyzing the literature and in accordance with the ED physicians' own views. In a different type of staffing regime, say a fee-for-service model, for instance, where physicians are incentivized to see more patients by increasing billing reimbursements, doctors may experience different stress factors. We therefore acknowledge that there may be stress factors other than those considered in our study. One example would be the (sometimes unpaid) extra time required to see all scheduled patients, which physicians cite as one of their main stressors. Nevertheless, the methodology proposed in this paper is general enough to be adjusted to the monitoring of physician job stress in any ED, with the help of the case study and supplementary material (questionnaires and guidelines included in Appendix B, and mathematical details included in Appendix A) presented here. All that is

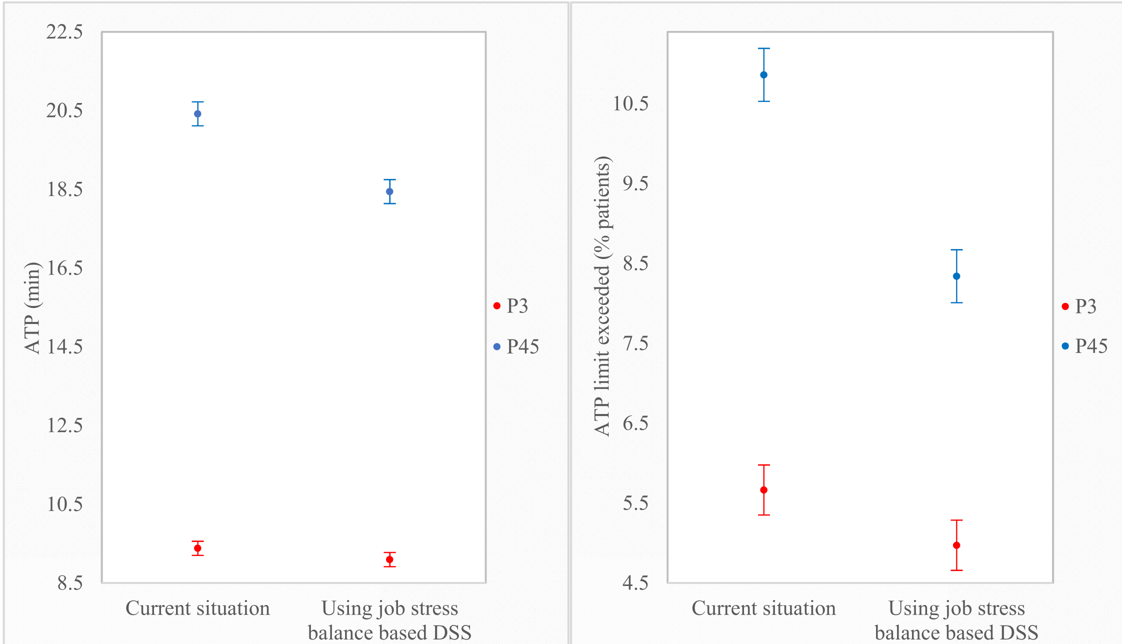



**Fig. 10.** Waiting time (left) and percentage of patients who exceed their APT time limit (right).

required is that physicians assess different workload scenarios following steps 1–4 (these scenarios will be created as part of the experimental design, taking into account the stress factors identified as relevant by the ED physicians); the stress function is then estimated by analyzing the data following steps 5–7.

## CRediT authorship contribution statement

**Marta Cildoz:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Amaia Ibarra:** Conceptualization, Validation, Investigation, Resources. **Fermin Mallor:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition, Project administration, Funding acquisition.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.seps.2020.100828.

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