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Review paper

HUMAN ERROR ANALYSIS – A CASE STUDY

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Abstract. *Due to the high risk and unpredictability of situations that firefighters encounter during fire-rescue interventions, assessing human reliability is crucial, as any mistake can have serious consequences for the safety of firefighters, vulnerable individuals, as well as natural and material assets. In this paper, the Success Likelihood Index Method (SLIM) was applied to analyze human errors in fire rescue interventions. A scenario involving a fire on the 7th floor of a student dormitory near the Faculty of Electronics in Niš was used for the human error analysis.*
In this paper, typical performance shaping factors (PSFs) were analyzed, and 10 characteristic errors of firefighters-rescuers were identified, for which the human error probability (HEP) was determined. The analysis revealed that "errors in routine operations" have the highest probability of occurrence, with the most significant contributing PSFs being teamwork and procedures. The results show that SLIM enables the identification of critical points where errors most often occur and provides good guidelines for defining corrective measures and reducing the likelihood of errors occurring among firefighters-rescuers.

Key words: *human error (HE), Success Likelihood Index Method (SLIM), human error probability (HEP), Performance Shaping Factors (PSFs), fire-rescue interventions.*

1. INTRODUCTION

Human errors (HEs) in the workplace often lead to unforeseeable consequences. The causes of these errors vary, but they become particularly problematic in emergency situations. In such cases, the time available for a person to respond is limited, which increases stress and, consequently, the probability of making an error [1].

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Human error is often the result of a complicated series of events, so a comprehensive definition of human error is very difficult to formulate. Human error can be defined as the failure of planned actions to achieve desired goals without the intervention of external or unpredictable events. This definition was provided by Reason [2]. In addition, Swain's [3] definition is frequently cited in the literature, which states that human error occurs when any procedural step within a set of activities exceeds a certain threshold of acceptability – whether through actions or omissions by the operator or team – that cannot be tolerated, whereby acceptable performance limits of the operator are defined within the performance of the system in which the operator works.

According to the traditional approach, human error is the cause of failure in the functioning of the system and the cause of accidents, while according to the modern approach, human error reflects deeper problems that exist in the system and is the result of systemic relationships between people, tools, tasks and the work environment [4, 5]. That is why the majority of researchers who deal with the issue of human reliability assessment agree that errors made by a person (operator) are a specific result of his performance, actions, or characteristics.

Fire and rescue units carry out a wide range of tasks, from extinguishing fires and performing technical interventions to mitigating the consequences of disasters. They are organized to ensure a prompt response at all times, with minimal preparation time required before deploying to interventions. The goal of this paper is to apply the Success Likelihood Index Method (SLIM) to analyze human errors during fire-rescue interventions, specifically in the scenario of "Extinguishing a fire in a room on the 7th floor of a student dormitory near the Faculty of Electronics in Niš."

The Success Likelihood Index Method (SLIM) is based on expert evaluation of performance shaping factors (PSFs) and the quality of the task being analyzed. Through this assessment, the probability of human error occurrence is determined. PSFs are factors that can either positively or negatively affect human performance. They are considered the root causes of errors, and during the SLIM process for a given task, a group of experts identifies these factors [6, 7]. Typical PSFs used in the analysis of human errors include [8]: time pressure, quality of information, task complexity, teamwork, training, operator experience, type and quality of procedures, and more. During the implementation of this method, a group of experts evaluates potential human errors that may occur during a specific activity or task, while also assessing the extent to which performance-shaping factors influence the likelihood of those errors.

This paper examines 10 most common human errors when performing fire-rescue interventions: Failure to use or not wearing personal protective equipment that is correctly fitted, Errors in routine operations, Routine work/tasks, Underestimating the situation and focusing only at its segments, Omitting procedural steps in the field, Failure to perform or refusal to carry out the commander's orders, Poor mental and physical condition of workers, Failure to use means of communication (radio station), Use of untested equipment (e.g., the owner's ladder), and Inadequate use and maintenance of equipment. Also, 6 typical PSFs were selected, which influence the occurrence of these errors: Training, Procedures, Time, Teamwork, Communication, and Experience.

2. A DESCRIPTION OF THE CASE STUDY

For the purposes of research, and in cooperation with the employees of the Fire and Rescue Unit in Niš, the scenario "Extinguishing a fire in a room on the 7th floor of a student dormitory near the Faculty of Electronics in Niš" was selected [9].

After receiving the fire incident report at 1:29 p.m., the report was verified, confirming it as a real event. A team comprising 12 personnel and 4 vehicles was dispatched to the scene: one naval vehicle with 5 personnel, one tanker with 4 personnel, one hydraulic telescopic platform with 1 person, and one command vehicle with 2 personnel. Meanwhile, a telephone operator and 8 personnel, along with the deputy brigade commander, remained at the unit. At 1:33 p.m., the Information Center and the police were notified, followed by a notification to the Electric Power Company service at 1:34 p.m.

The distance between the event site and the Fire and Rescue Unit is approximately 2,500 meters. During the arrival at the fire scene, traffic was regular. The "Tetra" system was used for radio communication between the action manager and the Communication Center.

Upon arrival, the fire-rescue team observed thick black smoke and flames billowing from one of the windows. They received additional information indicating that the burning student room was located on the 7th floor and that several students and maintenance workers remained inside the building.

The team found the fire in an advanced stage, affecting the room on the 7th floor in the southeast corner of the building, with a tendency to spread vertically. The police, emergency medical services, and a team from Electric Power Company service were also on-site because of the large number of students present and the pressing need to focus on rescue and firefighting.

At the time of arrival of the fire-rescue unit, the area affected by the fire was approximately 15 m² out of a total floor area of 600 m². The aggravating circumstances included: high temperatures inside the building, the number of floors, a large number of people inside, heavy smoke spreading from the 4th to the 10th floor, and the inoperability of the hydrant network due to a power outage.

Upon arrival of the fire-rescue unit, the formation of two work sectors began immediately:

1. Rescue and Evacuation Sector (internal rush and external rush using a hydraulic telescopic platform);
2. Firefighting Sector (internal rush).

In conjunction with reconnaissance efforts, the evacuation of vulnerable individuals from the upper floors was carried out, along with the opening of vents and windows to clear the space. An order was issued to clear a path through the staircase inside the building. Additionally, a logistics team was formed to deliver the necessary equipment to the scene and refill compressed air bottles.

Within both work sectors, two sub-sectors were formed. The first sub-sector, responsible for rescuing and evacuating individuals inside the building threatened by smoke, consisted of three members. The second sub-sector, focused on external rescue and evacuation, conducted reconnaissance using a hydraulic telescopic platform with three operators.

In the firefighting sector, the first sub-sector, with four members, was tasked with scouting and extinguishing the fire in the room on the seventh floor and protecting the rooms on the eighth floor. The second sub-sector was responsible for establishing a track from the vehicle to the room on the seventh floor, supported by the remaining available personnel. As operations progressed, regular rotations were made to replace tired personnel with more rested team members.

The fire was contained at 2:04 p.m. After localization, rested personnel replaced the initial team, and the extinguishing of smaller hotspots began. Both the deputy commander of the Fire and Rescue Brigade in Niš and the deputy head of the Emergency Situations Administration in Niš were present at the scene. They received verbal and radio reports from sector leaders, as well as from the crew leader.

Logistics continually delivered the necessary equipment to the scene. Coordination with members of the traffic police from the Niš Police Department ensured faster access for fire engines. The fire was fully extinguished at 3:40 p.m. through the coordinated efforts of all sectors, as well as other personnel involved in the intervention.

After the fire was extinguished, the personnel were replaced by a new team from the Fire and Rescue Brigade in Niš, who remained on duty until 7:30 p.m. Following that, the fourth crew conducted several inspections of the building throughout the night.

During the intervention, around twenty people were evacuated, and approximately 600 m² of living space on the seventh and eighth floors was saved. The fire chief remained in command throughout the intervention, with no need to involve additional firefighting units, local government, or citizens. There were no equipment failures during the operation.

The primary dangers included high temperatures, thick smoke, working at heights, and the risk of injuries, cuts, and burns. To ensure safety during rescue, evacuation, and firefighting operations, all personnel involved in the internal rush wore appropriate personal protective equipment (protective suits, helmets, belts, gloves, and boots), as well as shared equipment (respiratory protection devices and Tetra radio stations). This minimized the risk of injury.

Throughout the intervention, the weather conditions were as follows: the outside air temperature was 26°C, with a wind speed of approximately 2 m/s. The weather remained mostly unchanged during the operation, with no precipitation.

2.1. Description of the SLIM Procedure

The human reliability assessment in fire-rescue interventions was conducted using SLIM. Based on the described scenario, potential errors were identified and quantified to establish preventive and corrective measures, ensuring the safe and reliable operation of fire-rescue units during interventions.

2.2. Selection of Experts

This research involved four experts and a coordinator, all of whom have professional experience in firefighting and rescue interventions.

2.3. Human Error Identification

The experts identified several characteristic mistakes made by firefighters and rescuers that occur or may occur during interventions [9]:

1. Failure to use or not wearing personal protective equipment that is correctly fitted;
2. Errors in routine operations;
3. Routine work/tasks;

4. Underestimating the situation and focusing only at its segments;
5. Omitting procedural steps in the field;
6. Failure to perform or refusal to carry out the commander's orders;
7. Poor mental and physical condition of workers;
8. Failure to use means of communication (radio stations);
9. Use of untested equipment (e.g., the owner's ladder);
10. Inadequate use and maintenance of equipment.

2.4. Elicitation of Typical PSFs

For this research, six typical PSFs were selected that influence the occurrence of errors during the interventions of fire and rescue teams:

1. Training (exercises);
2. Procedures (type and quality of procedures);
3. Time (time pressure);
4. Teamwork (team structure and cooperation);
5. Communication (written or verbal);
6. Experience (current level of experience and skill).

The experts assessed the impact of each PSF on the 10 selected errors using a scale from 1 to 9, where 1 represents the least impact and 9 represents the greatest impact.

3. Results and discussion

After identifying potential human errors and defining the PSFs, the experts assessed the impact of each PSF on the ten previously identified errors. Further data processing, including value normalization, determined the contribution of each PSF to the occurrence of errors. The experts' ratings and the normalized values of the PSFs are presented in Table 1.

Table 1 The estimated and normalized PSF values

Error N°	$^{*}R_{ij}$						∑
	Training	Procedures	Time	Teamwork	Communication	Experience	
1.	6	9	7	9	6	7	44
2.	5	8	8	9	7	6	43
3.	8	8	9	9	7	8	49
4.	6	9	6	9	5	8	43
5.	7	8	7	9	6	7	44
6.	6	9	8	9	7	8	47
7.	8	8	9	9	7	7	48
8.	8	9	8	9	7	6	47
9.	7	9	7	8	8	6	45
10.	7	9	8	9	6	7	46
∑ *PSF*	68	86	77	89	66	70	456
W_i**	0.149	0.188	0.169	0.195	0.145	0.154	1

$^{*}R_{ij}$ rating of task on the given PSF
(1 represents the smallest, while 9 represents the highest influence of PSF on a specific task);
W_i** normalized importance weighting for the given PSF

The total Success Likelihood Index (*SLI*) for a specific task j (denoted as SLI_j) is calculated using the following expression [10]:

$$SLI_i = SUM(R_{ii} \cdot W_i) \ , \text{ for i=1, … i=x} \tag{1}$$

where x is the number of PSFs considered.

The obtained values of the SLI are presented in Table 2.

Table 2 Success Likelihood Index (SLI)

Error N°	R_{ij}*						∑SLI
	Teamwork	Procedures	Time	Experience	Training	Communication	
1.	1.755	1.692	1.183	1.078	0.894	0.870	7.472
2.	1.755	1.504	1.352	0.924	0.745	1.015	7.295
3.	1.755	1.504	1.521	1.232	1.192	1.015	8.219
4.	1.755	1.692	1.014	1.232	0.894	0.725	7.312
5.	1.755	1.504	1.183	1.078	1.043	0.870	7.433
6.	1.755	1.692	1.352	1.232	0.894	1.015	7.940
7.	1.755	1.504	1.521	1.078	1.192	1.015	8.065
8.	1.755	1.692	1.352	0.924	1.192	1.015	7.930
9.	1.560	1.692	1.183	0.924	1.043	1.160	7.562
10.	1.755	1.692	1.352	1.078	1.043	0.870	7.790

The *SLI* serves as an indicator of the relative probabilities of different errors, ranking them in order of likelihood but does not define absolute probabilities. The transformation of *SLI* into *HEP* is achieved by establishing their logarithmic relationship using the following expression [10]:

$$\log(HEP) = a(SLI) + b \tag{2}$$

where a and b are coefficients that can be derived by the process of simultaneous equalization until at least two measurement probabilities are evaluated. In this way, the probability of the occurrence of specific human errors is reached.

For this research, the values assigned to coefficients a and b are – 0.75 and 2.35, respectively. The resulting Human Error Probability (HEP) values are also presented in Table 3.

Table 3 Human Error Probability (HEP)

Error N°	HEP
1. Failure to use or not wearing personal protective equipment that is correctly fitted	0.00056
2. Errors in routine operations	0.00076
3. Routine work/tasks	0.00015
4. Underestimating the situation and focusing only at its segments	0.00073
5. Omitting procedural steps in the field	0.00059
6. Failure to perform or refusal to carry out the commander's orders	0.000248
7. Poor mental and physical condition of workers	0.0002
8. Failure to use means of communication (radio stations)	0.00025
9. Use of untested equipment (e.g., the owner's ladder)	0.00048
10. Inadequate use and maintenance of equipment	0.00032

The HEP values for each of the considered errors are shown in Figure 1.

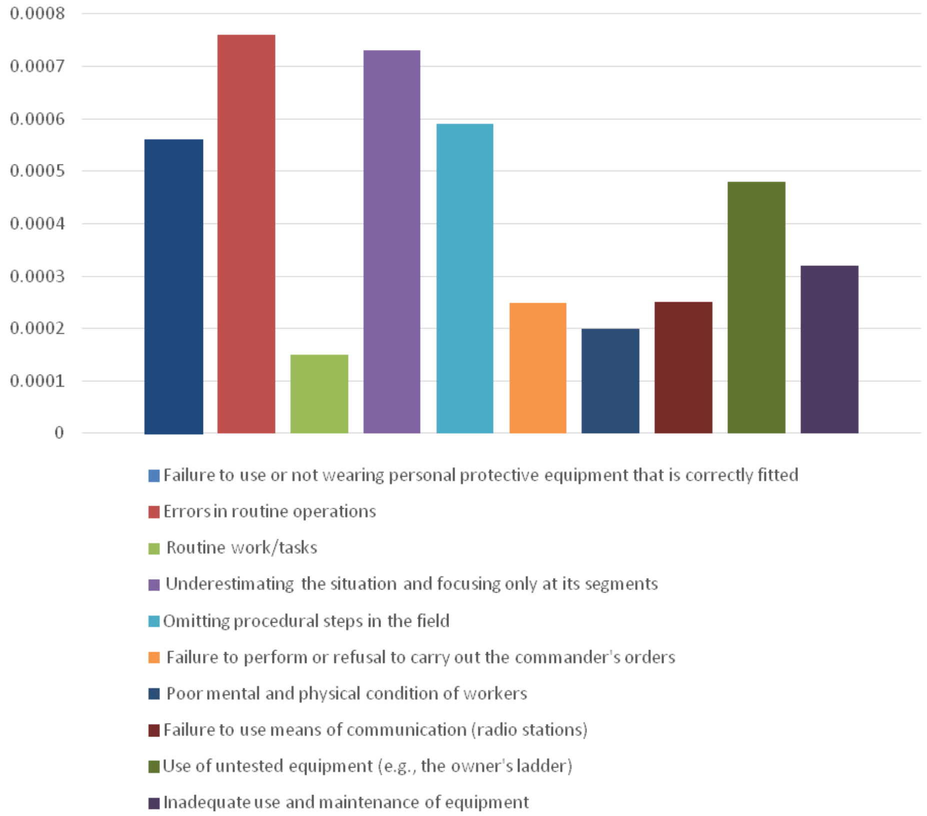

Fig. 1 HEP values for specific tasks during firefighting interventions

Based on the results and normalized PSF values (Figure 2), it can be concluded that "Teamwork" and "Procedure" are the two most significant factors influencing performance, with the greatest impact on error occurrence. These are followed by "Time" and "Experience," while "Training" and "Communication" were evaluated as the PSFs contributing the least to human error in this case.

Given that "Teamwork" is the PSF with the greatest impact on error occurrence, it can be concluded that aspects such as team structure, socializing with colleagues, positive interpersonal relationships, cooperation, and mutual support in completing tasks contribute to reducing human errors. Effective teamwork requires strong communication, mutual respect, and trust, as well as collaboration in distributing tasks and responsibilities.

The second most PSF is "Procedures," highlighting the critical need for the manager to be aware of the order of priorities at all times during the intervention. These priorities include the safety of firefighters and rescuers, the safety of vulnerable individuals, event stabilization, and property protection. Deviating from this order can lead to unforeseeable consequences.

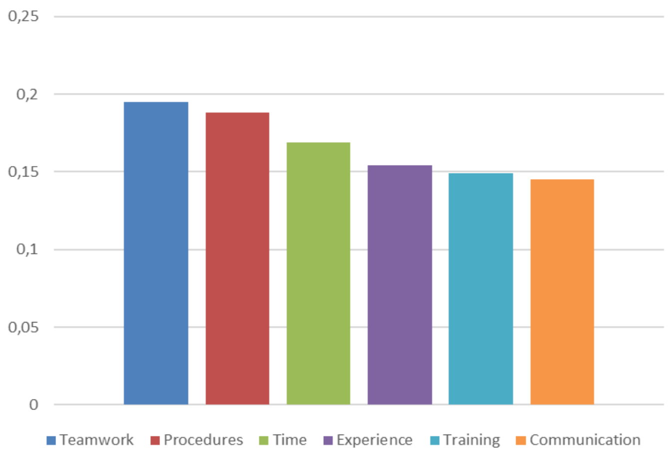

Fig. 2 Normalized PSF values

Firefighter-rescuer interventions are characterized by constant, dynamic changes in conditions. As a result, "Time" was rated as the third most important PSF, with "Experience" ranked fourth. Due to the lack of time to assess the situation, constant changes in the intervention conditions and correction of the primary decision are inevitable. Decision-making and action are often based on past experiences, making "Experience" a crucial factor in shaping performance, one that should not be overlooked.

One of the key causes of human error is insufficient knowledge of how tasks should be performed, particularly in critical and dangerous situations. In the analyzed case, "Training" ranked as the fifth most important PSF, while "Communication" was placed sixth. During interventions, communication can occur directly or via radio, and an effective exchange of information can significantly accelerate the decision-making and management process.

4. Conclusion

To analyze human errors and quantify performance-shaping factors (PSFs) that can both contribute to and reduce errors in fire-rescue interventions, the Success Likelihood Index Method (SLIM) was applied to the scenario "Extinguishing a fire in a room on the 7th floor of a student dormitory near the Faculty of Electronics in Niš."

In this scenario, human errors with the highest probability of occurrence are „Errors in routine operations" (HEP = $7.6 \cdot 10^{-4}$), "Underestimating the situation and focusing only at its segments" (HEP = $7.3 \cdot 10^{-4}$) and „Omitting procedural steps in the field" (HEP = $5.9 \cdot 10^{-4}$). After that, the following errors are "Failure to use or not wearing personal protective equipment that is correctly fitted" (HEP = $5.57 \cdot 10^{-4}$), „Use of untested equipment (e.g., owner's ladder)" (HEP = $4.8 \cdot 10^{-4}$), and "Inadequate use and maintenance of equipment" (HEP = $3.2 \cdot 10^{-4}$). Similar probabilities of occurrence have „Failure to use means of communication (radio stations)" (HEP = $2.5 \cdot 10^{-4}$) and „Failure to perform or refusal to carry out the commander's orders" (HEP = $2.48 \cdot 10^{-4}$). Errors with the lowest probability of occurrence value are, „Poor mental and physical condition of workers" (HEP = $2 \cdot 10^{-4}$), and „Routine work/tasks " (HEP = $1.5 \cdot 10^{-4}$).

In the given example, the selected PSFs were: "Training (exercise)," "Procedures (type and quality of procedure)," "Time (time pressure)," "Teamwork (team structure and cooperation)," "Communication (written or verbal)," and "Experience (current level of experience or skill)." The analysis revealed that "Teamwork" has the greatest impact on the occurrence of errors, while "Errors in routine operations" have the highest probability. The research results demonstrate that SLIM provides an effective framework for identifying and assessing human errors, as well as for defining corrective measures to reduce the likelihood of errors during fire-rescue interventions.

The complexity and seriousness of various fire-rescue interventions highlight that the readiness and proper equipment of these units for rapid and effective response is a fundamental prerequisite for successfully protecting and rescuing people and property. This is especially crucial in cases of extinguishing large-scale fires and mitigating their aftermath. Observing real situations during interventions reveals that implementing protective measures, using specialized protective equipment, and adhering to operational protocols significantly reduce the number of risky events. Moreover, if any such events do occur, their negative consequences – such as property damage or injuries to intervention participants – are minimized.

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ANALIZA LJUDSKIH GREŠAKA – STUDIJA SLUČAJA

Zbog visokog rizika i nepredvidivosti situacija u kojima se vatrogasci nalaze u vatrogasno-spasilačkim intervencijama, procena ljudske pouzdanosti je od suštinske važnosti, jer bilo kakva greška može imati ozbiljne posledice po bezbednost vatrogasaca, ugroženih osoba, prirodna i materijalna dobra. U ovom radu primenjena je metoda indeksa verovatnoće uspeha (SLIM) za analizu ljudskih grešaka u vatrogasno-spasilačkim intervencijama. Za analizu ljudskih grešaka korišćen je scenario gašenja požara na 7. spratu studentskog doma kod Elektronskog fakulteta u Nišu.

U radu su analizirani tipični faktori oblikovanja učinka (PSFs), a identifikovano je i 10 karakterističnih grešaka vatrogasaca-spasilaca, za koje je određena verovatnoća nastanka grešaka (HEP). Procenjeno je da "greške u rutinskim operacijama" imaju najveću verovatnoću, a faktori oblikovanja učinka koji najviše doprinose njihovoj pojavi su timski rad i procedure. Rezultati pokazuju da SLIM omogućava identifikaciju kritičnih tačaka gde greške najčešće nastaju, i daje dobre smernice za definisanje korektivnih mera i smanjenje verovatnoće nastanka grešaka kod vatrogasaca-spasilaca.

Ključne reči: *ljudska greška, metoda indeksa verovatnoće uspeha (SLIM), verovatnoća ljudske greške (HEP), faktori oblikovanja učinka (PSFs), vatrogasno – spasilačke intervencije.*