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Design and psychometric evaluation of a prehospital emergency response performance tool for mass-casualty traffic incidents: a mixed-methods study

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Abstract

Background

Prehospital emergency medical services (EMS) play a vital role in managing mass-casualty incidents (MCIs) resulting from road traffic crashes. The lack of a locally developed, context-specific instrument to assess the performance of these services under crisis conditions represents a significant gap in Iran's health system. Therefore, this study aimed to develop and psychometrically evaluate a comprehensive instrument for assessing prehospital services in mass-casualty traffic incidents in Iran.

Methods

This study used an exploratory sequential mixed-methods design. In the qualitative phase, data were collected through 31 semi-structured interviews with experts and operational personnel from relief organizations in the provinces of Yazd, Fars, Kohgiluyeh and Boyer-Ahmad, and Qom, and analyzed using content analysis. In the quantitative phase, an initial item pool was developed based on the qualitative findings. Face and content validity were assessed (using CVR and CVI), after which construct validity was evaluated using exploratory factor analysis (EFA) with oblique Promax rotation, based on data collected from personnel of relief organizations nationwide. Reliability was examined using Cronbach's alpha together with the split-half method.

Results

Three main themes emerged from the qualitative analysis: prehospital response, staff skill and efficiency, and integrated management of relief organizations. In the quantitative phase, the initial 121-item instrument was reduced to 49 items across the validation stages. EFA indicated that the three extracted factors jointly accounted for 45.87% of the total variance. Sampling adequacy was confirmed by a Kaiser-Meyer-Olkin (KMO) index of 0.937 and a significant Bartlett's test of sphericity ($P < 0.001$). Cronbach's alpha exceeded 0.8 for both the full instrument and its subscales, indicating satisfactory reliability.

Conclusions

The 49-item instrument developed in this study, with its strong psychometric properties, provides a valid framework for assessing the preparedness and performance of the emergency response system in mass-casualty traffic incidents. Its particular emphasis on integrated management and staff competence makes it a practical tool for crisis managers to identify weaknesses, assess training needs, and improve the quality of services at crash scenes.

Background

Mass-casualty incidents (MCIs) are among the most critical challenges confronting emergency medical services (EMS) worldwide. The large number of casualties involved overwhelms existing health systems and personnel and quickly exceeds local capacity and resources (1). MCIs are diverse in nature and span a wide range of events, including road traffic crashes, terrorist attacks, civil unrest, large-scale destruction, and chemical, biological, radiological, nuclear, and explosive (CBRNE) incidents (2).

Today, road traffic crashes are one of the leading public health challenges worldwide and have considerable adverse effects on the health of individuals and communities (3). Every year, about 1.19 million people worldwide die in road traffic crashes, a figure that has fallen by about 5% since 2010. Nearly 9 in 10 road traffic deaths (about 90%) occur in low- and middle-income countries (LMICs), where the risk of death is roughly three times higher than in high-income countries. Road traffic crashes remain the leading cause of death among children and young people aged 5–29 years and the twelfth leading cause of death

across all age groups (4). These deaths predominantly affect people of working age and, beyond medical costs, impose substantial economic burdens on societies (5).

Iran has one of the highest rates of road traffic crashes and related mortality in the world (6). Each year, approximately 17,000 people die and 300,000 sustain injuries or permanent disability, and 57% of road-traffic-related deaths in Iran occur during the prehospital phase (7). In mass casualty traffic incidents, prehospital EMS as one of the key organizations involved plays a pivotal role in the initial response by providing immediate care to casualties at the scene (8).

Previous studies evaluating emergency care systems in LMICs have focused mainly on the service-delivery capacity of healthcare facilities or EMS, examining physical and human resources such as equipment, knowledge, and skills (9). Some have assessed emergency systems from a broader health-system perspective, including leadership, financing, political commitment, and regulatory mechanisms (10, 11); however, none has specifically addressed prehospital services. Others have focused solely on EMS systems, while paying little attention to informal emergency care providers or post-treatment care such as rehabilitation and discharge support (12). Because an effective response to such events requires evaluation of the entire response system across its various dimensions of performance and inter-organizational coordination, the absence of this approach in existing tools is evident (1).

Existing tools differ in focus and have paid limited attention to the operational requirements and specific nature of mass-casualty traffic incidents. Many previous studies have prioritized the assessment of hospital preparedness while giving less attention to the critical prehospital phase, which represents an essential initial stage of the chain of survival (13). Moreover, tools developed within the prehospital domain have often been designed for security-related scenarios such as terrorist attacks (8) or for assessing personnel competencies in disaster situations (14), which differ fundamentally from the specific features of road crashes, such as the need for extrication and traffic safety. Furthermore, although recent research has taken a valuable but individual-centered approach focusing on the specialized skills of personnel (15), a gap remains for a tool that addresses coordination and integrated systemic management at the scene. In addition, earlier efforts have mainly produced discrete performance indicators (16) or investigated the root causes of death (7), and the absence of a structured, context-specific instrument with established psychometric properties, capable of systematically assessing the service-delivery process in mass-casualty traffic incidents persists. The present study was therefore conducted to design and psychometrically evaluate a tool for assessing the performance of the prehospital emergency response system in mass-casualty traffic incidents. Here, the construct of interest is "the performance of the prehospital emergency response system in mass-casualty incidents" a multidimensional construct that, in addition to operational response and the skills of emergency personnel, encompasses inter-organizational coordination among prehospital EMS, the police, the Red Crescent, and hospitals.

Methods

Study design

This was a mixed-methods study using a sequential exploratory design, conducted in two main phases: qualitative and quantitative. In the qualitative phase, a content analysis approach was used to explore prehospital services in mass-casualty traffic incidents in depth, identify their dimensions and constructs, and generate questionnaire items accordingly. In the quantitative phase (item reduction), the validity of the instrument—including face, content, and construct validity—was examined, and its reliability was assessed using two methods: internal consistency (Cronbach's alpha) and the split-half method.

Phase One: Concept clarification and item generation

In the qualitative phase, a study based on the content analysis approach of Elo and Kyngäs was conducted to explore the dimensions of prehospital services in mass-casualty traffic incidents in depth (17). Participants were 31 operational personnel from relief organizations across four provinces Yazd, Fars, Kohgiluyeh and Boyer-Ahmad, and Qom each with at least two years of work experience, selected through purposive sampling followed by snowball sampling until data saturation was reached.

Data were collected through semi-structured interviews, and the trustworthiness of the data was assessed using Guba and Lincoln's criteria (18). The full methods and findings of the qualitative phase have been published separately, and their details are available in the corresponding publications (19–22).

Item generation

After the qualitative data were analyzed and the categories and subcategories extracted, an initial item pool was formed. Items were developed based on their theoretical and operational definitions, and an initial 121-item questionnaire was developed. Each item was scored on a five-point Likert scale (always = 5, often = 4, sometimes = 3, rarely = 2, never = 1). The main categories and subcategories identified as the basis for item development are presented in Table 1.

Phase Two: Psychometric evaluation

In this phase, the validity and reliability of the initial version of the instrument were examined through the following steps, resulting in item reduction.

Face validity: In the qualitative method, 10 members of the target population were interviewed to evaluate the items for difficulty, appropriateness, and ambiguity, and the necessary revisions were made to problematic items. In the quantitative method, to determine item importance and remove inappropriate items, a five-point Likert scale was used and the impact score of each item was calculated; items with an impact score below 1.5 were removed.

Content validity: To ensure adequate coverage of the constructs, content validity was examined through a survey of 10 experts in the fields of health in disasters and emergency medicine. The content validity ratio (CVR) was interpreted against the Lawshe critical value of 0.62 (for a 10-member expert panel), and the content validity index (CVI) was assessed against an acceptance threshold of 0.79. Items meeting the CVI criterion were retained; a small number of conceptually essential items with a borderline CVR (0.60) but a high CVI (≥ 0.80) were retained on the basis of the expert panel's judgment and their strong grounding in the qualitative phase.

Construct validity: To examine the factor structure of the instrument, a cross-sectional study was conducted in which the questionnaire was completed by personnel from several relief organizations, including prehospital EMS, the Red Crescent, and the police, from across the country. Respondents answered the items based on their experience in mass-casualty incidents, so that the resulting score reflects an overall assessment of the performance of the prehospital response system in such events rather than the performance of a single individual or organization. Of 346 usable questionnaires, factor analysis was performed on 315 questionnaires with complete responses (after listwise deletion of incomplete cases). Exploratory factor analysis (EFA) was conducted using principal component analysis (PCA) as the extraction method to identify the underlying factors. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) index (> 0.8), and the significance of the correlations was examined using Bartlett's test of sphericity. The number of factors was determined on the basis of eigenvalues greater than 1, the scree plot, parallel analysis, and the theoretical interpretability of the factors. For factor rotation, orthogonal Varimax rotation was applied first; because the factors were correlated, oblique Promax rotation was subsequently used. An item was retained if it loaded at least 0.30 on at least one factor; items loading below 0.30 on all factors, or loading 0.30 or higher on two factors simultaneously with a difference of less than 0.20 (cross-loading), were removed.

Reliability: The reliability of the instrument was examined through internal consistency. Cronbach's alpha was calculated for the total instrument and for each factor (using a minimum acceptable threshold of 0.70). As a second measure of internal consistency, the split-half method was used, and the Spearman-Brown and Guttman coefficients were calculated.

Ethical considerations

This study was conducted with ethical approval from Shahid Sadoughi University of Medical Sciences, Yazd, under the ethics code IR.SSU.SPH.REC.1397.020. The study objectives were explained to all participants, and written informed consent was

obtained. Participants were also assured that their information would remain confidential and that they were free to withdraw from the study at any time.

Use of large language models

During the preparation of this manuscript, the authors used a generative AI-based large language model (Claude, Anthropic) to assist with translation from Persian into English and with language editing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication. The tool was not used to generate scientific content, analyze or interpret data, or draw conclusions.

Results

Phase One: Item generation

In the qualitative part of the study, content analysis of 31 interviews yielded 1,172 initial codes. After repeated review, the removal of duplicate codes, and the merging of similar items, 30 subcategories, 8 categories, and 3 main themes were identified: "prehospital response" (21, 22), "staff skill and efficiency" (20), and "integrated management of relief organizations" (19) (Table 1). Based on the categories and subcategories extracted from the qualitative content analysis, an initial pool of 121 items was developed.

Table 1. Illustrative examples of the item-generation process based on qualitative data, organized by main theme

Sample meaning unit	Initial code	Subcategory	Category	Main theme	Generated item
"…the first crew that reaches the scene checks whether the scene is safe and whether any conflict is present…"	Checking scene safety; assessing potential hazards	Incident scene assessment	Comprehensive assessment	Prehospital response	The EMS technician ensures the scene is safe before entering.
"…at a scene with many casualties, patients in the black category who have no vital signs should not consume the crew's time and energy…"	Necessity of observing triage principles; not performing CPR during triage	Triage requirements and challenges	Professional performance	Staff skill and efficiency	The technician prioritizes patients according to the triage protocol.
"…the police should understand my triage, but they do not; under normal conditions we have no joint work with the Red Crescent…"	Staff's lack of awareness of each other's duties	Insufficient mutual knowledge among organizations	Lack of coordination among relief organizations	Integrated management of relief organizations	Relief-organization staff are familiar with the duties of other organizations.

One representative example is presented for each main theme. The complete list of categories and subcategories has been published previously in the authors' reports of the qualitative phase(20-22).

Phase Two: Psychometric evaluation

Face validity was assessed using both qualitative and quantitative methods. In the qualitative method, the questionnaire was given to 10 relief-organization staff, whose views on the appropriateness, difficulty, relevance, and ambiguity of the items were used to make the necessary revisions. In the quantitative method, the same 10 participants rated the importance of each item on a five-point Likert scale from "completely important" (score 5) to "not important at all" (score 1), and the impact score of each item was calculated by multiplying the frequency by the importance rating. At this stage, 49 items with an impact score below 1.5 were removed, reducing the number of items to 72. For content validity, the content validity ratio (CVR) and the

content validity index (CVI) were calculated from the opinions of 10 experts. The CVR was evaluated against the Lawshe critical value of 0.62. Following this assessment, 18 items were removed and 54 remained. All 54 retained items had an item-level content validity index (I-CVI) above 0.79, and the scale-level content validity index (S-CVI/Ave) was 0.967; a few conceptually essential items with a borderline CVR (0.60) were retained on the basis of their high CVI and strong grounding in the qualitative phase. In addition, two items with a two-stage response structure (first yes/no, then a Likert response if positive)-incompatible with the uniform five-point scale-were removed, so that a total of 52 items entered the construct-validity stage (Table 2).

Table 2. Face and content validity results of the 54 items

No.	Item	Impact score	CVR	CVI
1	The dispatch operator assesses the incident scene by phone.	5.0	0.80	0.90
2	The EMS technician receives information about the incident scene.	4.9	0.80	0.90
3	The dispatch operator specifies the access route to the scene for the EMS technician.	4.9	0.60	0.90
4	The EMS technician ensures the scene is safe before entering.	4.6	1.00	1.00
5	The EMS technician observes body substance isolation (BSI) principles before entering the scene.	4.8	0.80	0.90
6	A crew member of the first EMS ambulance assumes incident command until the senior commander arrives.	4.9	1.00	1.00
7	The crew of the first EMS ambulance estimates the needs of the scene.	4.8	1.00	1.00
8	The number of ambulances dispatched to mass-casualty incidents is sufficient.	4.8	0.60	1.00
9	All casualties are triaged by the first ambulance present at the scene.	4.9	1.00	1.00
10	Overall scene assessment is performed by the senior technician.	4.9	0.80	1.00
11	The EMS technician uses equipment appropriate to the scene.	4.8	0.60	0.90
12	Assessment of casualties continues until arrival at the medical center.	4.9	0.80	1.00
13	The EOC coordinates with trauma centers to distribute casualties.	4.8	0.80	0.90
14	Incident command maintains continuous communication with the dispatch center.	4.8	0.80	1.00
15	The EOC reports mass-casualty incidents to higher levels (university, regional hub, or ministry).	4.5	1.00	1.00
16	The EOC records the required information of casualties.	4.7	0.80	1.00
17	Actions taken by the operations team are documented.	4.9	0.60	1.00
18	The EOC evaluates prehospital service delivery after each mass-casualty incident.	4.7	0.60	1.00
19	The dispatch center is informed of the status of its stations at the start of each shift.	4.8	0.80	1.00
20	The prehospital EMS system can surge capacity, including human resources and equipment.	4.9	0.80	1.00
21	An ambulance bus is present to provide health services at the scene when needed.	5.0	1.00	1.00
22	The EMS system has appropriate communication equipment.	5.0	1.00	1.00
23	Intra-sectoral coordination exists within the university of medical sciences during incidents.	4.7	1.00	1.00
24	Unified and coordinated command among relief organizations exists at the scene.	4.9	0.80	1.00
25	A shared communication channel exists among relief organizations.	4.5	0.80	1.00
26	The first relief organization present summons the other relief organizations when needed.	4.8	1.00	1.00
27	The police or EMS technician installs incident warning signs at the scene.	4.7	0.80	1.00
28	Security forces establish scene security.	4.9	0.80	1.00
29	A safe area at the scene is provided by the police, incident commander, or EMS technician for relief services.	4.8	0.60	1.00
30	The police establish ambulance security at the scene.	4.8	1.00	1.00

31	Security forces protect casualties' belongings.	4.7	0.60	0.90
32	Red Crescent personnel extricate casualties trapped in damaged vehicles.	4.9	0.80	1.00
33	The EMS technician transports casualties based on triage.	5.0	1.00	1.00
34	The EMS training center regularly holds refresher courses for personnel.	4.7	0.80	1.00
35	The EMS system provides psychological support to personnel after stressful missions.	4.9	0.80	1.00
36	The EMS technician attends to the mental health of casualties' companions.	4.8	0.60	1.00
37	The EMS technician has an appropriate psychological condition for service delivery.	4.7	0.60	0.80
38	The EMS technician has appropriate physical fitness.	4.9	0.60	0.80
39	EMS technicians provide care based on up-to-date protocols.	5.0	0.60	1.00
40	EMS personnel observe professional ethics before, during, and after relief operations.	4.9	0.60	0.90
41	Professional interaction exists between the EMS technician and emergency department staff.	4.8	0.60	1.00
42	The hospital's treatment services are appropriate for mass-casualty victims.	4.7	0.80	1.00
43	The hospital emergency department admits casualties as quickly as possible.	4.9	0.80	1.00
44	The hospital has the treatment capacity required for mass-casualty incidents.	4.9	1.00	1.00
45	The hospital has the equipment required in mass-casualty incidents.	4.8	1.00	1.00
46	Relief organizations have the necessary coordination at the scene.	4.9	1.00	0.90
47	One organization assumes scene management according to its job description.	5.0	1.00	1.00
48	Relief organizations are familiar with the duties of other relief organizations.	5.0	0.80	0.90
49	The scope of work of relief organizations is defined.	4.9	0.80	1.00
50	The organization responsible for the deceased is defined.	4.8	0.80	0.90
51	The EOC holds an intra-organizational meeting to deliver services to casualties.	4.7	0.60	0.80
52	Relief organizations operationalize their commitments and agreements.	4.8	0.60	0.90
53	Relief organizations periodically hold drills to assess coordination.	4.6	0.80	1.00
54	Relief organizations arrive at the scene as quickly as possible when needed.	4.6	1.00	1.00

Impact score threshold >= 1.5; CVR interpreted against the Lawshe critical value of 0.62 (10 experts); I-CVI acceptance threshold >= 0.79. The scale-level content validity index (S-CVI/Ave) was 0.967. A small number of conceptually essential items with a borderline CVR of 0.60 but high CVI (>= 0.80) were retained on the basis of expert-panel judgment and their grounding in the qualitative phase. EMS, emergency medical services; EOC, emergency operations center; BSI, body substance isolation.

Construct validity (exploratory factor analysis)

In the quantitative phase, the 52-item questionnaire was distributed to relief-organization personnel, and 354 questionnaires were returned. After review, 346 questionnaires in which at least 80% of the items had been answered were deemed usable, and factor analysis was performed on 315 questionnaires with complete responses (after listwise deletion of incomplete cases). The demographic characteristics of the participants are presented in Table 3. Most participants were male (97.9%), held a bachelor's degree (51.8%), and had more than 10 years of work experience (46.7%).

Table 3. Demographic characteristics of participants (N = 346)

Variable	Category	n (%)
Age (years)	Mean ± SD	34.39 ± 6.73 (range 23–54)
Sex	Male	326 (97.9)
	Female	7 (2.1)
Education	Associate degree	128 (37.9)
	Bachelor	175 (51.8)
	Master	33 (9.8)
	Doctorate	2 (0.6)
Work experience	< 2 years	23 (6.8)
	2–5 years	64 (19.0)
	6–10 years	92 (27.4)
	> 10 years	157 (46.7)
Position	EMT/Technician	170 (54.1)
	Expert (BSc+)	88 (28.0)
	Associate technician	9 (2.9)
	Nurse	9 (2.9)
	Relief/Rescue worker	8 (2.5)
	Manager/Supervisor	20 (6.4)
	Other	10 (3.2)
No. of MCIs attended	2–5	117 (34.8)
	6–10	65 (19.3)
	> 10	154 (45.8)
No. of MCIs commanded	2–5	179 (56.3)
	6–10	47 (14.8)
	> 10	92 (28.9)

Data are presented as frequency (%), except age (mean ± SD). Percentages are based on valid responses for each variable. SD, standard deviation; EMT, emergency medical technician; MCI, mass-casualty incident.

To assess sampling adequacy and whether the variables were sufficiently correlated for exploratory factor analysis, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were computed. The KMO value was 0.937, indicating that the sample was adequate for factor analysis, and Bartlett's test was significant (chi-square = 9086.8, df = 1326, $p < 0.001$), confirming sufficient correlation among the variables (Table 4).

Table 4. Kaiser-Meyer-Olkin (KMO) measure and Bartlett’s test of sphericity

Index	Value
Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy	0.937
Bartlett's test of sphericity — approximate χ^2	9086.8
Degrees of freedom (df)	1326
Significance (p)	< 0.001

Principal component analysis (PCA) was used to extract the factors. The initial results showed that 10 components had eigenvalues greater than 1 (Table 5). However, the eighth to tenth components exceeded the threshold only marginally, and the eleventh to thirteenth fell only slightly below 1; determining the number of factors from the eigenvalue criterion alone was therefore difficult, and the scree plot was used for this purpose (Figure 1).

Table 5. Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	16.901	34.49	34.49	16.901	34.49	34.49	10.827	22.10	22.10
2	3.349	6.83	41.33	3.349	6.83	41.33	6.555	13.38	35.47
3	2.227	4.54	45.87	2.227	4.54	45.87	5.095	10.40	45.87
4	1.667	3.40	49.27						
5	1.424	2.90	52.18						
6	1.349	2.75	54.93						
7	1.238	2.53	57.46						
8	1.107	2.26	59.72						
9	1.086	2.22	61.93						
10	1.020	2.08	64.02						

Extraction method: principal component analysis. Rotation method: Varimax with Kaiser normalization. Ten components had eigenvalues greater than 1; three factors were retained based on the scree plot, parallel analysis, and interpretability, accounting for 45.87% of the total variance.

As the scree plot shows, the slope of the curve decreased sharply after the third component and then flattened. This clear break after the third factor, together with the theoretical interpretability of the items, indicated that a three-factor structure was the best model. To confirm the number of factors, parallel analysis was also performed; the actual eigenvalues exceeded the corresponding random eigenvalues (95th percentile) only for the first three factors, confirming the three-factor structure. The structure was first examined using Varimax rotation, and the three factors together explained 45.87% of the total variance (22.10%, 13.38%, and 10.40% for the first, second, and third factors, respectively). Because the loadings of some items were close across two factors—indicating that the factors were correlated-oblique (Promax) rotation was used to obtain the optimal structure. The factor correlations ranged from 0.46 to 0.57, supporting the use of oblique rotation. At this stage, three items were removed for loading below 0.30 on all factors: "the EMT ensures the scene is safe before entering" (maximum loading, 0.28), "the number of dispatched ambulances is sufficient" (0.28), and "the prehospital EMS system can surge capacity" (0.23). The final instrument was confirmed with 49 items (Table 6). Based on item content, the three factors were named prehospital response (27 items), staff skill and efficiency (13 items), and integrated management of relief organizations (9 items).

Table 6. Rotated pattern matrix and factor loadings of the items (Promax rotation)

No.	Item	Factor 1	Factor 2	Factor 3
	Factor 1 — Prehospital response [27 items]			
3	The dispatch operator specifies the access route to the scene	0.358		
21	An ambulance bus is present to provide health services at the scene	0.336		
22	The EMS system has communication equipment appropriate to scene needs	0.481		
23	Intra-sectoral coordination exists within the university of medical sciences	0.453		
25	Unified and coordinated command among relief organizations exists	0.642		
27	Relief organizations are summoned by the first organization present	0.355		
28	The police or EMT installs incident warning signs	0.671		
29	The police establish scene security	0.637		
30	A safe area is provided at the scene for relief services	0.610		
31	The police establish ambulance security at the scene	0.777		
32	The police protect casualties' belongings	0.481		
33	Red Crescent personnel extricate casualties trapped in vehicles	0.525		
36	The EMS system provides psychological support to staff after stressful missions	0.605		
38	The EMT has an appropriate psychological condition for service delivery	0.556		
42	Professional interaction exists between the EMT and emergency department staff	0.558		
43	The hospital has the treatment capacity required for MCIs	0.788		
44	The hospital can surge capacity during MCIs	0.757		
45	The hospital has the equipment required in MCIs	0.810		
46	Relief organizations have the necessary coordination at the scene	0.797		
47	One organization assumes scene management per its job description	0.617		
48	Staff are familiar with the duties of other relief organizations	0.686		
49	The scope of work of relief organizations is defined	0.660		
50	The organization responsible for the deceased is defined	0.604		
51	The EOC holds an intra-organizational meeting to deliver services	0.447		
52	Relief organizations operationalize their commitments and agreements	0.510		
53	Relief organizations periodically hold drills to assess coordination	0.631		
54	Relief organizations arrive at the scene as quickly as possible	0.602		
	Factor 2 — Staff skill and efficiency [13 items]			
5	The EMT observes body substance isolation (BSI) before entering the scene		0.601	
6	A crew member of the first ambulance assumes incident command		0.574	
7	The first ambulance crew estimates the needs of the scene		0.568	
9	All casualties are triaged by the first ambulance present		0.737	

10	Overall scene assessment is performed by the senior technician	0.646	
11	The EMT uses equipment appropriate to casualties' needs	0.683	
12	Assessment of casualties continues until arrival at the medical center	0.668	
34	The EMT transports casualties based on triage	0.595	
35	The EMS training center regularly holds refresher courses	0.324	
37	The EMT attends to the mental health of casualties' companions	0.675	
39	The EMT has appropriate physical fitness	0.463	
40	EMTs provide care based on up-to-date protocols	0.736	
41	EMS staff observe professional ethics before, during, and after relief	0.740	
	Factor 3 — Integrated management of relief organizations [9 items]		
1	The dispatch operator assesses the incident scene by phone		0.563
2	The EMT receives information about the incident scene		0.423
13	The EOC coordinates with trauma centers to distribute casualties		0.667
14	Incident command maintains continuous communication with dispatch		0.689
15	The EOC reports MCIs to higher levels		0.727
16	The EOC records the required information of casualties		0.710
17	Actions taken by the operations team are documented		0.356
18	The EOC evaluates prehospital service delivery after each MCI		0.434
19	The dispatch center is informed of EMS station status at shift start		0.489

Extraction: principal component analysis; rotation: oblique (Promax). Only factor loadings ≥ 0.30 are shown; each item is listed under the factor on which it loaded highest. Factor correlations ranged from 0.46 to 0.57.

Reliability

Reliability was assessed using internal consistency and the split-half method. Cronbach's alpha was 0.958 for the total scale and 0.950, 0.886, and 0.817 for the prehospital response, staff skill and efficiency, and integrated management of relief organizations factors, respectively—all above the 0.70 threshold, indicating good internal consistency. For the split-half method, the correlation between the two halves was 0.82, and the Spearman-Brown and Guttman coefficients were both 0.90, confirming the acceptable reliability of the instrument (Table 7).

Table 7. Reliability indices of the instrument (internal consistency and split-half)

Scale	No. of items	Cronbach's alpha
Prehospital response	27	0.950
Staff skill and efficiency	13	0.886
Integrated management of relief organizations	9	0.817
Total scale	**49**	**0.958**

Split-half reliability of the total scale: correlation between halves = 0.82; Spearman–Brown coefficient = 0.90; Guttman coefficient = 0.89.

Scoring of the instrument

The final 49-item instrument comprises three constructs: prehospital response (27 items), staff skill and efficiency (13 items), and integrated management of relief organizations (9 items). Each item is scored on a five-point Likert scale (always, often, sometimes, rarely, never; 5 to 1). The possible score range is 27–135 for prehospital response, 13–65 for staff skill and efficiency, 9–45 for integrated management of relief organizations, and 49–245 for the total questionnaire. For comparability across scales, each subscale was linearly transformed to a 0–100 range using the formula Transformed score = (Raw - Min) / (Max - Min) x 100, where Raw is the obtained score and Min and Max are the minimum and maximum possible scores of the subscale; the total score was then calculated as the mean of the three transformed subscale scores, yielding a value between 0 and 100, with higher scores indicating better prehospital emergency services in mass-casualty incidents. The instrument contains no reverse-scored items, and incomplete cases were handled through listwise deletion.

Discussion

This study was conducted to design and psychometrically evaluate an instrument for assessing prehospital emergency services in mass-casualty traffic incidents (MCIs). The final instrument comprised 49 items and three main factors: prehospital response, staff skill and efficiency, and integrated management of relief organizations. Exploratory factor analysis showed that these three factors together explained 45.87% of the total variance, and the psychometric indices (KMO = 0.937 and Cronbach's alpha > 0.8) indicated sampling adequacy and good internal consistency. Although several components had eigenvalues greater than 1 in the initial extraction, the three-factor structure was selected as the most appropriate and stable model on the basis of the clear break in the scree plot and the theoretical interpretability of the items. Beyond construct validity, face and content validity (with a satisfactory S-CVI) and reliability—assessed using both Cronbach's alpha and the split-half method—were also confirmed, together indicating that the instrument is psychometrically robust.

Comparison of our findings with those of Mohammadi et al. (2025), who developed the Emergency Medical Services Safe Care Scale (EMSSCS) (15), shows that both studies used a mixed-methods approach and identified three main factors; however, a closer analysis of these factors reveals fundamental differences that stem from the contrast between mass-casualty traffic incidents and routine safe care. Two factors in the two studies show considerable semantic overlap: the staff skill and efficiency and prehospital response factors in the present study correspond, respectively, to the efficient clinical skills and scene management factors in Mohammadi's instrument. This convergence confirms that, regardless of mission type (routine or disaster), mastery of clinical skills and the ability to control the scene are core competencies of emergency medical services. However, Mohammadi et al. (2025) treated stress management as a subcategory of scene management (15), whereas our instrument focused on the operational processes of the response. Moreover, in Mohammadi's instrument the "effective interaction" factor concerns interpersonal communication skills-such as patience, respect, and the manner of interacting with colleagues and patients-at the micro level, whereas the "integrated management of relief organizations" factor in the present study is distinct from this concept and emphasizes coordination at the inter-organizational level. This difference suggests that, under routine conditions, the main challenge for technicians is person-to-person interaction, whereas in mass-casualty traffic incidents the challenge extends beyond the individual level to the inter-organizational level. By identifying the integrated management of relief organizations as a core pillar, the present instrument shows that in traffic crises the main bottleneck is the lack of unified command among the police, EMS, and the Red Crescent, rather than the manner of patient care alone.

Our findings are consistent with those of Azami-Aghdash et al. (2021), who, in developing quality indicators for traffic incidents, introduced management as one of three main dimensions (alongside structure and performance) and argued that proper management has a considerable effect on prehospital emergency performance, and that managerial interventions are often less costly and more rapidly effective than increasing physical resources such as adding ambulances (16). In our study, too, participants' emphasis on the need for inter-organizational coordination and joint training reflects the fact that, without an integrated management structure, responding to mass-casualty incidents will face serious challenges even when adequate resources are available. Beyond the managerial dimension, the staff skill and efficiency factor in our final instrument corresponds to the indicators proposed in that study, which emphasized staff training in trauma and scientific competence.

Azami-Aghdash et al. (2021) showed that continuous training and professional competence-such as holding a relevant academic degree-are vital quality indicators. This overlap confirms that empowering human resources is the most central component in improving the quality and efficiency of prehospital services, regardless of incident type. That study recommends that policymakers localize and validate indicators according to their own national conditions before applying them. The instrument developed here was designed precisely in response to this need, taking into account the cultural and structural context of Iran's relief organizations, to fill the gap left by general assessment tools.

Mehmood et al. (2018), in a study on designing an EMS assessment tool for low-income countries, used the World Health Organization's six-component framework (service delivery, health workforce, information systems, medical products, financing, and leadership and governance) (23), which is structural and macro-level and measures the overall capacity of the system (for example, whether the budget is sufficient and whether regulations exist). In contrast, the instrument developed here is functional and task-oriented and focuses on the manner of response at the moment of crisis (point of care). The leadership and governance component, as a legal and political infrastructure, overlaps with the integrated management of relief organizations factor in the present study, although the two concepts are not identical. This difference indicates that in mass-casualty traffic incidents the main challenge is not the existence of upstream regulations but the coordinated implementation of those regulations at the scene and among the various organizations (police, EMS, Red Crescent). Our instrument fills the gap that the macro-level model of Mehmood et al. (2018) leaves in measuring the dynamics of the incident scene. In our instrument, the medical equipment and products component is merged into the prehospital response and staff efficiency factors. This is consistent with our finding that, in mass-casualty incidents, merely possessing equipment does not guarantee quality; rather, the ability to use equipment skillfully and rapidly under the tense, unpredictable conditions of the scene are more important. With its process-oriented approach, the present instrument therefore provides more precise criteria for assessing prehospital emergency services. The financing dimension, designed for macro-level policymaking, is absent from our instrument because the study focused on operations at the incident scene.

With respect to the psychometric indices, the explained variance of Mohammadi et al.'s instrument was 48.72% (15), whereas that of the present instrument is 45.87%. This difference does not necessarily indicate a weakness of the present instrument and may partly reflect the more multidimensional nature of the phenomenon under study. Mohammadi's study measured a specific, intra-individual construct (safe care) whose variables are more homogeneous and under the technician's control. In contrast, services in mass-casualty traffic incidents are affected by numerous variables beyond the control of the health system, such as road safety, driver behavior, traffic, and the performance of other organizations. The lower variance in the present study therefore supports the multidimensional nature of the phenomenon, whose full dimensions are harder to capture in a single questionnaire than individual competencies are.

The instrument developed in this study was tested not only qualitatively but also quantitatively. Conducting exploratory factor analysis (EFA) and obtaining a coherent factor structure with a satisfactory KMO and 45.87% explained variance provides good preliminary evidence for the construct validity of the instrument, the final confirmation of which will require confirmatory factor analysis on an independent sample. Although Azami-Aghdash et al. (2021) used the Delphi technique to identify valuable indicators through expert consensus (16), their approach relied mainly on qualitative validation and lacked quantitative psychometric evaluation. By contrast, a notable strength of the present study is its use of a mixed-methods approach and its rigorous psychometric procedures. By localizing concepts and focusing on executive bottlenecks such as inter-sectoral coordination and skills at the scene, this study has produced an instrument that, as a complement to macro-level models, can offer a more realistic picture of the operational capability of Iran's emergency services.

Limitations

Despite these strengths, the study has limitations that should be considered when interpreting the findings. First, because the factor analysis was performed on a single sample, the factor structure requires re-confirmation through confirmatory factor analysis (CFA) on an independent sample in future studies. Second, the data were collected within a limited geographical and organizational context, so the findings should be generalized to regions with different organizational structures only with caution. Third, the data were based on participants' self-reports, which may be subject to response bias. Future research

should, in addition to confirming the instrument's structure with CFA and examining convergent and divergent validity, also assess its criterion validity and temporal stability (test-retest).

From a practical standpoint, the instrument can serve as a native, process-oriented measure for assessing the preparedness and performance of prehospital emergency stations in mass-casualty incidents, and can reveal the inter-organizational coordination bottlenecks that macro-level tools overlook. Managers and policymakers can use it to identify operational weaknesses, target joint training programs among the police, EMS, and the Red Crescent, and continuously monitor improvements in service quality. Although global frameworks such as the model of Mehmood et al. (2018) provide theoretical foundations for system assessment, they lack the sensitivity needed to measure the complexities of mass-casualty traffic incidents. By localizing concepts and focusing on executive bottlenecks such as inter-sectoral coordination and skills at the scene, this study has produced a valid and reliable instrument that, as a complement to macro-level models, can offer a more realistic picture of the operational capability of Iran's prehospital emergency services in mass-casualty incidents.

Conclusions

Drawing on a mixed-methods approach and systematic psychometric procedures, this study designed and validated a native, specific instrument for assessing prehospital services in mass-casualty traffic incidents. The final instrument comprises 49 items within three main factors, prehospital response, staff skill and efficiency, and integrated management of relief organizations reflecting the multidimensional and complex nature of managing such incidents. The results indicate that the effectiveness of the response to mass-casualty incidents does not depend solely on equipment or individual skills; rather, organizational synergy, inter-sectoral coordination, and unified command at the scene play decisive roles in the success of rescue operations. The satisfactory validity (face, content, and construct) and high reliability indices confirm that the instrument is scientifically adequate for the structured and reliable assessment of prehospital system performance under both real conditions and operational drills. The instrument can be used as a standard measure within the crisis-management system and applied systematically in performance monitoring and accreditation, needs assessment, and evidence-based training planning. Institutionalizing it in national disaster-management protocols and policies, by strengthening evidence-based decision-making, can help improve the quality of prehospital services. The effect of applying this instrument on clinical outcomes (such as response time or mortality) remains to be examined in future studies. The instrument can also help emergency-system managers identify shortcomings precisely and implement effective corrective measures to deliver safe, coordinated, and efficient services.

Abbreviations

EMS: Emergency medical services; MCI: Mass-casualty incident; CBRNE: Chemical, biological, radiological, nuclear, and explosive; LMIC: Low and middle income country; EOC: Emergency operations center; BSI: Body substance isolation; EMT: Emergency medical technician; CVR: Content validity ratio; CVI: Content validity index; I-CVI: Item-level content validity index; S-CVI/Ave: Scale-level content validity index, average; EFA: Exploratory factor analysis; PCA: Principal component analysis; KMO: Kaiser-Meyer-Olkin; CFA: Confirmatory factor analysis; LLM: Large language model.

Declarations

Ethics approval and consent to participate:

This study was approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd (IR.SSU.SPH.REC.1397.020). Written informed consent was obtained from all participants before data collection, and confidentiality and anonymity were ensured throughout the study.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

All authors contributed to the study design, data collection, analysis, and manuscript preparation. All authors read and approved the final manuscript.

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Use of large language models:

During the preparation of this manuscript, the authors used a generative AI-based large language model (Claude, Anthropic) to assist with translation from Persian into English and with language editing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication. The tool was not used to generate scientific content, analyze or interpret data, or draw conclusions.

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Figures

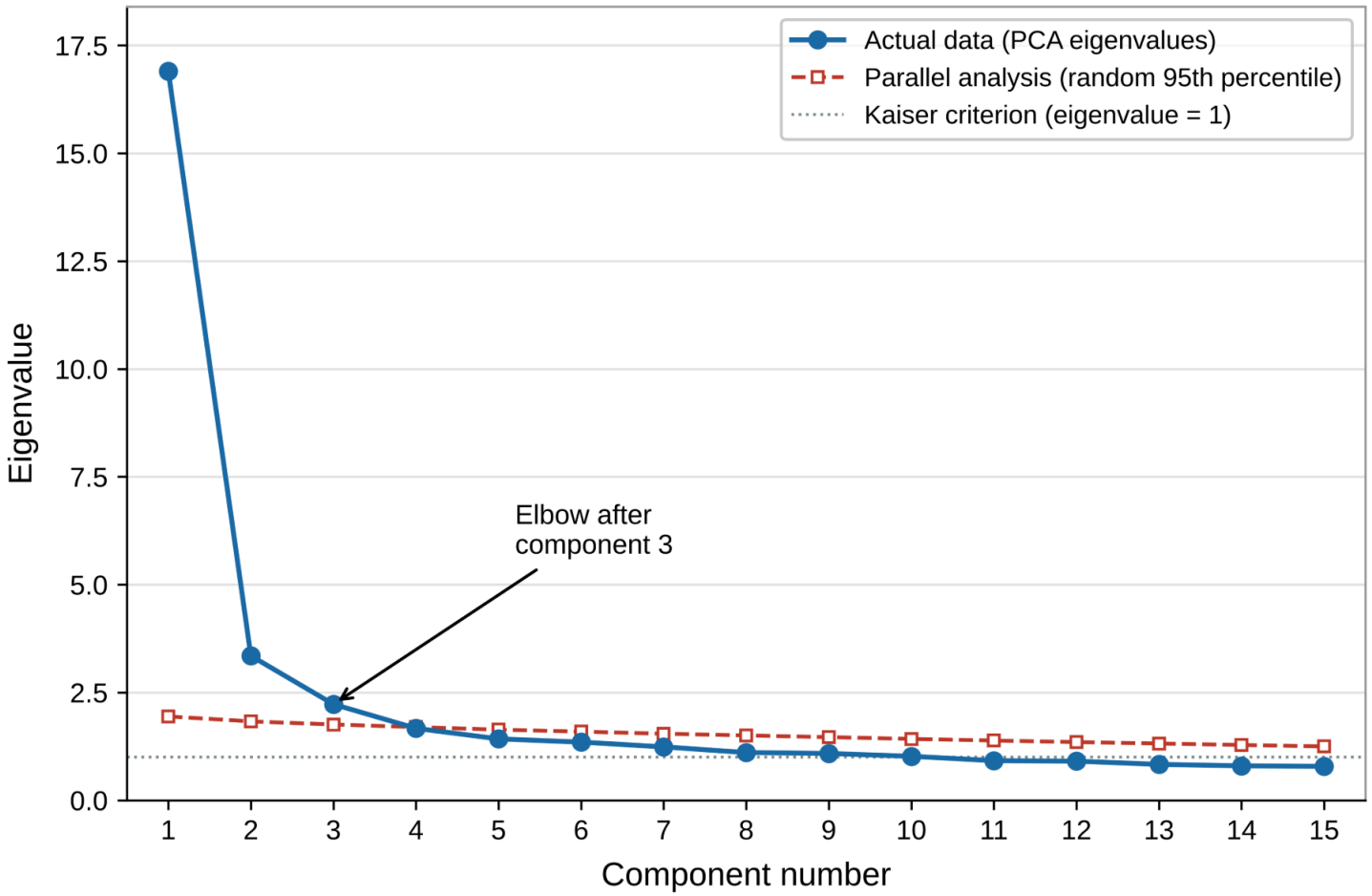


Figure 1

Scree plot of the exploratory factor analysis with parallel analysis. The actual eigenvalues (solid line) exceed the random (95th percentile) eigenvalues (dashed line) only for the first three components, supporting a three-factor solution.